Highlight on Detector technology

Manqi Ruan

Outline

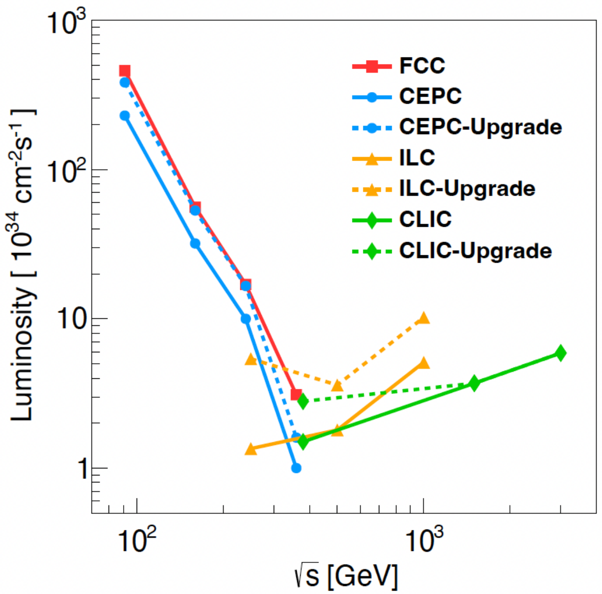
- Introduction
- MDI: 10 talks
- Silicon: 13 talks
- Gaseous detector: 14 talks
- Pid & Others: 14 talks
- Calorimeter: 14 talks
- Software & TDAQ: 17 talks
- Summary

- *Disclaimer: apologize for my limited acceptance & mis-interpretations*

CEPC Physics

Table 3.1: Main design indicators for the CEPC 30 MW beam power operation scheme

Operation mode	Z	W	Higgs
Center-of-mass energy (GeV)	91	160	240
Operation time (year)	2	1	10
Instantaneous luminosity/IP ($10^{34}\text{cm}^{-2}s^{-1}$)	115	16.0	5.0
Integrated luminosity (ab^{-1}, 2 IPs)	60	3.6	12
Event yield (30 MW)	2.5×10^{12}	1.0×10^{8}	2.5×10^{6}
Event yield (50 MW)	4.0×10^{12}	1.6×10^{8}	4.0×10^{6}



- Huge data: i.e., LEP-I data in o(1) minute
- Extremely high precision/sensitivity: to control uncertainties from
  - Theoretical: new tools/development of theory, high-precision pheno. calculation...
  - Experimental:
    - Stable & high-lumi collider
    - Stable & adequate detector

Requirements & technologies

- Be suited to the collision environment: High radiation, High rate, Beam background
- High hermiticity
- Lower energy/momentum threshold (especially for Z)
- Good intrinsic Energy/Momentum resolution
- A clear separation of the final state particles
  - Physics object identification
  - Resolution for composited objects, i.e., jets
- BMR (Boson Mass Resolution)
  - < 4% for Higgs physics, much demanding for New Physics & Flavor Physics Measurements
- Pid: Pion & Kaon separation > 3σ
- Jet: Flavor Tagging & Charge Reconstruction
- Extremely Stable

Radiation robust detector
Fast & low power electronics

Compact forward region, MDI/detector protection

Tracker & Calorimetry: Low noise, High precision
Low threshold calorimeter, adequate B-Field,
High efficiency tracker

Particle Flow Oriented detector, or Dual Readout
(or alternatives)

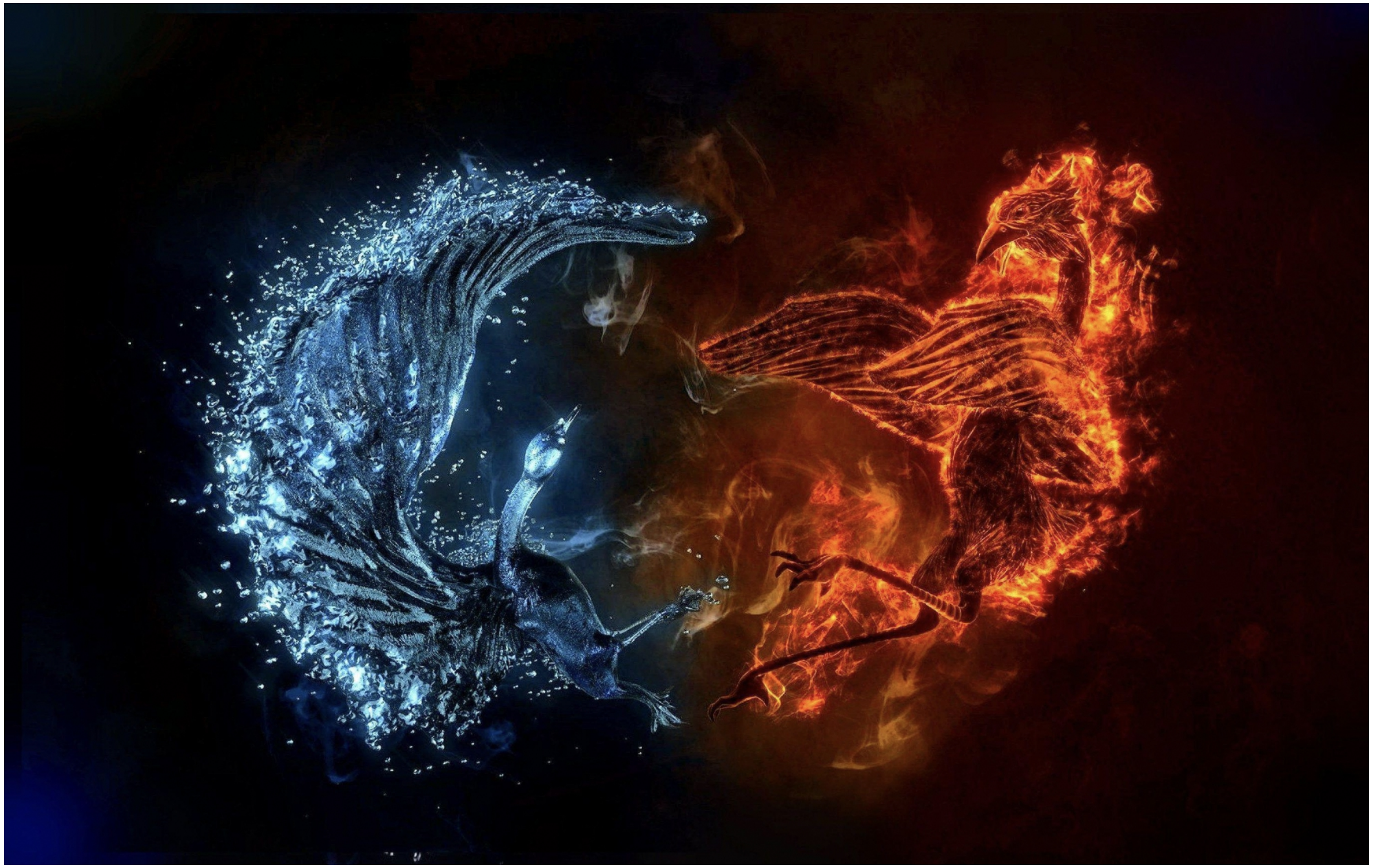
Abundant high quality detector information +
suited algorithm

dEdx or dNdx with resolution ~ 3%, ~ 50 ps ToF
(or alternatives)

Low material, high precision vertex placed close
to the IP

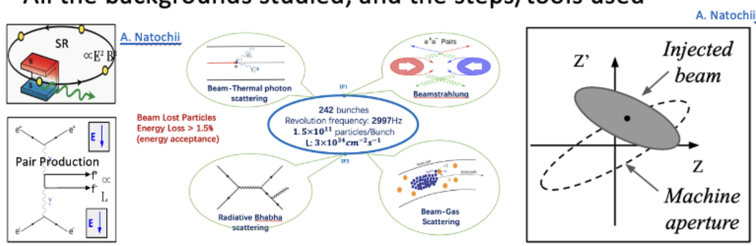
Mechanic & Integration

MDI



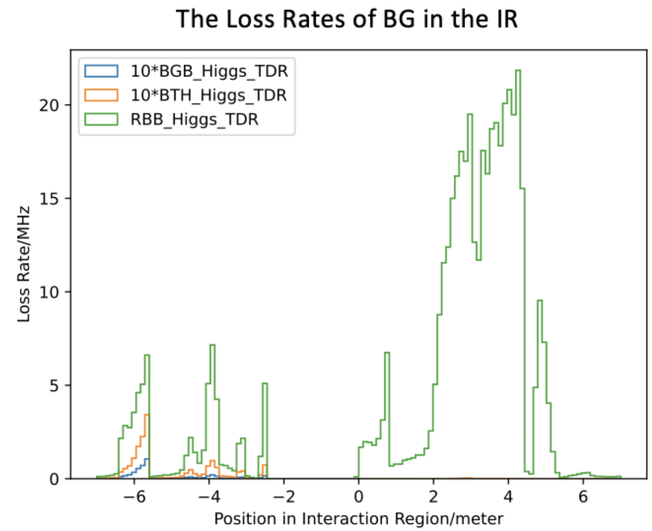
Beam background: CEPC, Belle II, BES III

All the backgrounds studied, and the steps/tools used



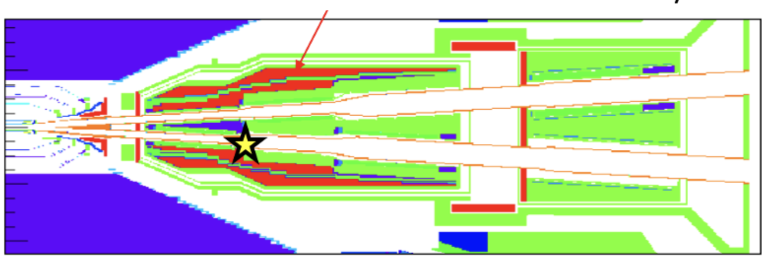
Photon BG | Beam Loss BG | Injection BG

Background	Generation	Tracking	Detector Simu.
Synchrotron Radiation	BDSim	BDSim/Geant4	Mokka/CEPCSW
Beamstrahlung/Pair Production	Guinea-Pig++	SAD	
Beam-Thermal Photon	PyBTH[Ref]		
Beam-Gas Bremsstrahlung	PyBGB[Ref]		
Beam-Gas Coulomb	BGC in SAD		
Radiative Bhabha	BBBREM		



With Collimators, the BG in IR has been mitigated significantly

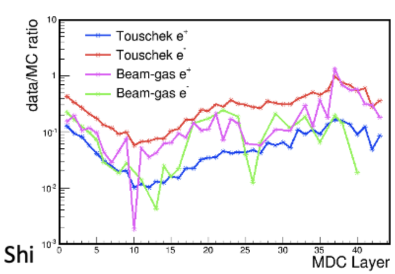
Thick tungsten layers of BELLEII | H. Nakayama



The experience at SuperKEKB reminds us to reserve enough space for the BG shields between detectors and beam pipes

BG Experiment at BESIII/BII in 2021, to check our simulation model. It seems fine.

H. Shi

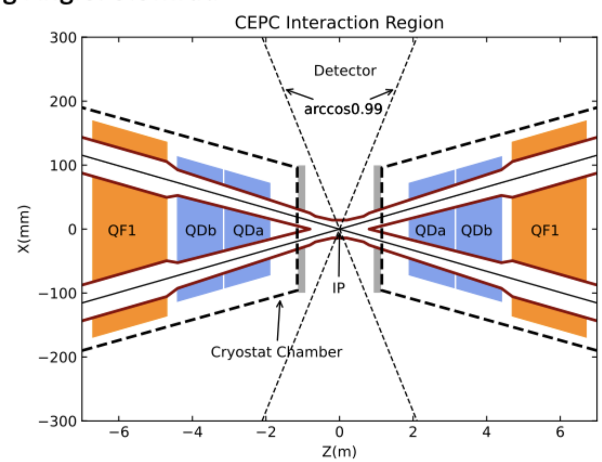


BGs at BII/BESIII dominanted by Touschek and Beam-gas:

- Touschek: MC is 1~2 order of magnitude higher than experiment
- Beam-gas: fluctuation is caused by small rate and indirect measurement

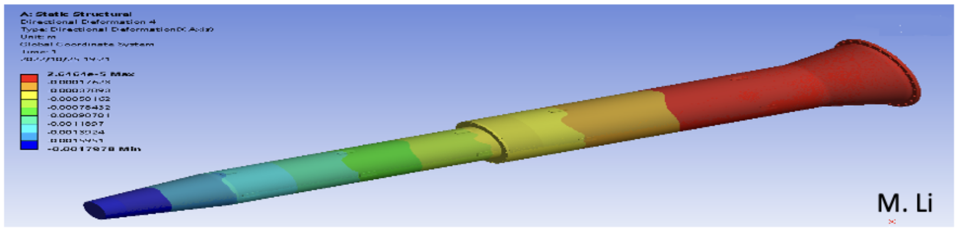
MDI/beam pipe design

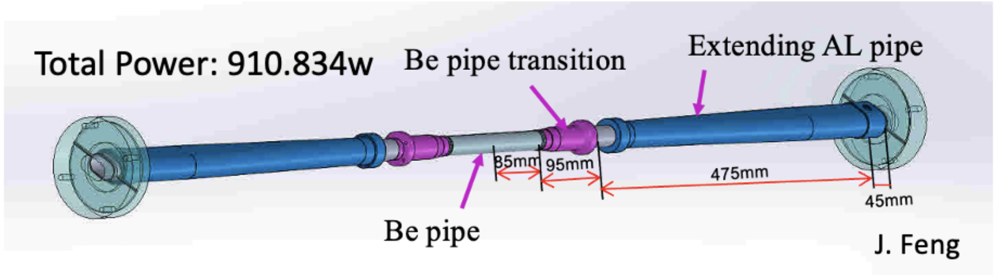
IR Length: 14m
Focal Length: 1.9m
Crossing Angle: 3.3mrad



J. Feng

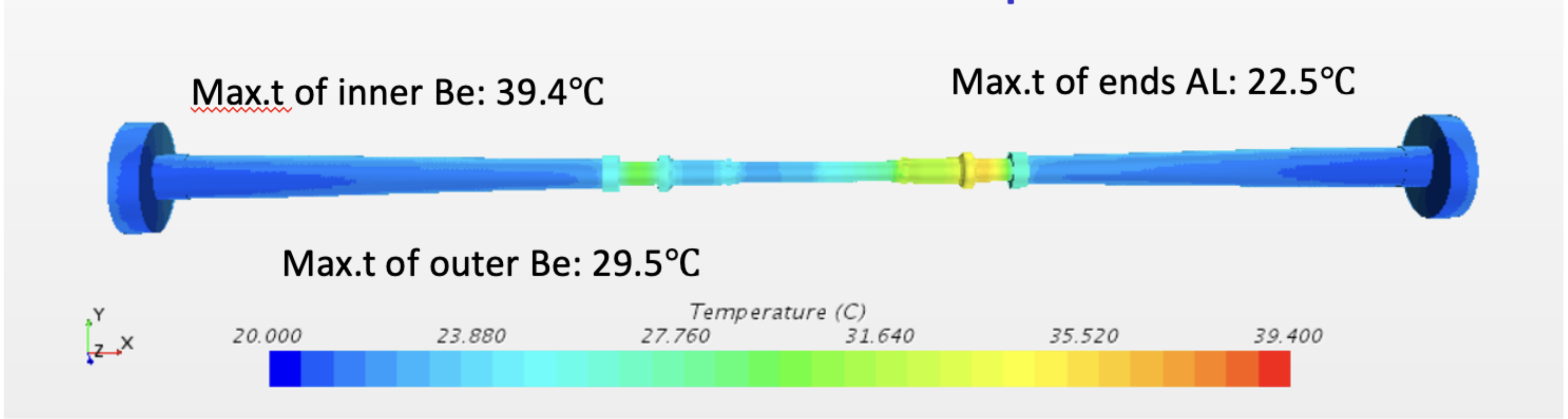
Deformation Analysis of the Cryostat Chamber



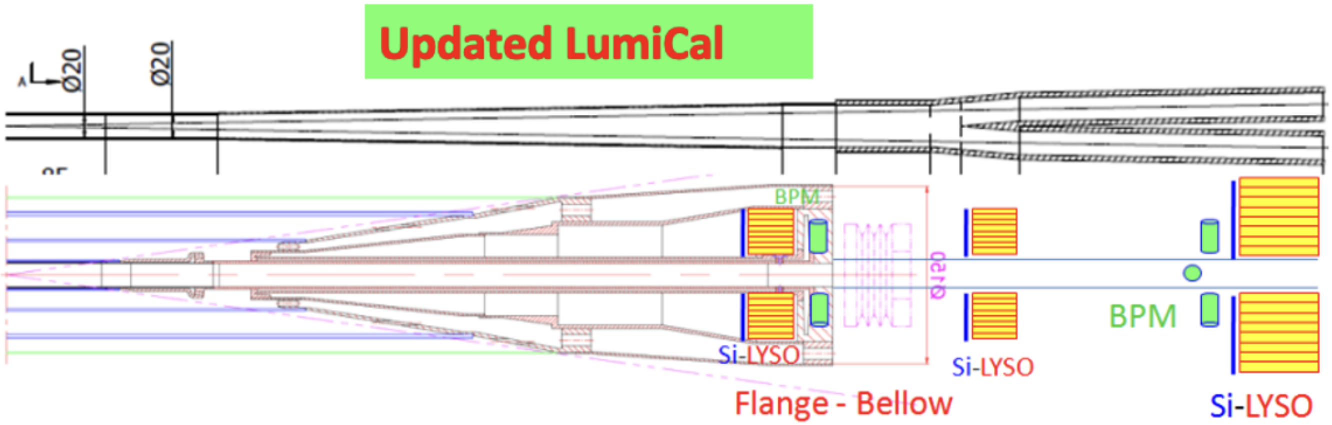


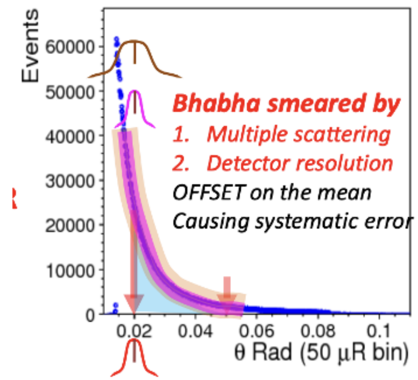
Δt of two ends of outer Be: 7.4℃<10℃

meet the requirements of the vertex detector

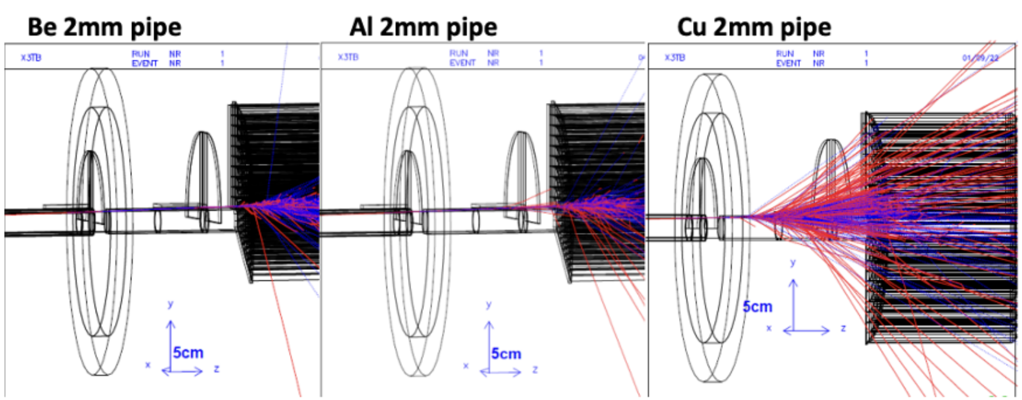


Luminosity monitoring & Impact



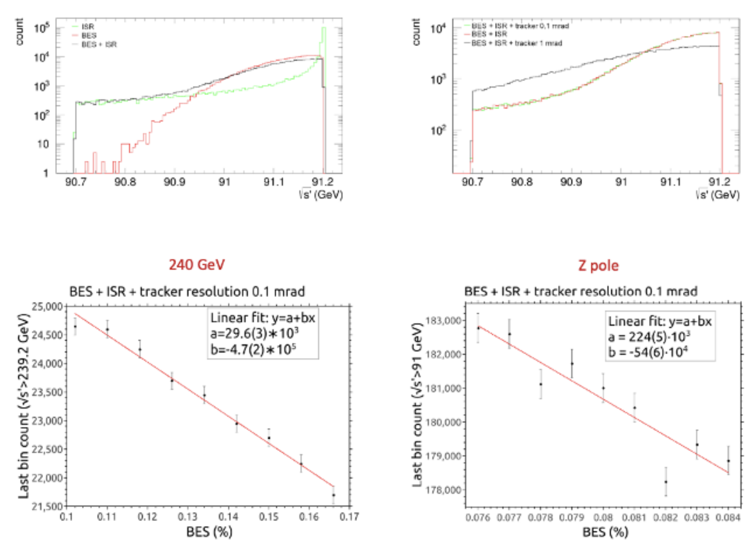


The Multiple scattering due to small angle must be taken special care of



S. Hou

I. Bozovic

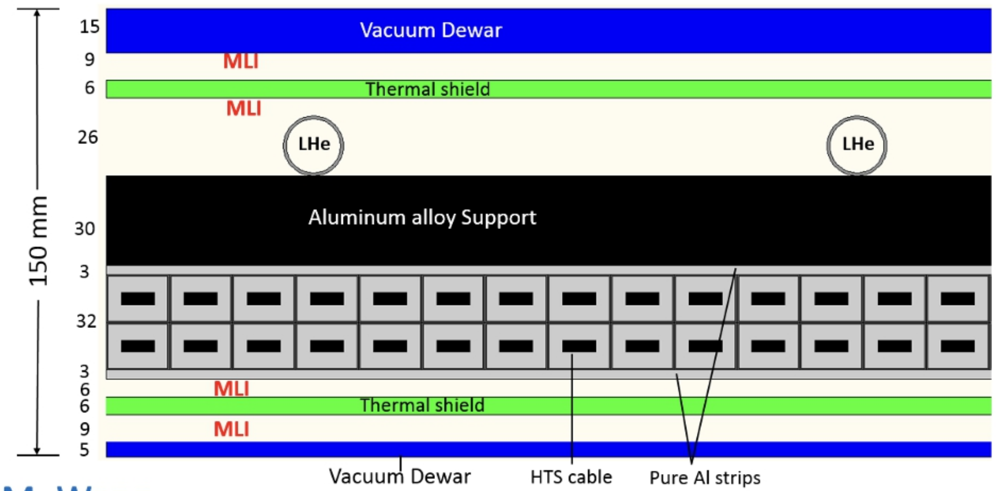


With the CEPC post-CDR design, Beam Energy Spread can be determined with the total relative accuracy of 25% corresponding to 9 MeV beam energy uncertainty in only 3 minutes of data-taking at the Z–pole

And to the systematic uncertainty of the EW observables at the Z^0-pole: $\delta(\sigma_Z)\sim 2.6\cdot 10^{-3}$, $\Delta\Gamma_Z\sim 30$ MeV, $\Delta m_Z<100$ keV

BPM @ MDI and Solenoid design

Conceptual mechanical design of the ultra-thin & transparent cryostat – 150mm

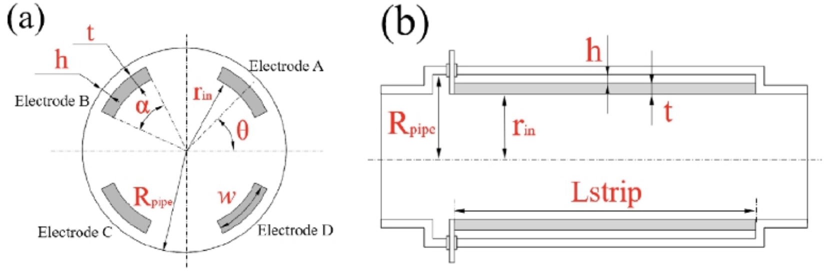


M. Wang

Progress of LTS detector magnet

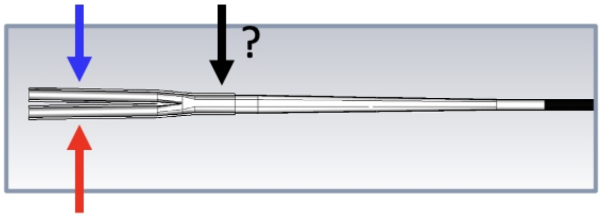
Winding platform of Dummy coil

- Dummy cable: 6061 Aluminum alloy, cross section 56mm*22mm
- Dummy coil: 4 layers, 10 turns per layer.

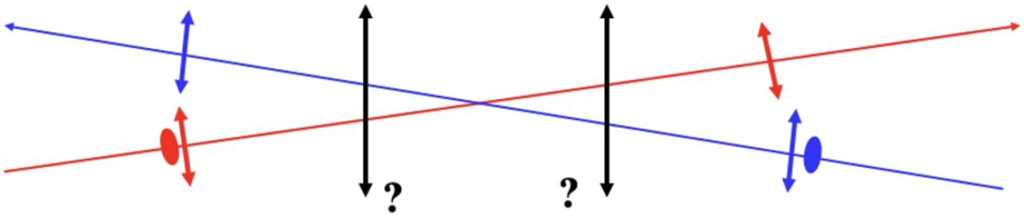


CEPC BPM design: stripline-type

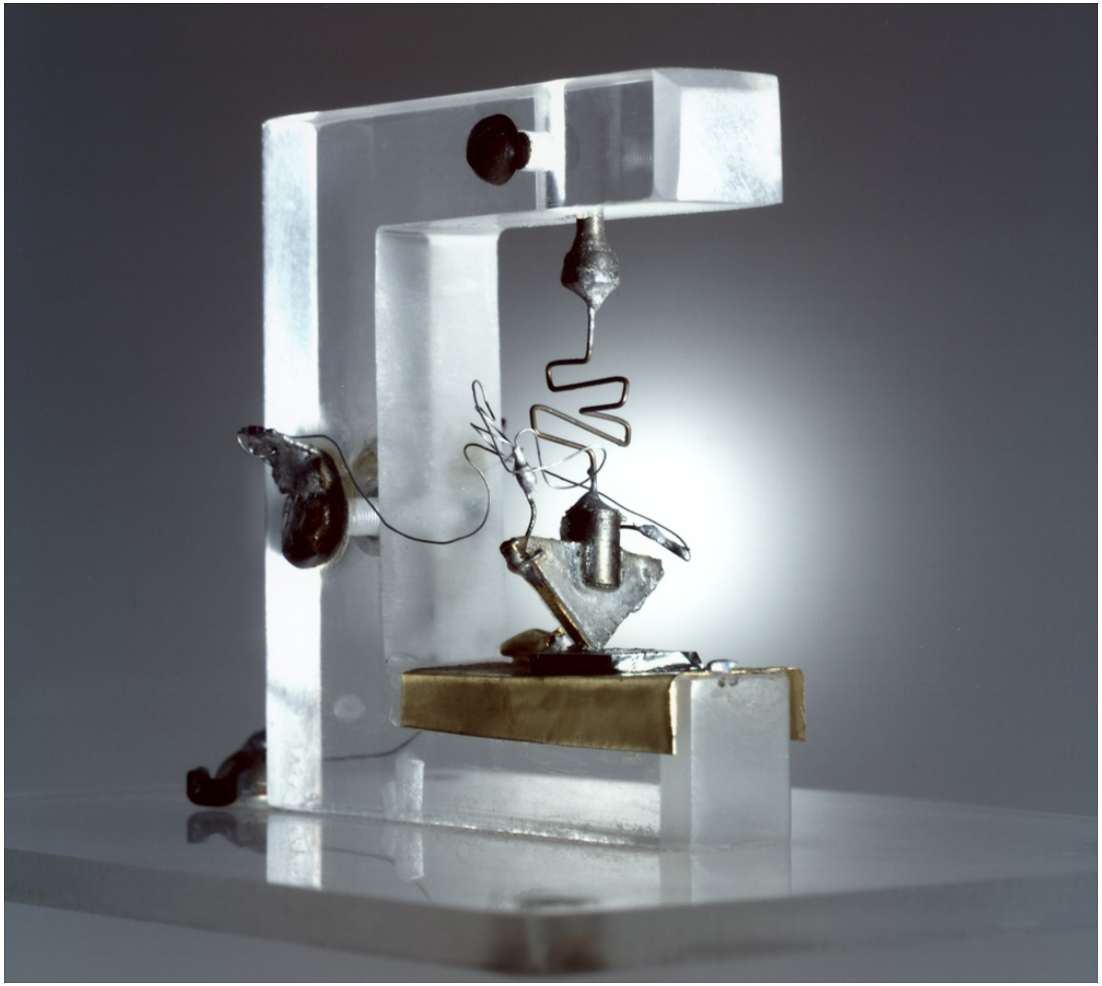
J. HE



Try to Deliver an IP BPM Design

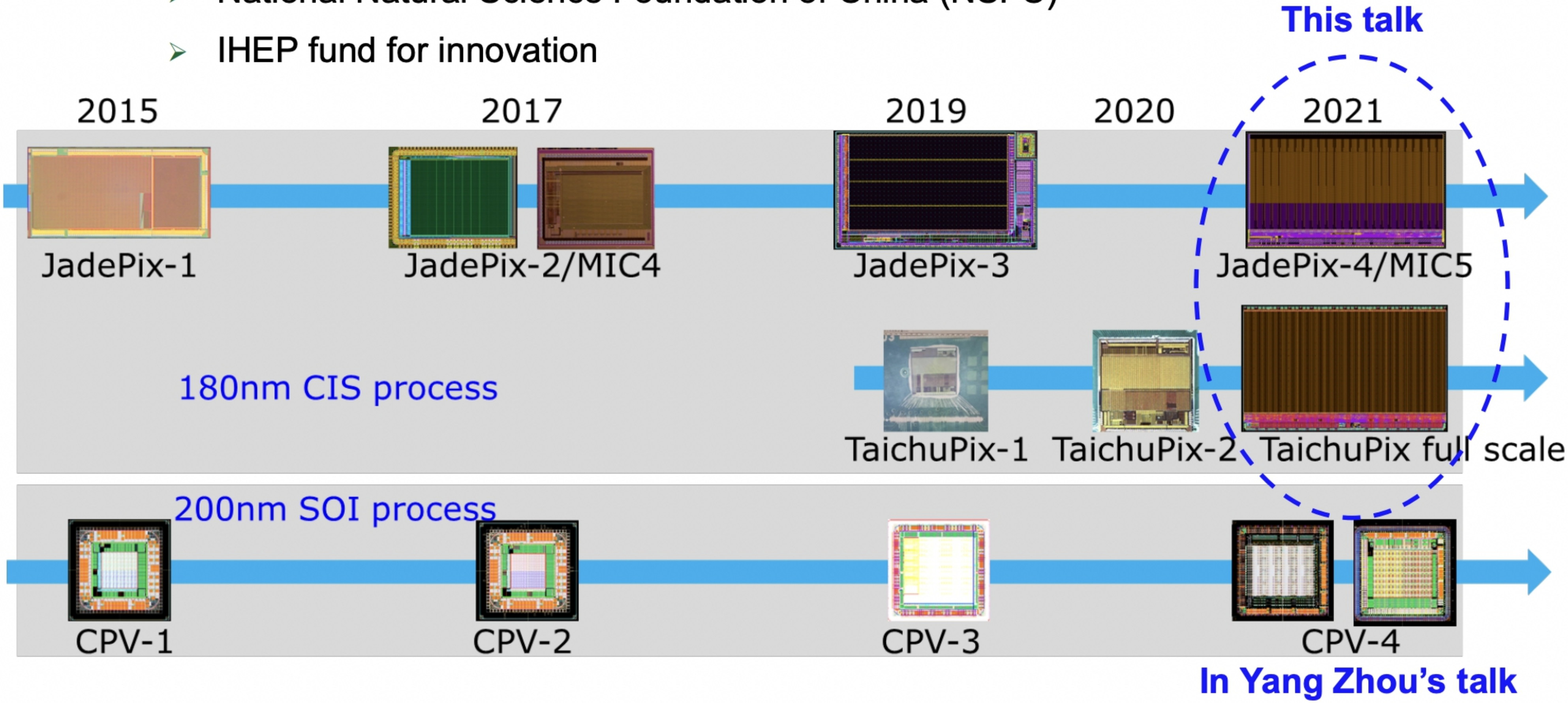


Silicon



Overview of pixel sensors in China for CEPC VTX

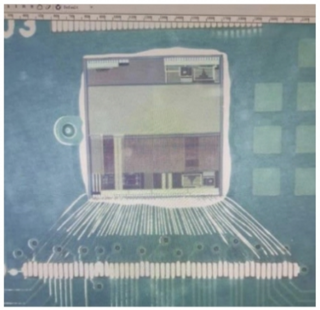
- **Development of pixel sensors for CEPC VTX supported by**
  - Ministry of Science and Technology of China (MOST)
  - National Natural Science Foundation of China (NSFC)
  - IHEP fund for innovation



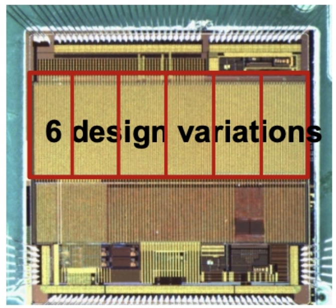
Ref: "Status report on MAPS in China", 2021 CEPC workshop, Yunpeng Lu

CEPC VTX Chips

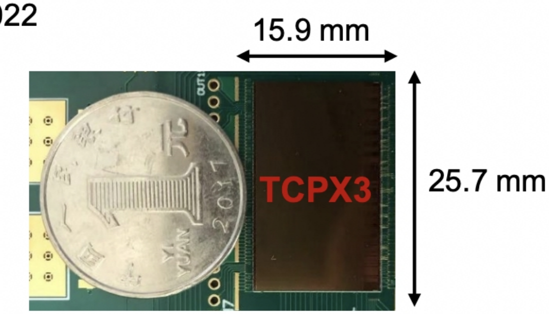
- 1^{st} engineering run
  - Full-scale chip: TaichuPix-3, received in July 2022



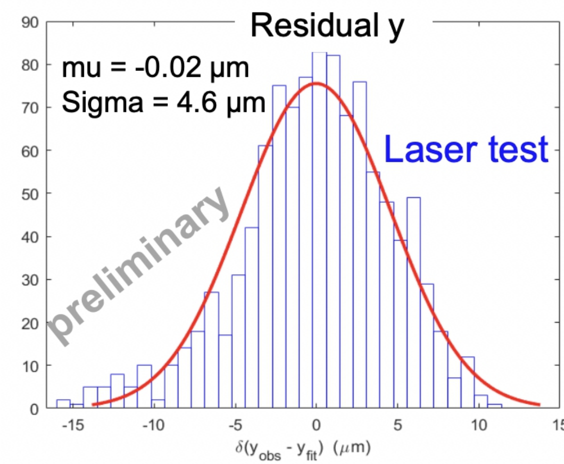
TaichuPix-1

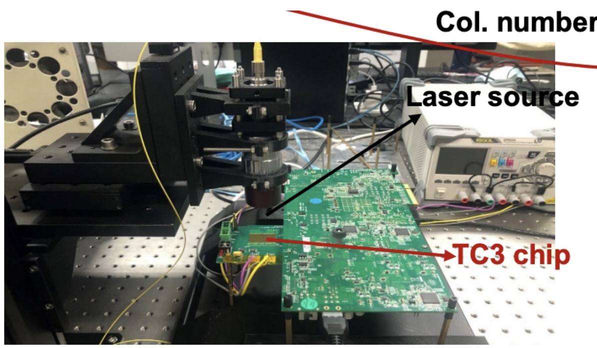


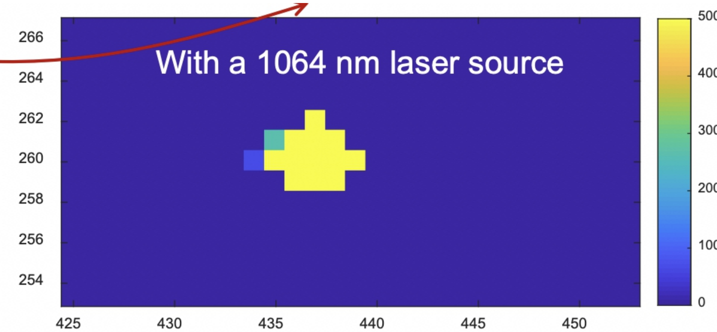
TaichuPix-2

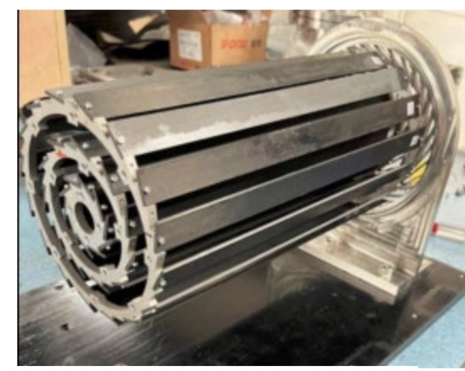


TaichuPix-3
Pixel size：25 μm × 25 μm



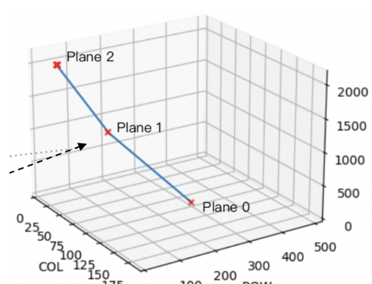


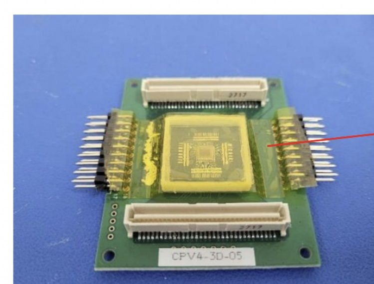




- **Functionality of the full signal chain proved**

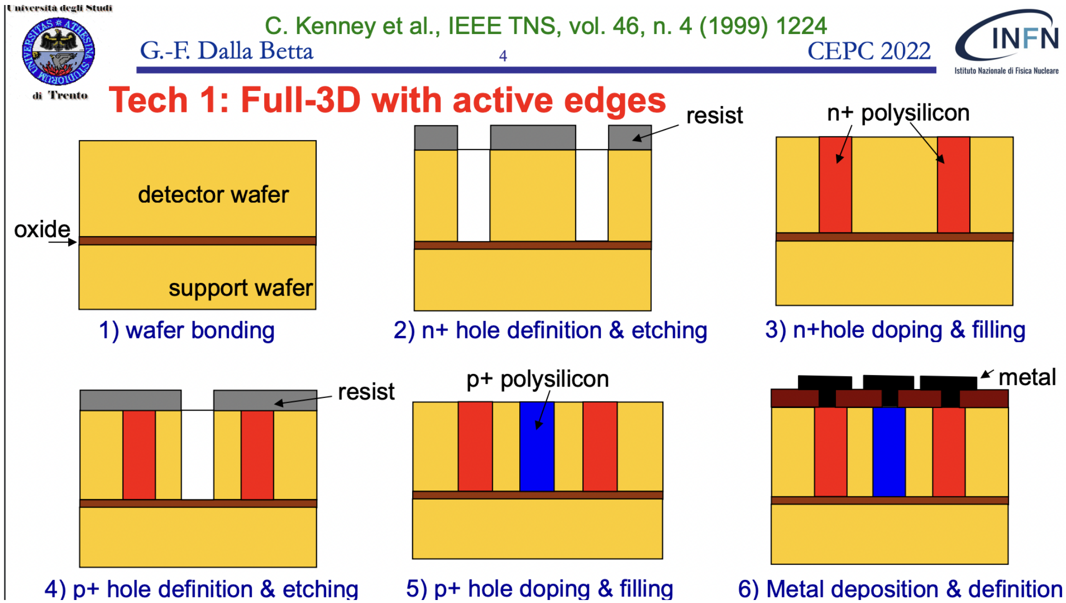
CPV-4-3D: ready for the 3D chips test

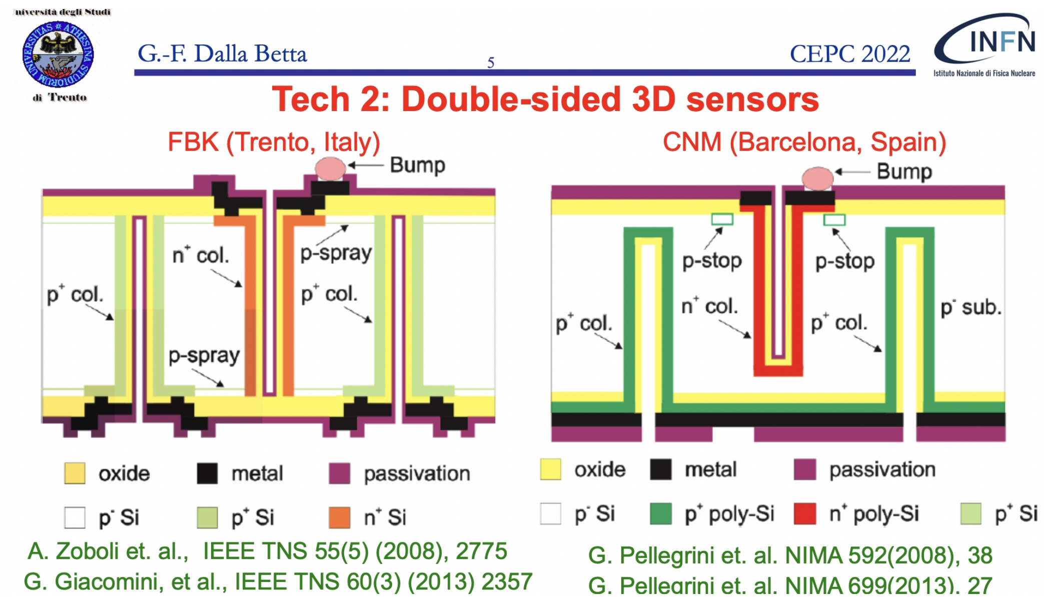


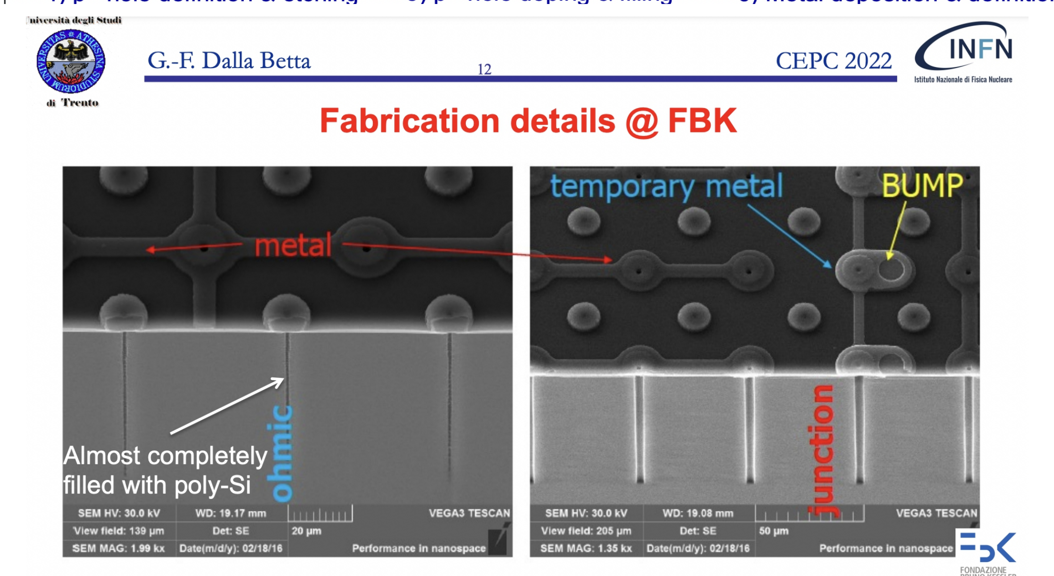


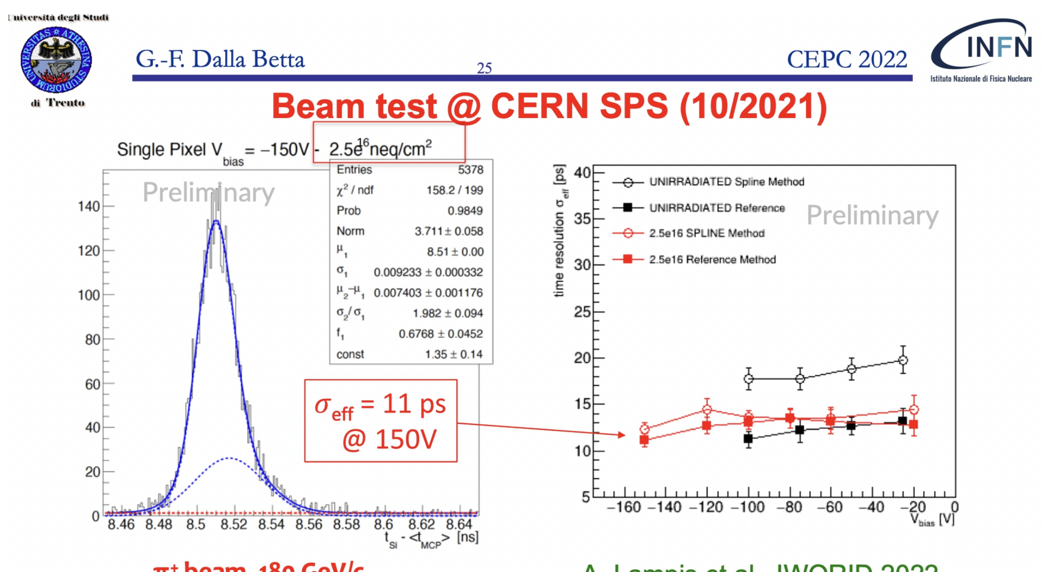
Combined test beam at DESY: Dec 2022

3D-sensor: ~ o(10)ps!

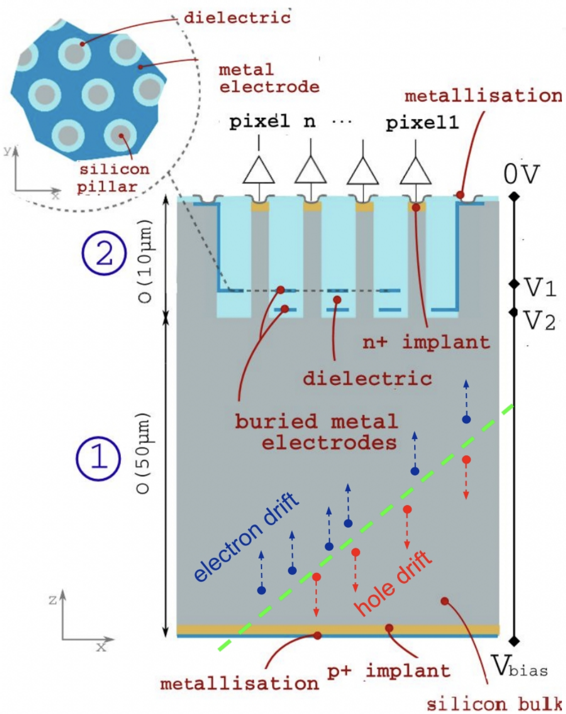


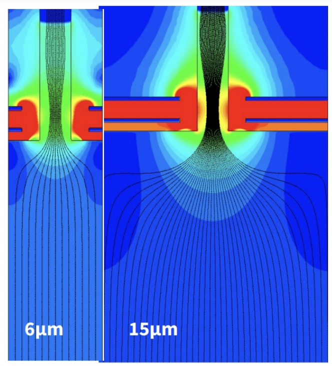


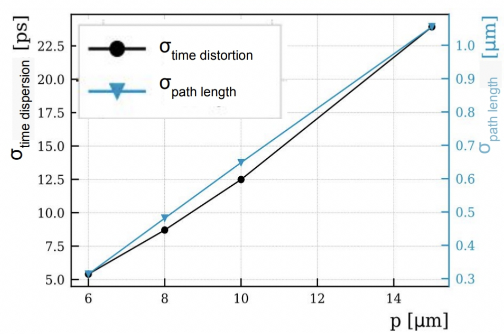




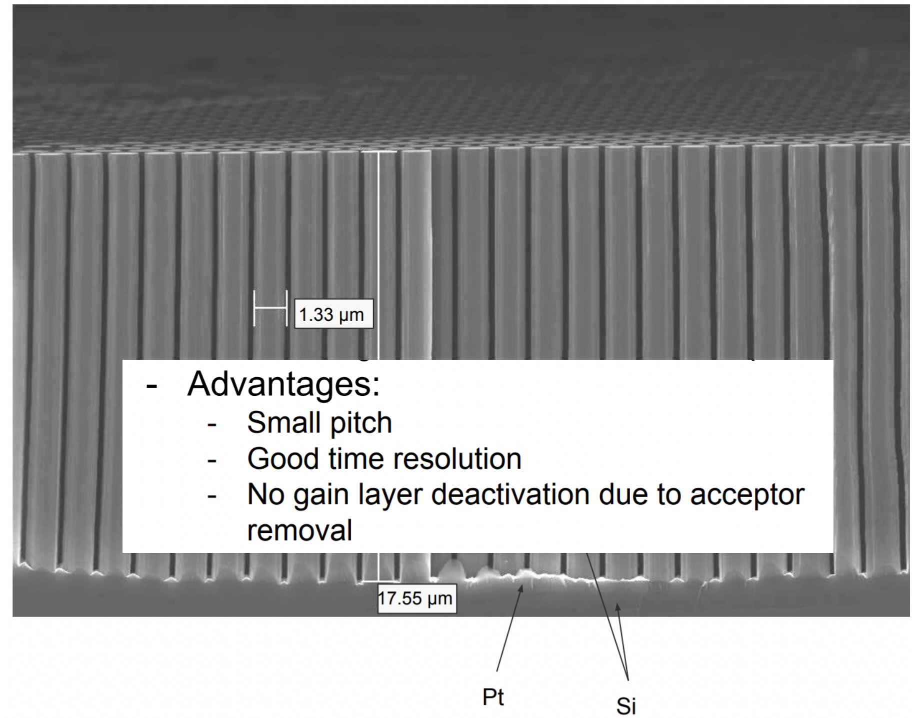
Silicon electron multiplier sensor







Marius Halvorsen



- Advantages:
  - Small pitch
  - Good time resolution
  - No gain layer deactivation due to acceptor removal

Our approach

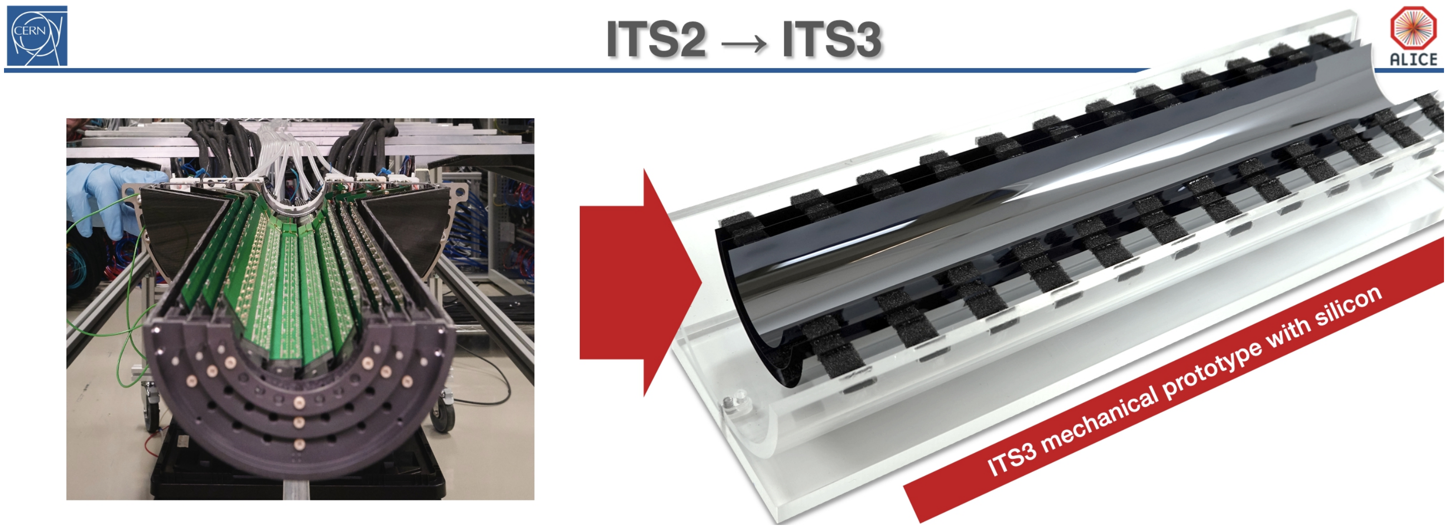
UNIVERSITETET I OSLO

- Gain, doping independent
- Small pitch
- Small thickness, radiation hardness

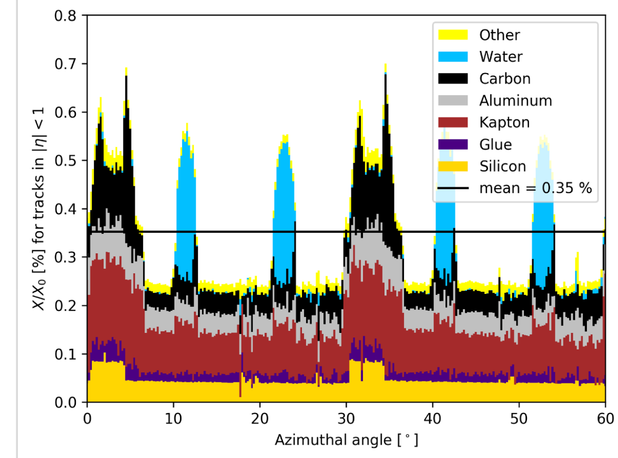
Future inner tracker detectors will require
- Time resolutions below 50 ps
- Pixel pitch down to 25 μm
- Radiation hardness up to 10^{17} n_{eq}

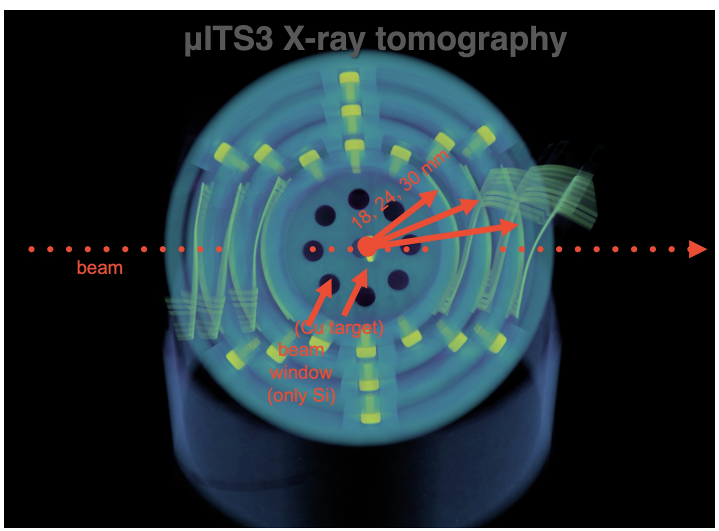
Structure realized via Chemical Etching, enabling lots of future tests: IV, TCT, Beta-source...

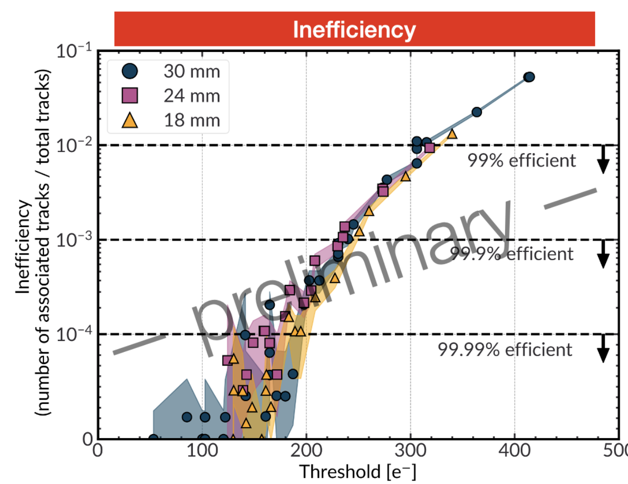
ALICE ITS3

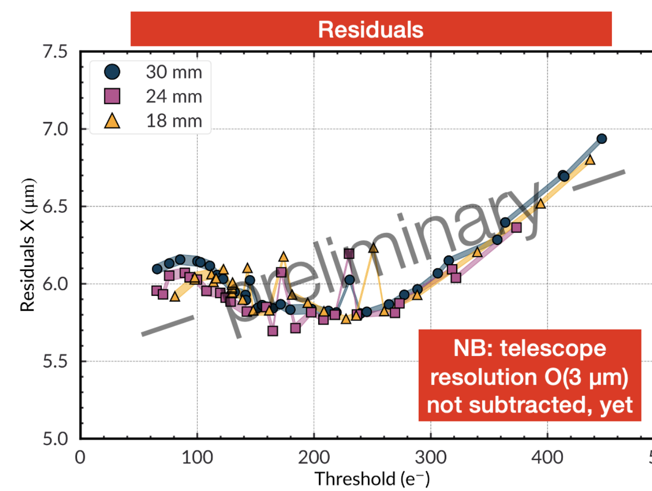


A. Kluge





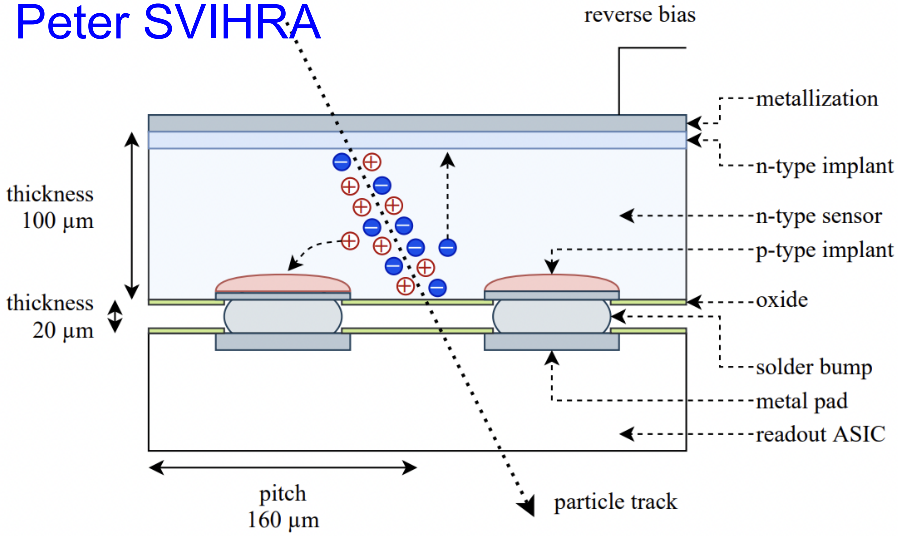




- Bending doesn't show effects in main performance figures.
- Next step to prove stitching and power/signal distribution.
- *Far future... put inside the beam pile??*

Small pitch pixel detector hybridsation and integration

Peter SVIHRA



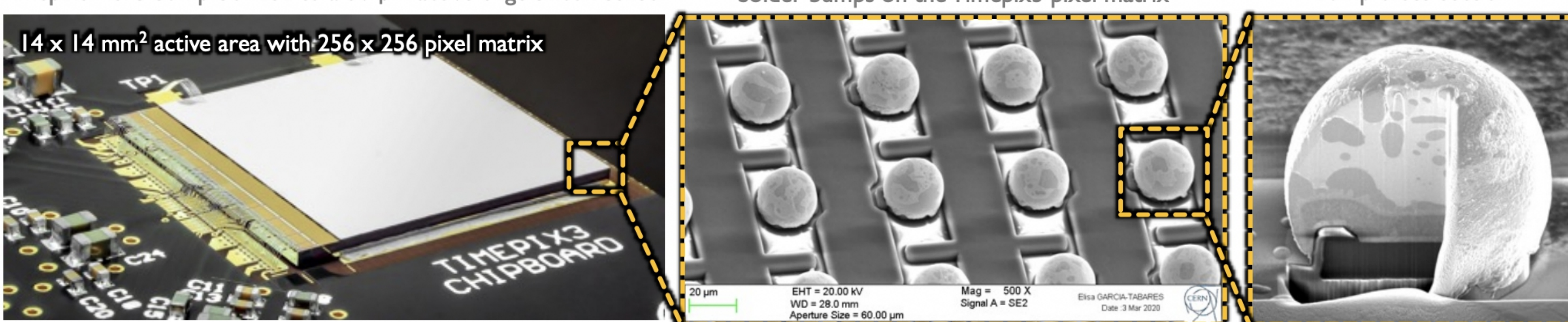
Generic hybrid pixel detector with planar p-on-n silicon sensor

- **Small pitch bump bonding**
  - Single die process developed for 25 µm pitch CLICpix2 hybrid assemblies
    - Very good efficiency results for 50 µm thick sensors
  - Laboratory and beam-test results show excellent yield of above 99.7 %
- **ACF interconnect** Anisotropic Conductive Film
  - In-house UBM plating and in-house ASIC-sensor connection
    - Extensive ENIG studies to achieve uniform metal growth
  - Good yield achievable for 55 µm pitch, better control of ENIG required
  - Ongoing improvements of the bonding parameters and ACF materials
  - ACF can be also used for module integration

Timepix3 ASIC bump-bonded to a 50 µm active edge silicon sensor

Solder bumps on the Timepix3 pixel matrix

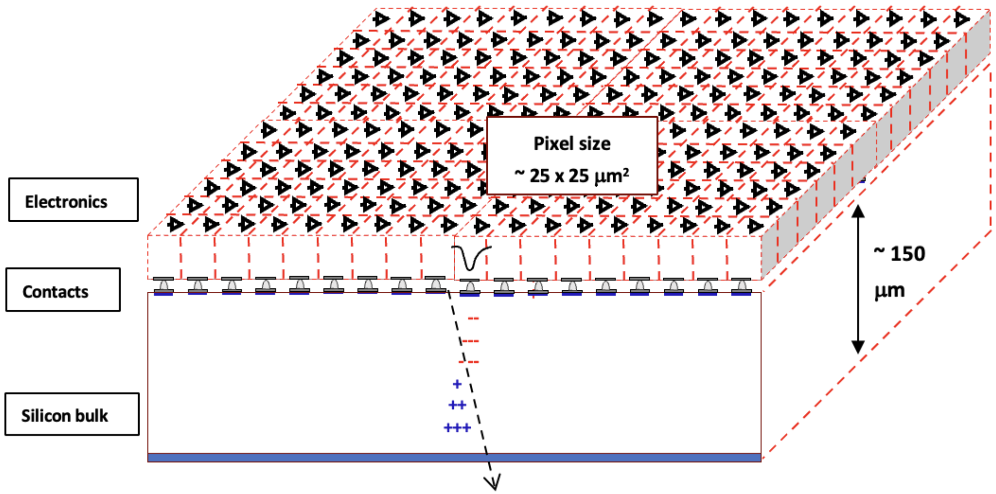
Bump cross-section



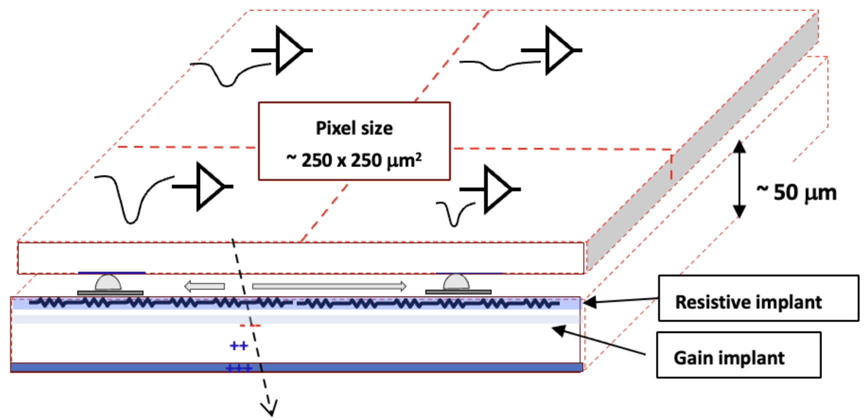
Under Bump Metallisation

LGAD - 4D tracking

A complete new tracker based on RSD



Standard Silicon Detector



Resistive Silicon Detector

The innovative design of a tracker based on RSD

- It delivers ~ 30 -40 ps temporal resolution
- For the same spatial resolution, the number of pixel is reduced by 50-100
- The electronic circuitry can be easily accomodated
- The power consumption is much lower, it might even be air cooled (~ 0.1-0.2 W/cm²)
- The sensors can be really thin

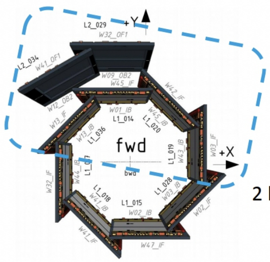
M. Ferrero
INFN Torino

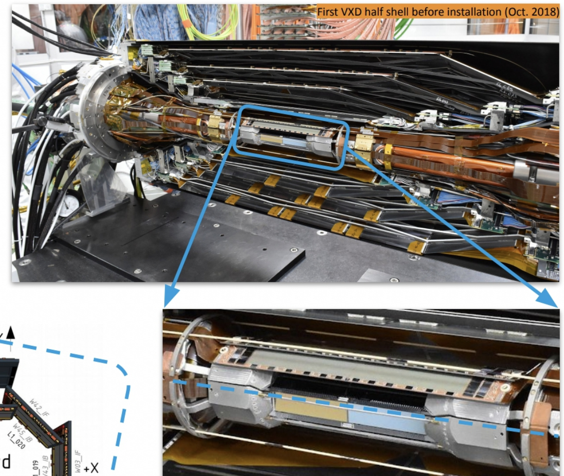
Belle II VTX & upgrade

Setting the Scene

Belle II Vertex Detector (VXD)

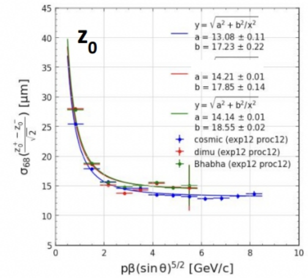
- **Silicon Vertex Detector (SVD)**
  - 4 layers of 2-sided silicon strips
  - r ≤ 140 mm
- **Pixel Vertex Detector (PXD)**
  - 2 layers at radii 14 mm and 22 mm
  - 8 inner + 12 outer module-pairs ("ladders")
    - ⇒ only 8 (inner) + 2 (outer) ladders installed
  - ~7.7 x 10^6 pixels
  - ~0.21 % X_0 / layer material budget
- **acceptance**
  - 17° < Θ < 150°
  - p_T ≥ 40 MeV

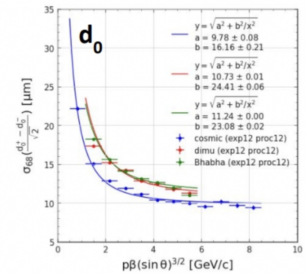




2 half shells

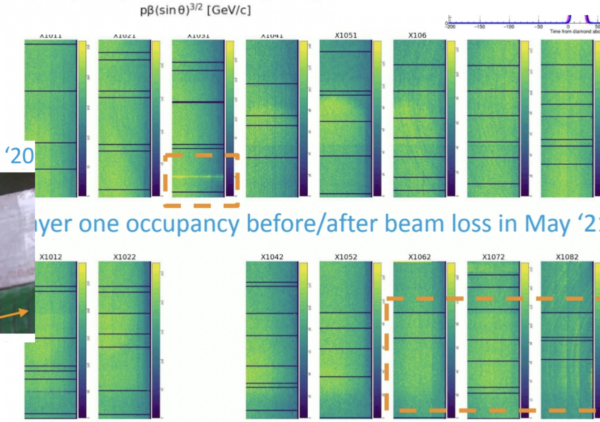
DESY.





Arthur Bolz

LER collimator damage on Nov 15 '20



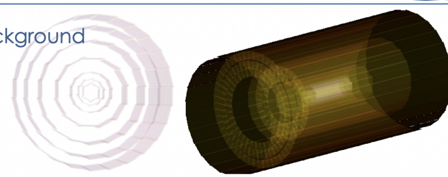
…yer one occupancy before/after beam loss in May '21

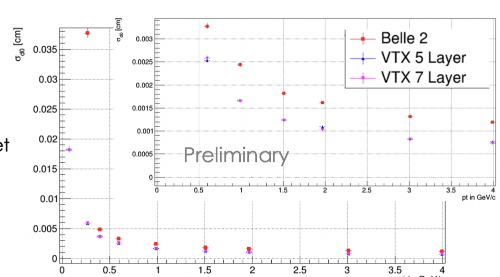
VTX simulated tracking performances

IPHC

Context = full Belle II simulation framework, including background

- Realistic pixel sensor model
  - Digitizer assuming
    - fully depleted thin layer 30 μm
    - Pixel 33x33 μm² with 7bits Time over Threshold
  - Tuned with Monopix-1 beam data
- Geometry
  - Taken from fast simulation
  - 5 or 7 barrel layers with/without 2 forward disks
  - Crude layer description but with targeted material budget
    → per layer: 0.1 % X_0 for radii <4 cm then 0.3 % X_0
- Full tracking chain
  - VTX standalone } then combined
  - CDC standalone }





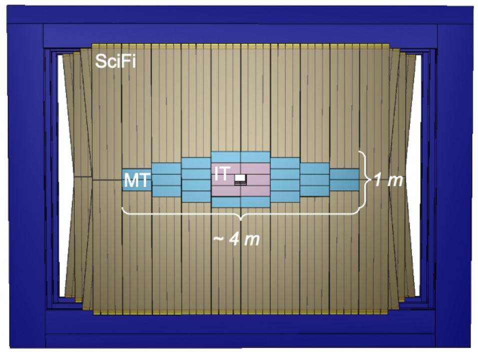
Jerome Baudot

Tech. Monopix
Obelix

Power supply, HV CMOS

Mighty Tracker Ivan Peric

- SciFi Tracker
  - Scintillating fibres with SiPM readout
- Inner Tracker and Middle Tracker
  - Silicon sensors meet requirements of radiation hardness and granularity
  - Baseline technology: HV-CMOS pixel chip **MightyPix**
  - In total over 46000 silicon sensors to cover area of 18 m^2 (minus beam-pipe hole)

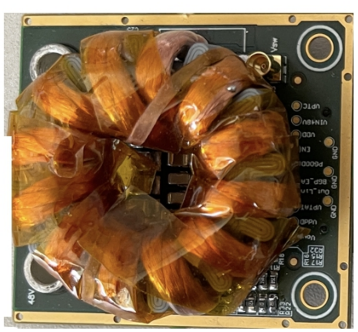


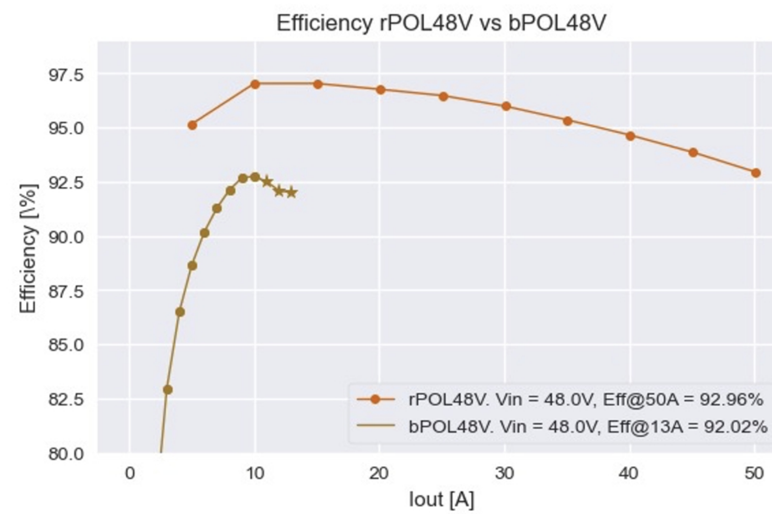
Schematic of one layer of the Mighty Tracker. [1]

Parameter	Required Value	Notes
Chip size	~2 cm × 2 cm	
Pixel size	~ 50 μm × 150 μm	
Time resolution	< 3 ns	Hit assigned to right BX
Power consumption	$< 0.15\ W/cm^2$	
NIEL[3]	6×10^{14} 1 MeV n_{eq}/cm^2	Includes safety factor of 2
Cooling	< 0°C	Test beam studies

- First prototype MightyPix-1 submitted this May

bPOL48V (buck) production grade vs. rPOL48V (resonant)

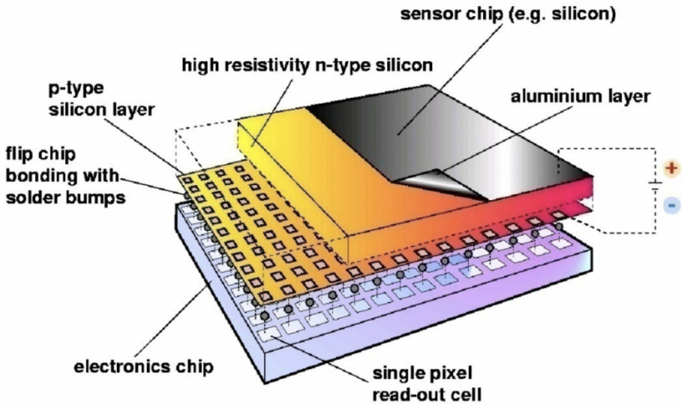


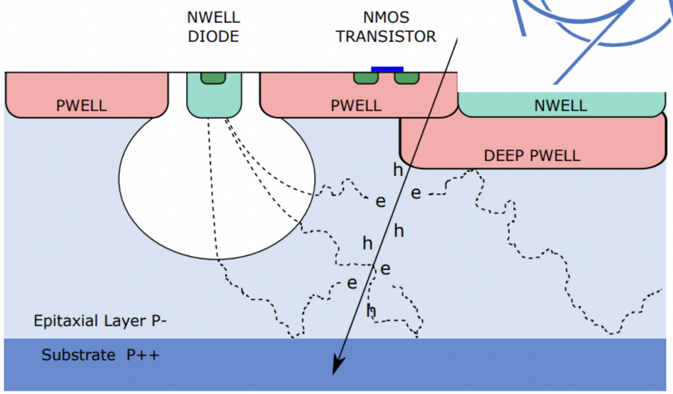


Giacomo Ripamonti

Hybrid vs Monolithic

Walter. Snoeys





Hybrid

- Large majority of presently installed systems
- 100 % fill factor easily obtained
- Sensor and ASIC can be optimized separately
- Spin-off from HEP developments:

  for example spectral photon counting chips in this workshop

Monolithic

- Easier integration, lower cost
- Potentially better power-performance ratio and strong impact on material budget

Motivation for intense R&D since more than 30 years

- Trend towards more standard technologies

New technologies (TSV's, microbumps, wafer stacking…) make the distinction more vague.

MAPS are one of the few areas where production volume even within HEP would not be negligible, but where our community can have an impact not only on the quality of its own measurements, but also on society in general, and which we should try to exploit to enable access to the most advanced technologies.

Gaseous Detector

Gas detectors: Time Projection Chambers for CEPC

Paul Colas

- New ILD strategy and consequences on ILD tracking
- TPC = “ultimate” drift chamber, with 3D precision tracking with low material budget and PID through dE/dx or cluster counting
- Main recent progress on
  - Use of multiple layers of MPGDs (GEM or Micromegas) to significantly reduce ion back-flow (IBF) even without gating (crucial for circular colliders)
  - Use of MPGDs with pad/pixelated readout to reduce occupancy (crucial for high-lumi runs @Z).
- The possibility to use a TPC at the future Higgs factory is appealing (particle ID for free, low material), but requires a large amount of difficult studies to meet physics requirements of Z peak at the highest luminosity of circular colliders. Ion backflow suppression without loss of resolution
  - Possibility to correct for distortions (on average? or event by event?)
  - Especially difficult at the Z peak at the highest luminosity
  - What is our requirement for resolution at the Z peak?
  - Update all beam background estimates at the HZ energy.

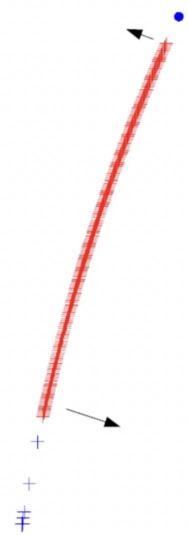
LD
r 2

In-situ calibration of distortion?

- Tracks corresponding to positive/negative charge, will be biased towards different direction:
  - Increase of Pt for one charge and decrease for another.
- Larger biases at higher Pt.

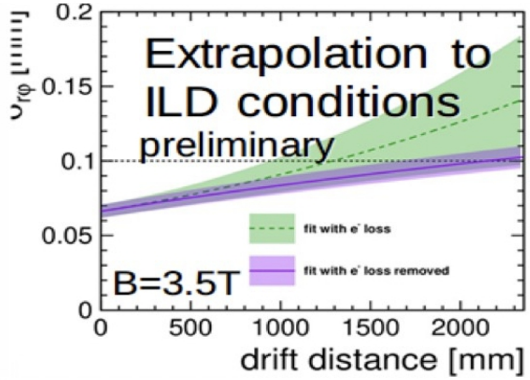
- Z -> mumu events happens at a rate of 2k Hz (1/20 of Hadronic Z), while the momentum shall be measured to a relative precision of 0.1% at each track.
- I guess the full energy lepton tracks, especially muon ones, can provide a solid reference for the correction...

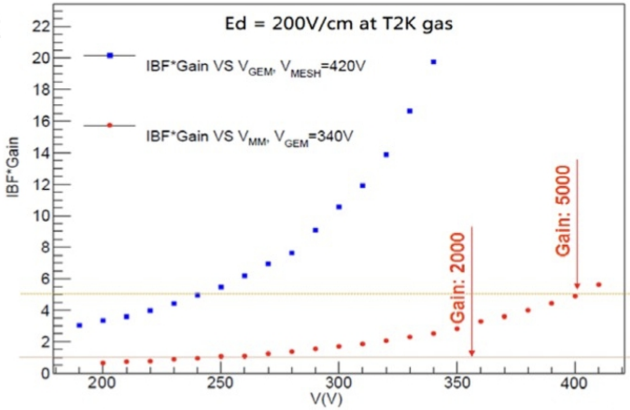
- But certainly needs more quantification!

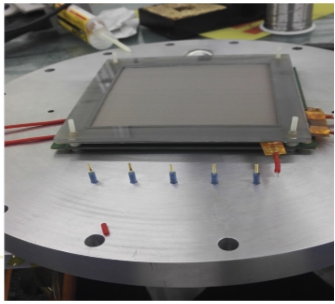


Huirong Qi, Zhi Deng

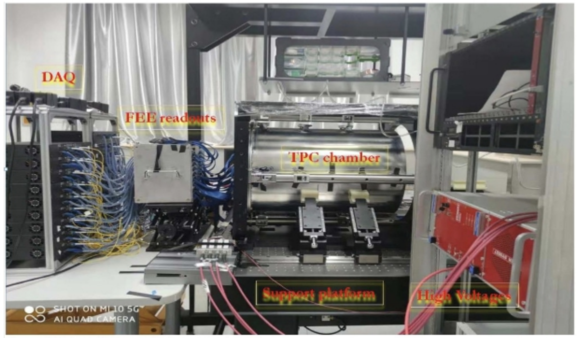
- Pad TPC with multiple GEMs or GEMs/Micromegas:
  - IBFxGain ~1 at Gain=2000 in recent testbeams with GEM/MM readout
  - Hit resolution of $\sigma_{r\varphi} \leq 100$ μm at ILD conditions also achieved



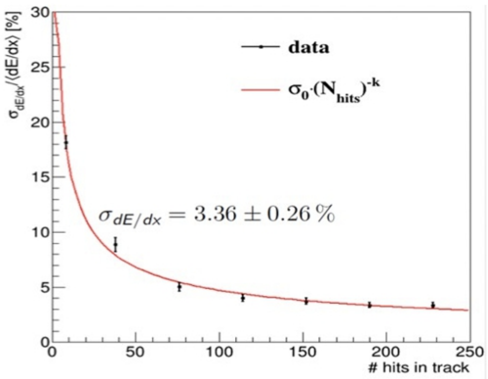


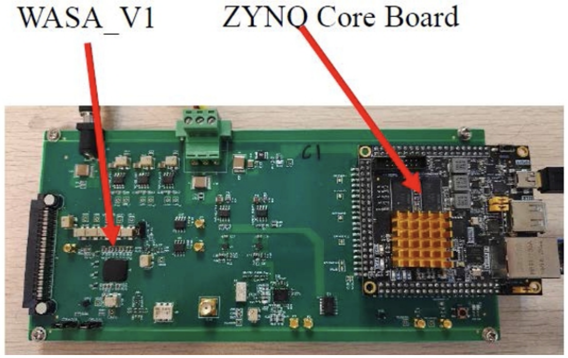


- TPC prototype recently developed by CEPC with integrated 266nm UV laser to generate pseudo-tracks
  - dE/dx about 3.4% for (pseudo-)tracks with 220 hits (as expected for CEPC baseline detector concept)



https://doi.org/10.1016/j.nima.2022.167241



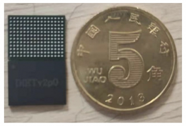


R&D on Macro-Pixel TPC Readout

Long term Goal： power consumption ~ 0.1 w/cm^2

Summary

- A 16 channel low power readout ASIC WASA has been successfully developed and evaluated
  - The power consumption is 4.94 mW/ch @ 40 MHz
    - P_{AFE}=1. 38 mW/ch
    - P_{ADC} = 0.83 mW/ch
    - $P_{Digital}$ = 2.73 mW/ch
  - ENC = 569 e+14.8 e/pF @ gain=10 mV/fC with on-chip digital trapezoidal filter
  - Next step: BGA package 16 x 11 (11.05 mm x 7.8 mm)



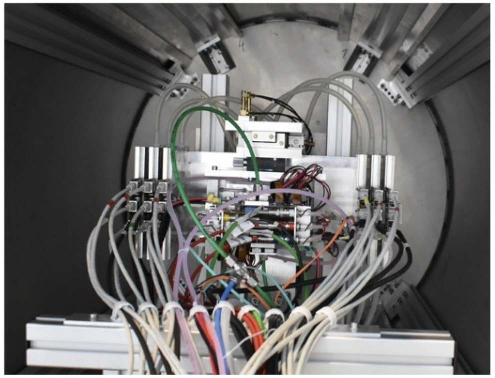
TPC R&D - pixelated technology

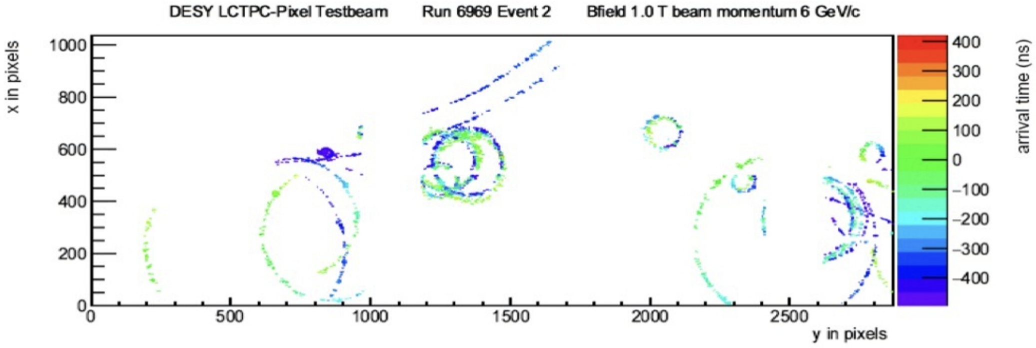
Peter Kluit

- Initial Timepix3-based GridPix detector module tests already indicate excellent tracking and dE/dx performance (4.1% resolution for 1m track length)

https://arxiv.org/abs/1902.01987

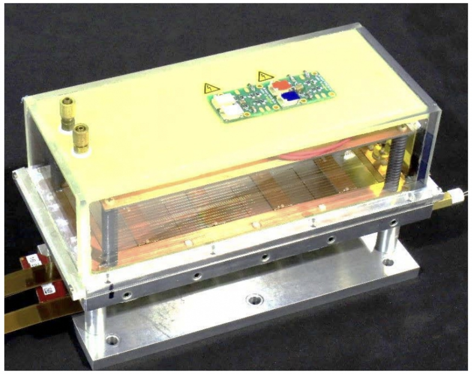
- Prototype with 160 GridPixes covering an active area of 320 cm² (10M pixel detector) also built and tested in beam at B=1T in DESY in June 2021, to prove large-scale production, integration, and readout => 1e6 events successfully collected





DESY testbeam in June 2021

- Development of new ASIC (Timepix4) ongoing (lower power consumption, easier assembly, better coverage)
- dN/dx cluster counting: should be feasible with high granularity readout, challenging for low power consumption, to be addressed by dedicated R&D.
- Preliminary full simulation studies (Geant4) foresee, compared to pad TPC w/ 6mm pads:
  - Momentum resolution improvement: 15%
  - dE/dx improvement: 30% (with cluster counting)

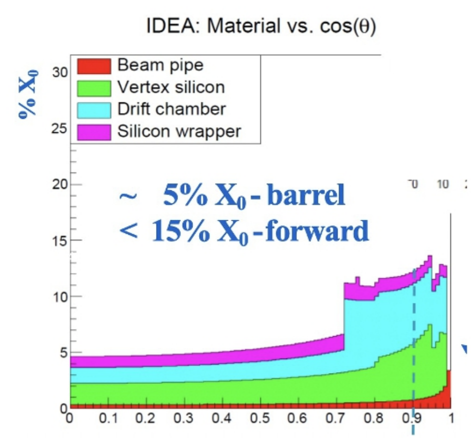


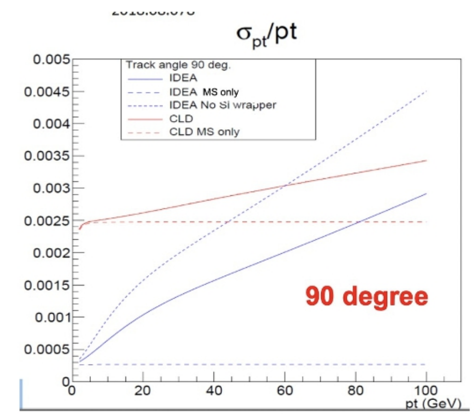
- The current power consumption is 1W/cm². So good cooling is important but in my opinion no show stopper; but needs extensive R&D.

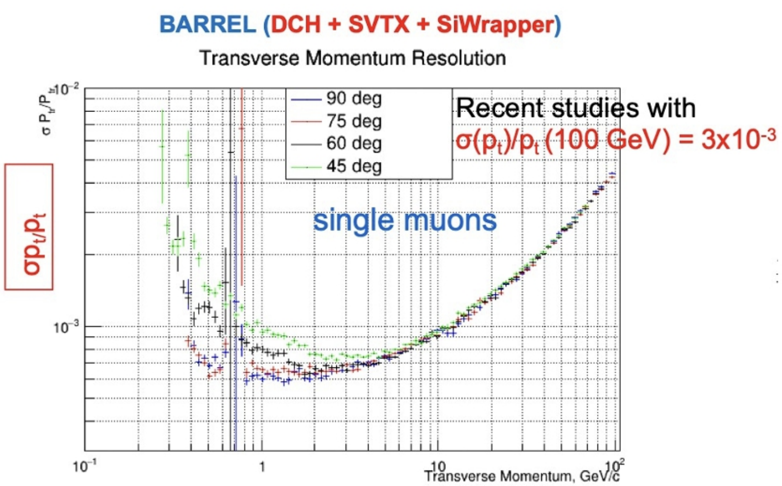
Gas detectors: the IDEA drift chamber for CEPC

Nicola De Filippis

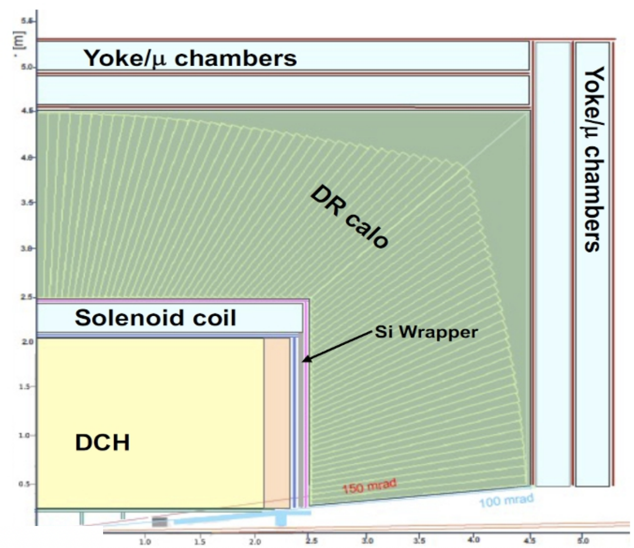
- Transparent drift chamber to minimise multiple scattering contribution to pT resolution at low pT
  - 112 coaxial layers, L = 4m, 0.35m < R < 2m => 343.968 wires
  - Large number of wires requires novel wiring procedure developed for MEG-II
  - Mechanical assembly also separates gas containment/wire support functions leading to very low material in inner cylinder and end-plates
- Full sim in FCC framework and DCH model available in DD4hep

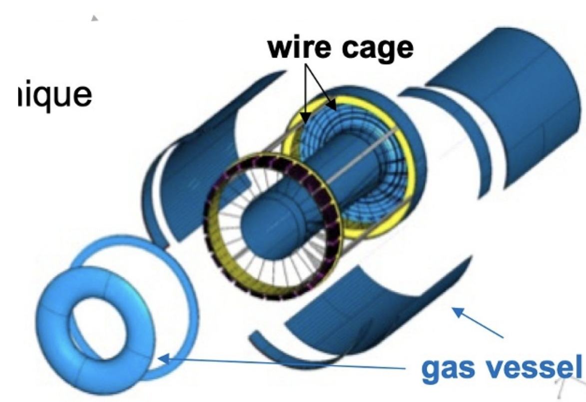






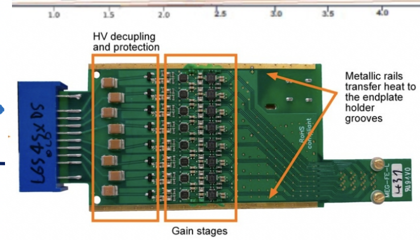
Recent studies with $\sigma(p_t)/p_t$ (100 GeV) = 3×10^{-3}

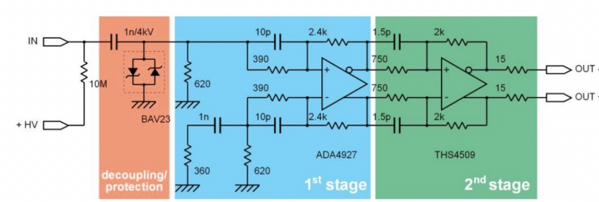




FE and DAQ electronics for a cluster counting drift chamber

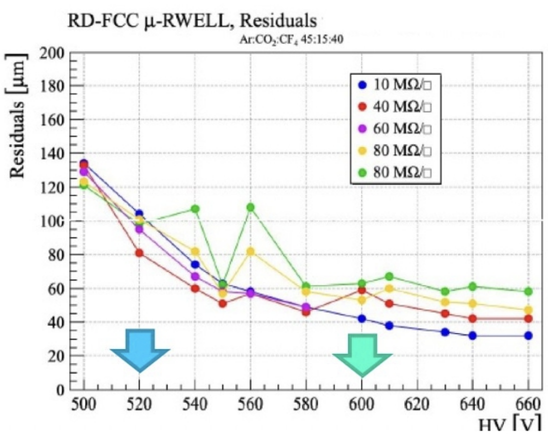
Gianluigi Chiarello
INFN Lecce

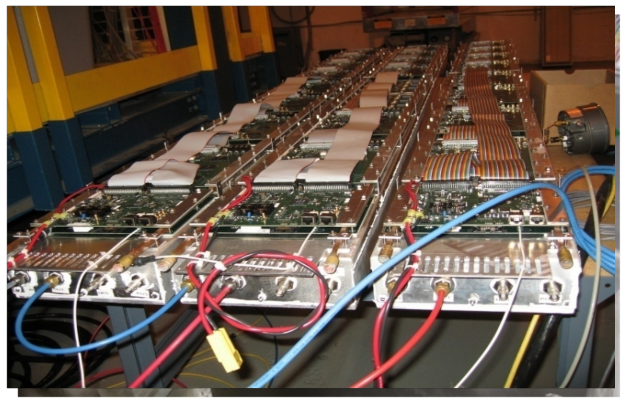




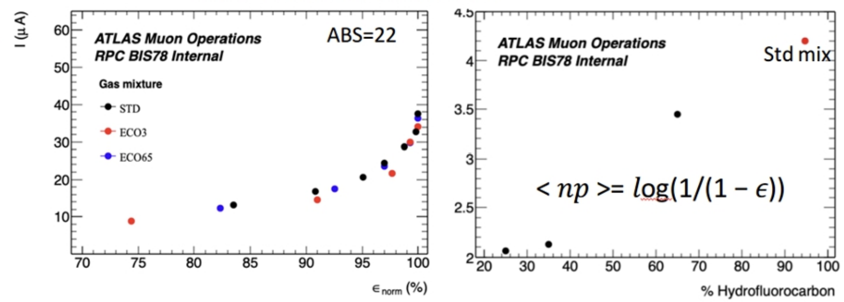
Muon chambers / MPRC TOF / Eco-friendly gas

- μ-RWELL: cheap, can sustain high rates => good choice for muon detectors of future collider detectors at large R (=>large area)
  - straight-forward for ee factories, requiring an R&D for the harsher conditions of SppC & FCC-hh
- Sealed MRPC was developed in THU (>7kHz/cm^2)

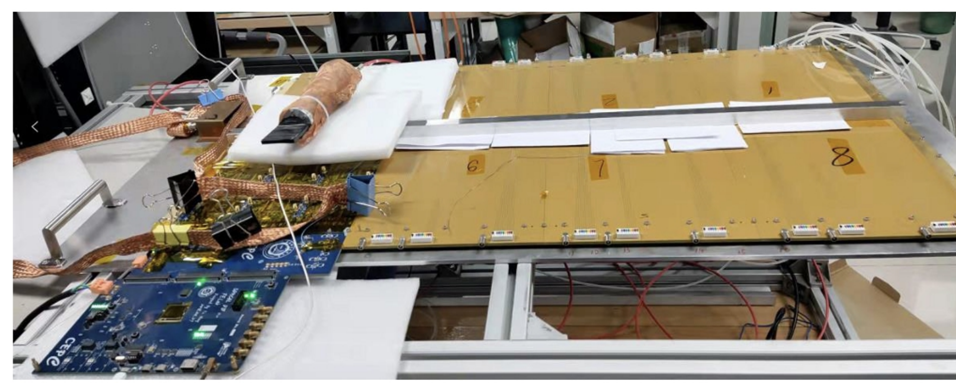




Mixtures from ECOGAS@GIF collaboration: ECO3 = 25%HFO/70%CO2/4%ISO/1%SF6
ECO2 = 35%HFO/60%CO2/4%ISO/1%SF6
ECO65 = 65%HFO/30%CO2/4%ISO/1%SF6

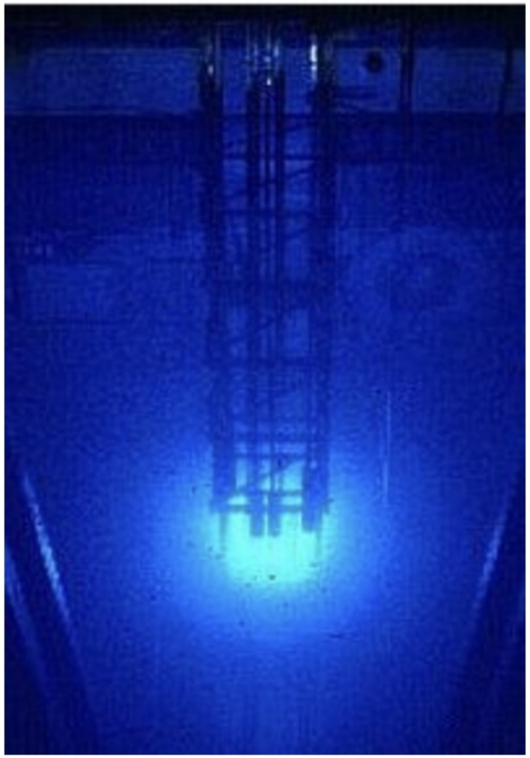


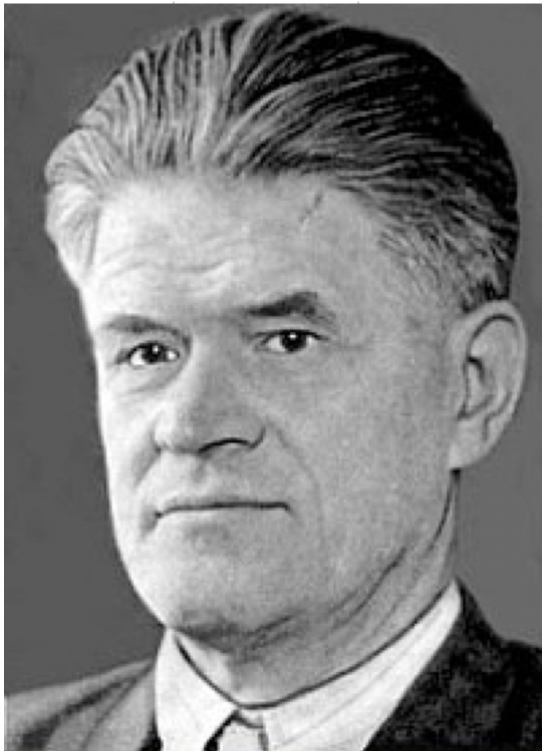
- RWELL detector was produced. Gain uniformity of ~ 14%@~5200 gain, and rate capability >100 kHz/cm2, are achieved.
- Search for Eco-friendly gases for gaseous detectors
- Long-term studies with HFO gas mixtures



Gas type	GWP
CO2	1
HFC-134a	1430
SF_6	23900
HFO-1234ze	4
He	<1

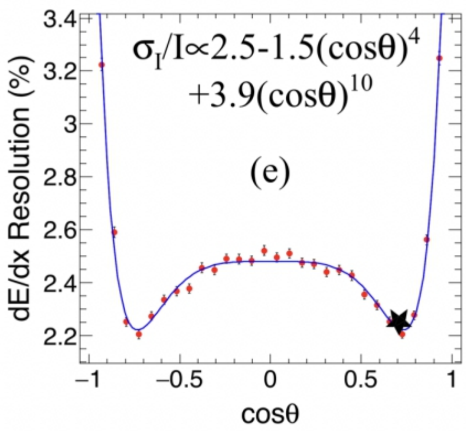
Pid & other technology

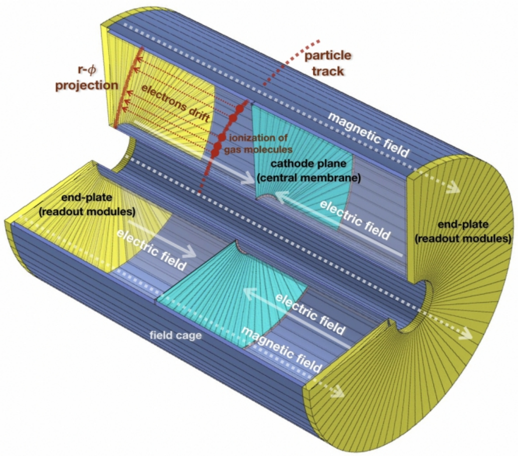


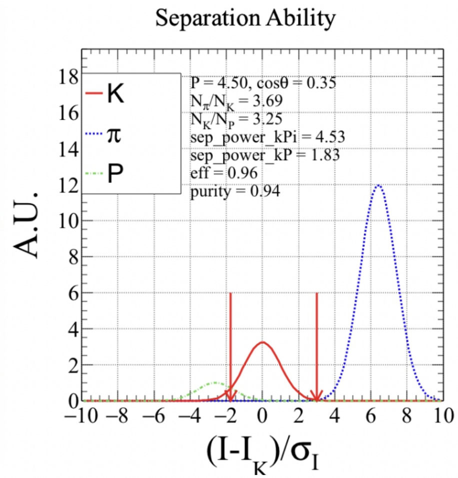


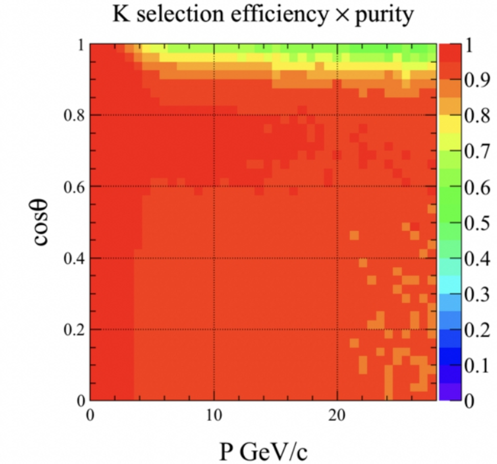
Pid requirement

Yongfeng Zhu



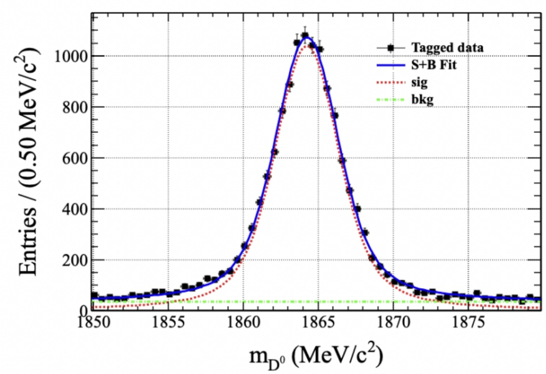




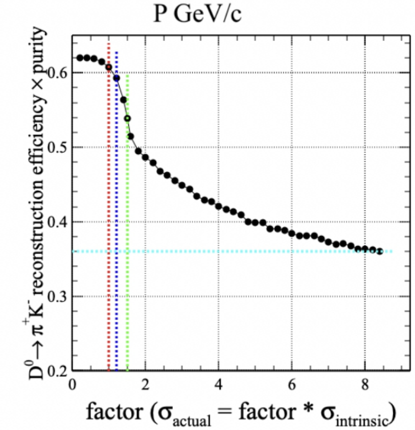


$D^0 \to \pi^+ K^-$ reconstruction

	ϵ (%)	p (%)
$\lvert mass - mass_{D0}\rvert < 0.01\,GeV/c^2$	90.39	2.16
IMP > $0.02\,mm^2$	79.12	5.04
vertex fitted $\chi^2 < 5.15$	72.62	15.36
dis of vertex to IP > $0.305\,mm$	69.24	28.41
PID	68.19	89.05



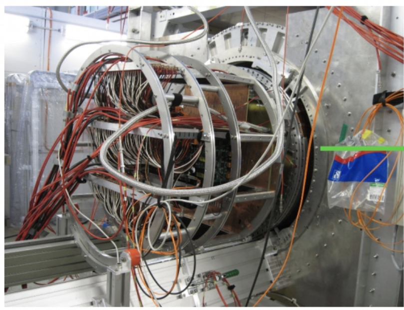
fitted mass : $1864.259 \pm 0.025\,MeV/c^2$



- Geant4: TPC @ baseline gives a resolution of 2.5% at MCTruth, together with 50 ps ToF, an overall eff/purity of 98%/97% is anticipated for Kaon@Z->qq, with significant dependence on polar angle.
- Physics object (D, Φ) reconstruction strongly suggest dE/dx resolution < 3%

TPC: Pad or Pixel

Ulrich Einhaus



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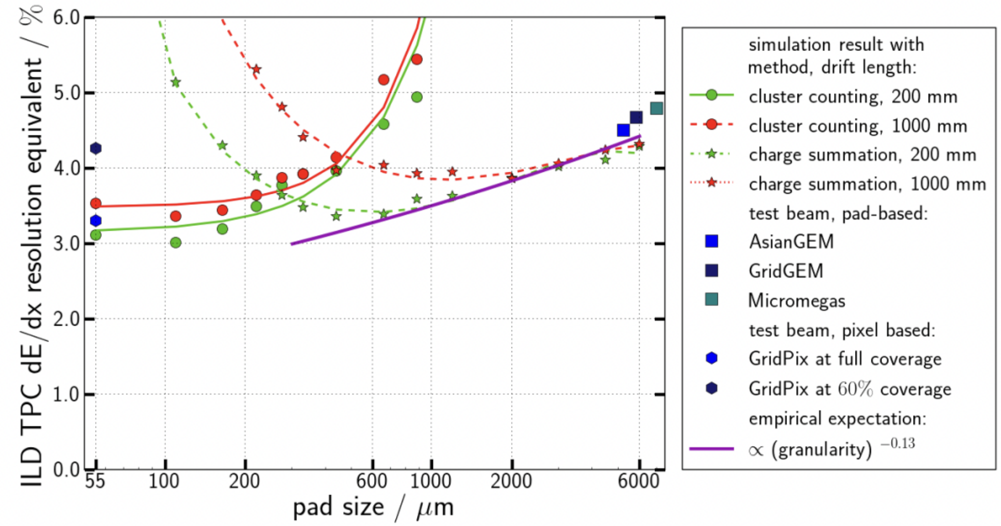
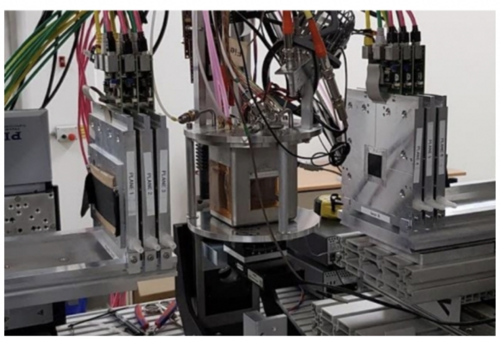
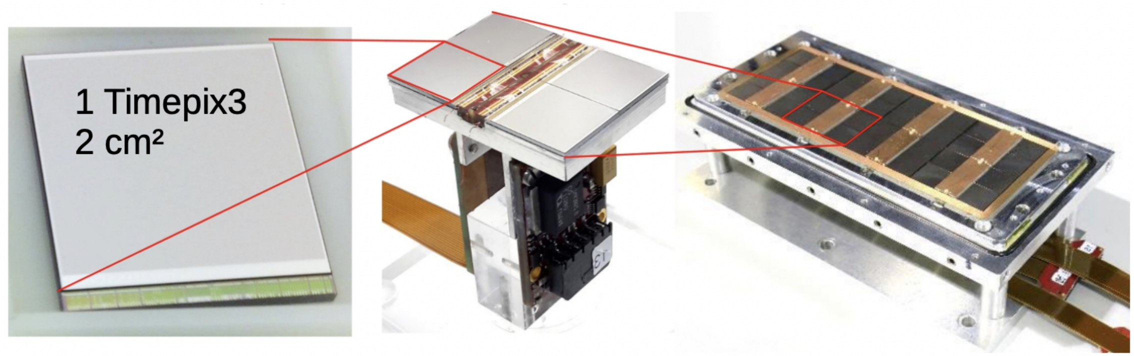
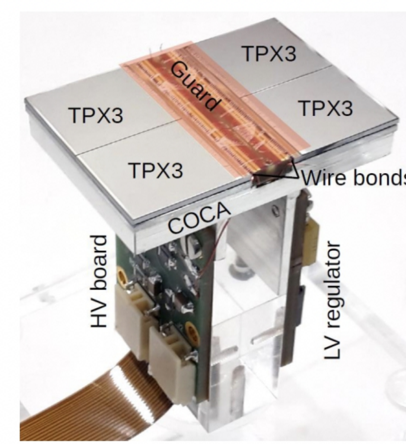




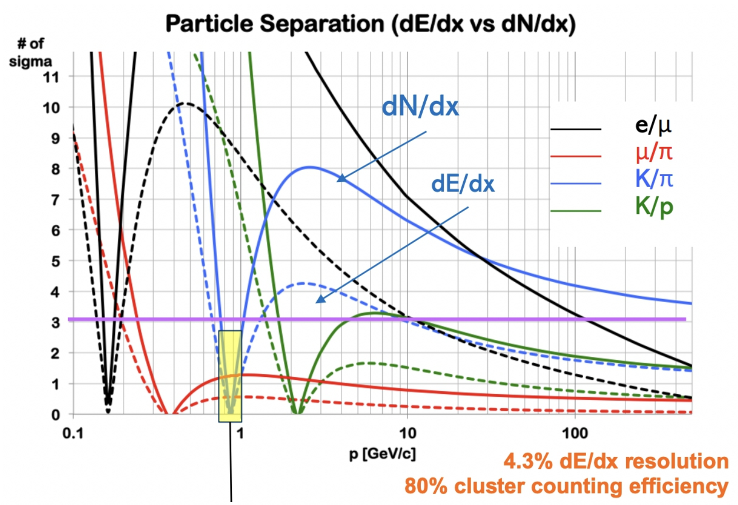


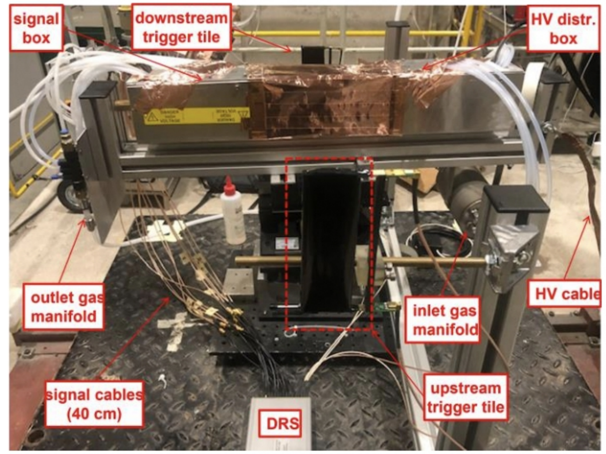
Uli Einhaus | PID Potential with a TPC | 26.10.2022 | Page 8

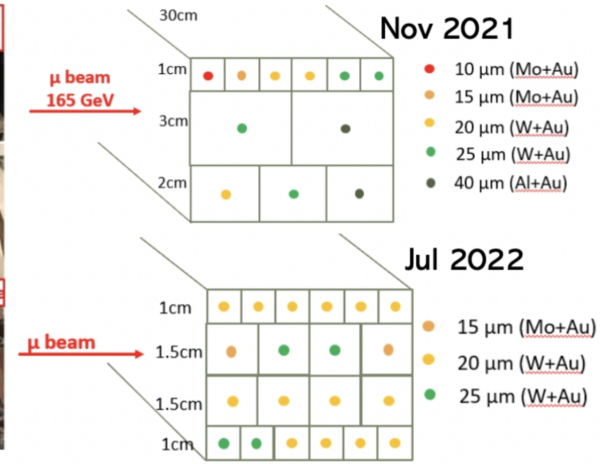


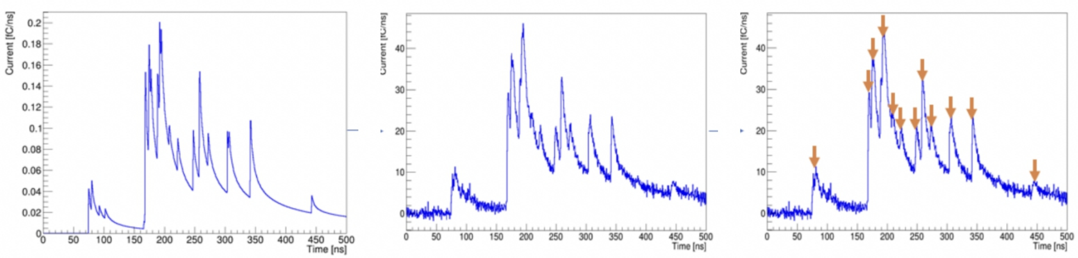
- 4.6 - 5%/3.3 - 3.6% dEdx resolution measured from TB, with Pad/Pixel readout
- Hopefully to be further improved with pad size optimization, noise control, etc

Drift Chamber: Cluster counting in time

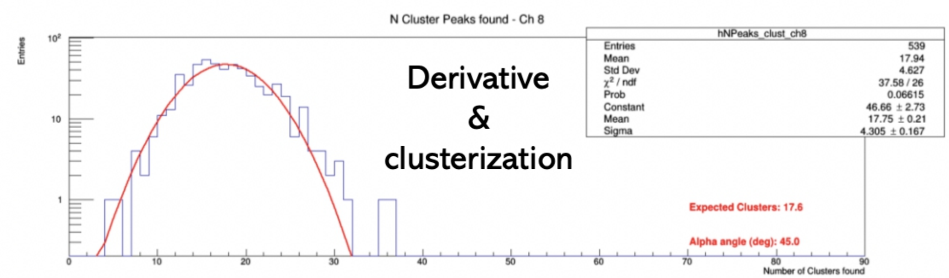




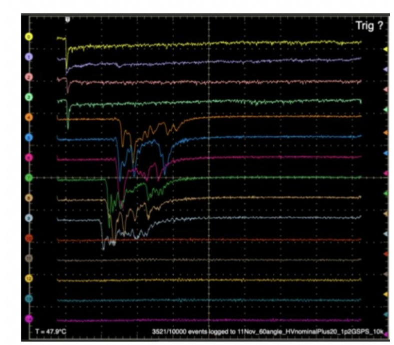




Simulation Digitization Reconstruction

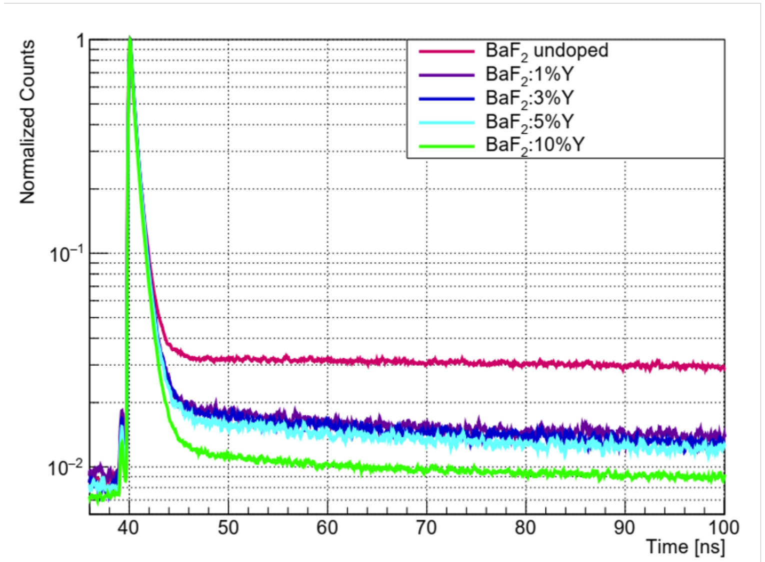


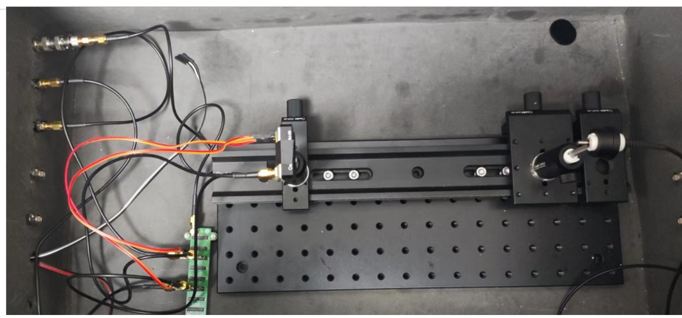
- Essential to have a high efficiency and accurate counting of Clusters
- Multiple peak finding algorithm are developed & tested
- Test beam result seems matched the expectation

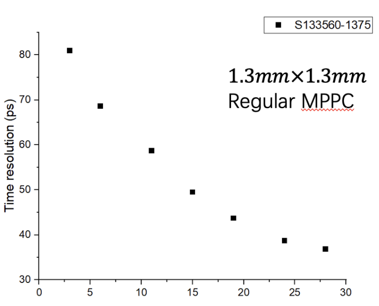


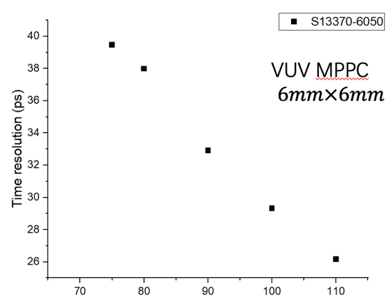
Brunella D'Anzi
Federica Cuna,
Yue Chang,
Shuiting Xin

ToF with Xstal, etc

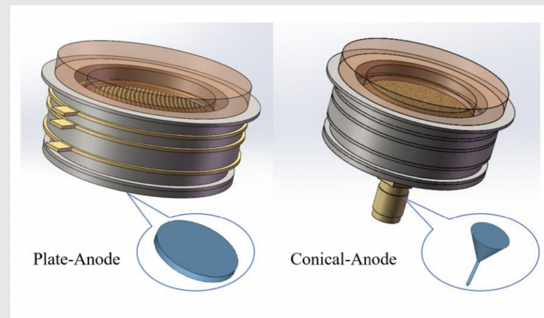


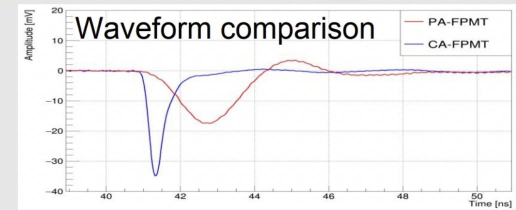


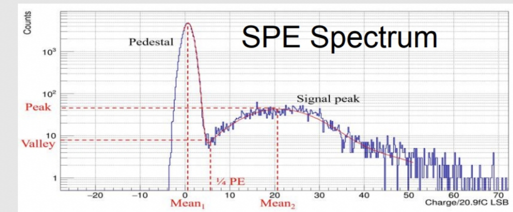




Anode Optimization

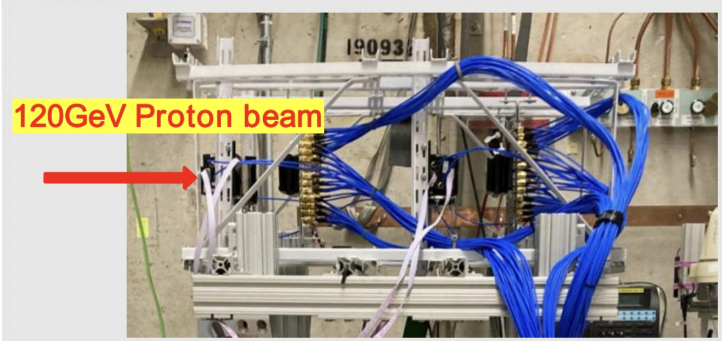






	HV/V	Gain	P/V	Amp(SPE)	RT	FT	Width	TTS@SPE	TTS@MPE
Photek 210	-4700	2.9E6	2.0	93.2mV	95.8ps	348ps	190ps	43.5ps	10.3ps
Plate-Anode	-2000	1.9E6	28.8	7.59mV	1.41ns	1.42ns	1.8ns	71ps	25ps
Conical-Anode	-3181	2.6E6	6.3	53mV	153ps	419ps	328ps	27.2ps	4.2ps

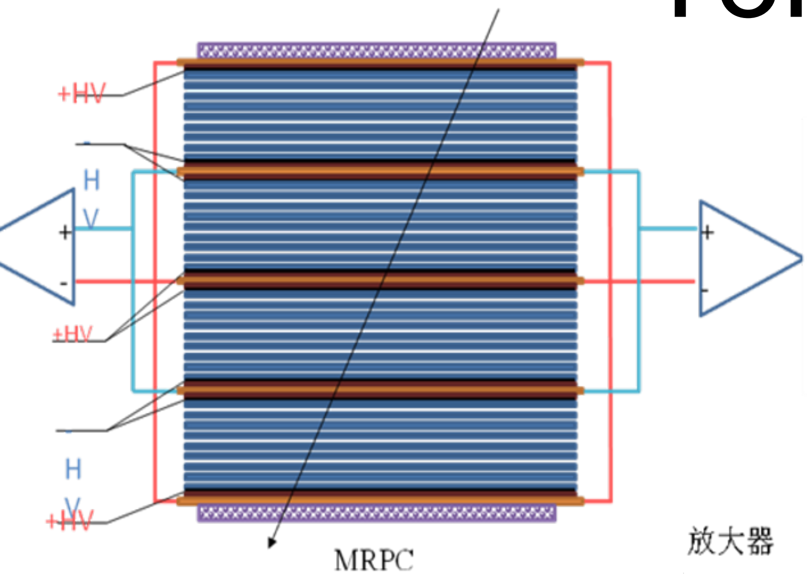
Ref: Lishuang MA et al., R & D of a novel single anode fast timing MCP-PMT，2022，Pre-proof，NIMA.

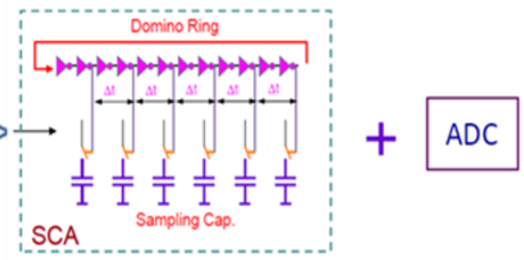


- Beam：120GeV Proton
- Crystal：LYSO & BGO
- PMT：NNVT 8*8 FPMT
- DAQ：CAEN V1742~50ps

Xiaolong Wang
Hongyu Zhang
Sen Qian

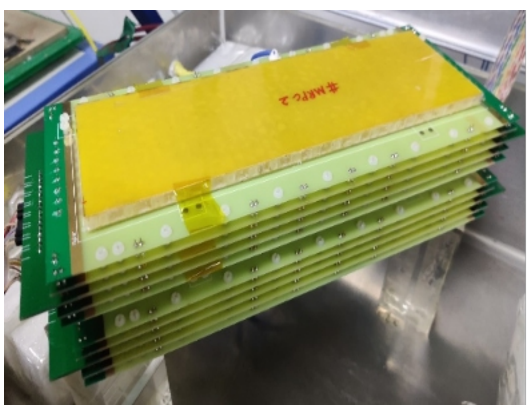
ToF with MRPC

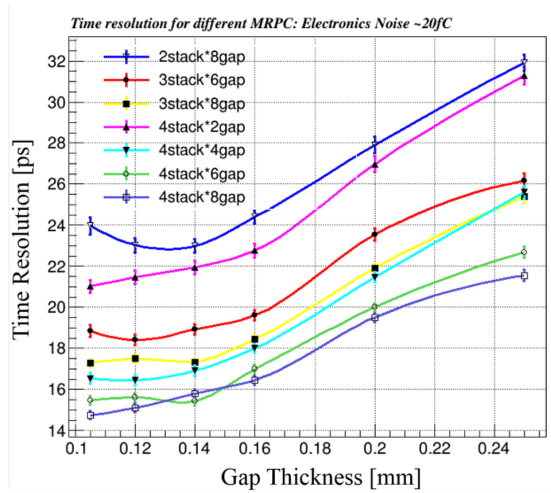


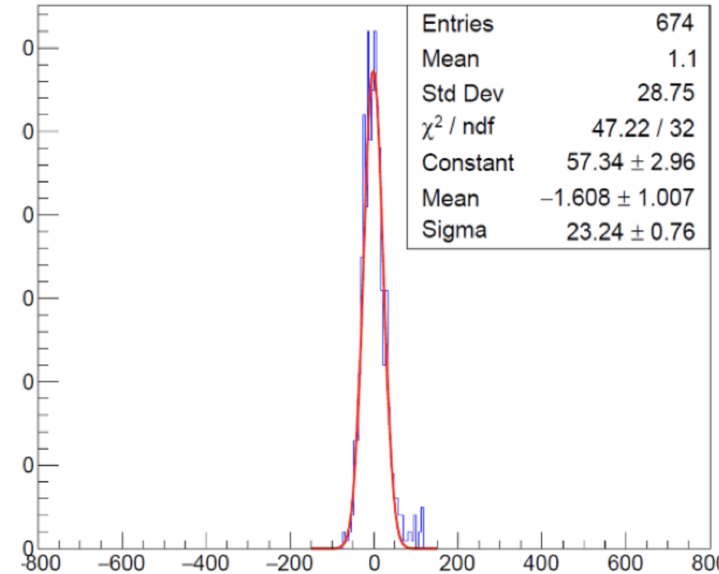


放大器

波形采样系统







- Total time resolution

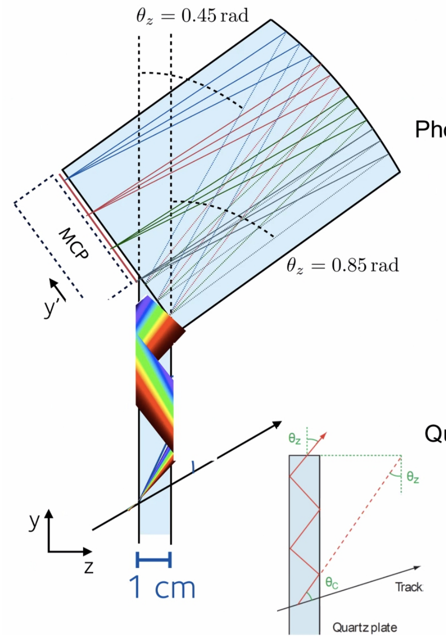
$$\sigma = \frac{23.24\text{ps}}{\sqrt{2}} = 16.43\text{ps}$$

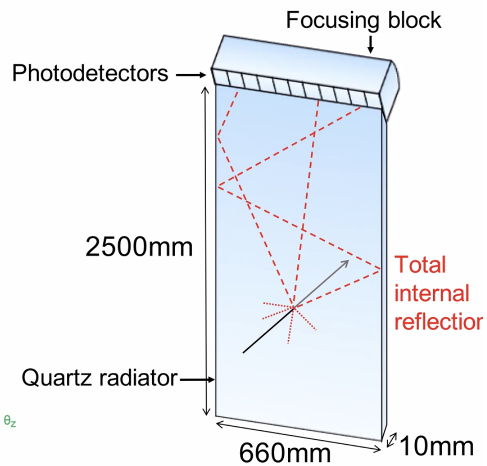
- Technology used at STAR & CBM experiments (60 ps, o(100) m^2)
- New tech: sealed MRPC, eco-friendly gas...

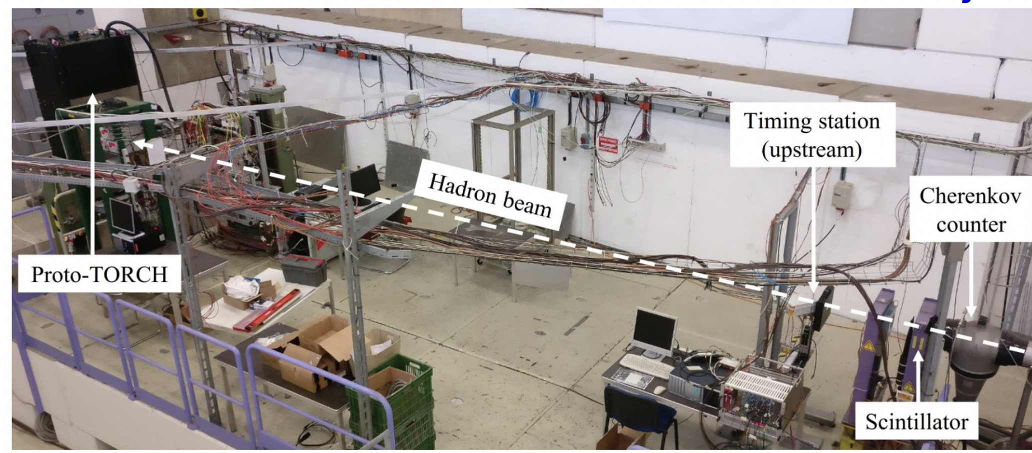
Yi Wang

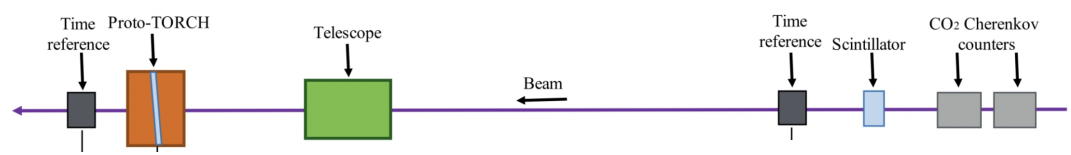
Torch

Maarten van Dijk

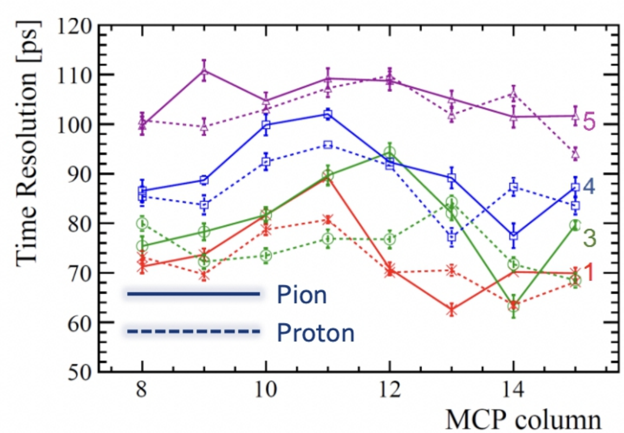


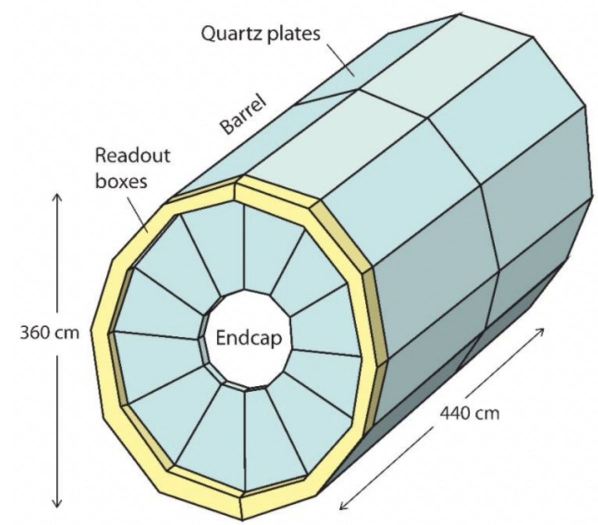






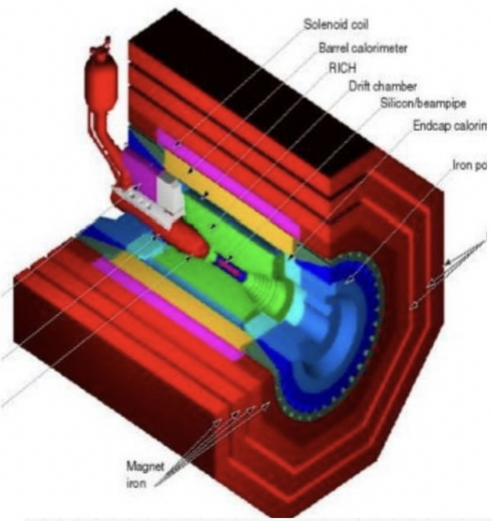
- ~70ps/photon reached for the LHCb upgrade
- Need ~ 25 ps/photon for ee Higgs factory
- Rely on better reco. Better electronics...





RICH @ CLEO

Marina Artuso



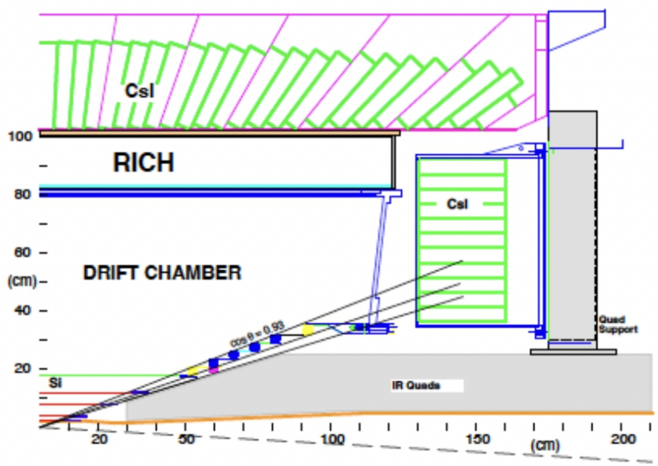
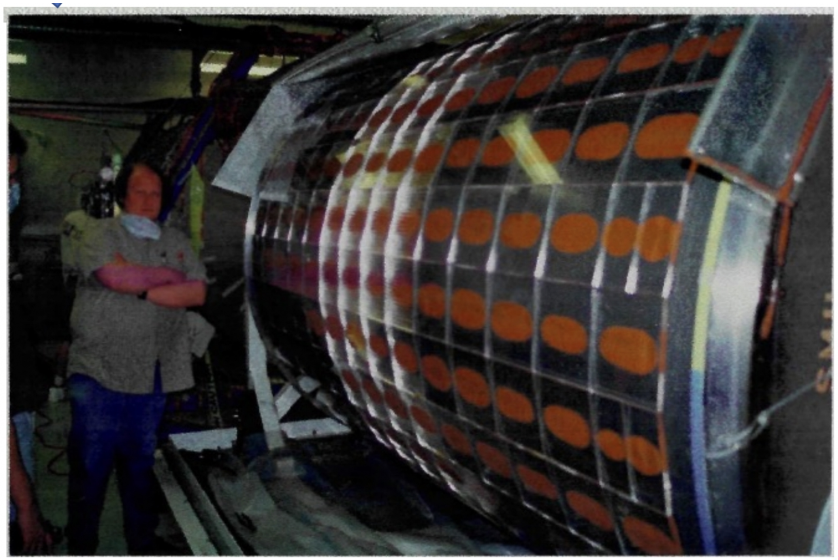
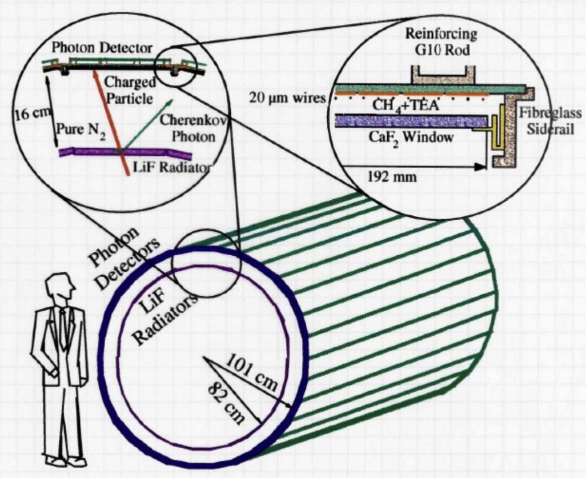


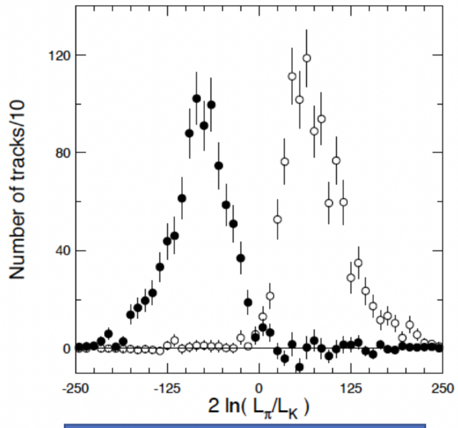
Fig. 3. The CLEO RICH, shown in CLEO-III configuration.



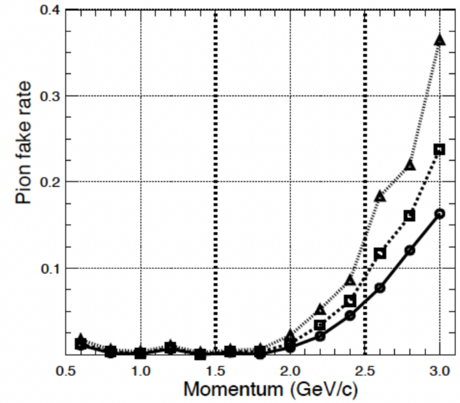
System Overview

- Outer ring of 30 γ detectors
- Inner ring of radiator tiles, 14 rows in length and 30 sectors in azimuth
- $N_2 + CH_4$ TEA gas systems





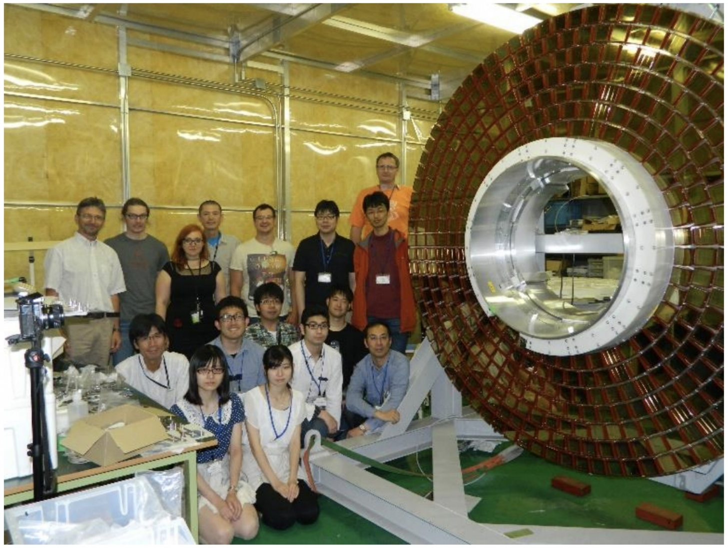
Likelihood variable used to assign hadron ID

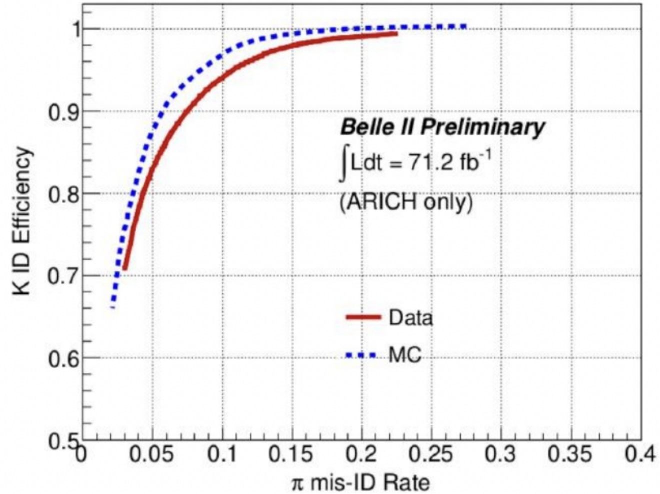


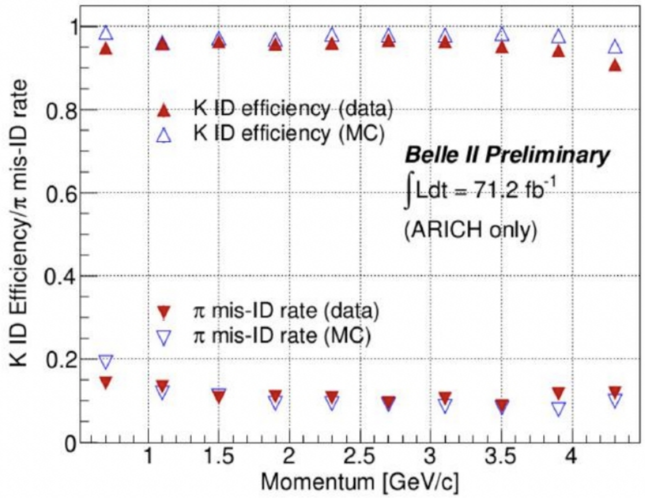
Pion fake rates as a function of the particle momentum for different K efficiencies [80% [circles], 85%[squares], and 90% [triangles]

RICH @ BelleII

Shohei Nishida

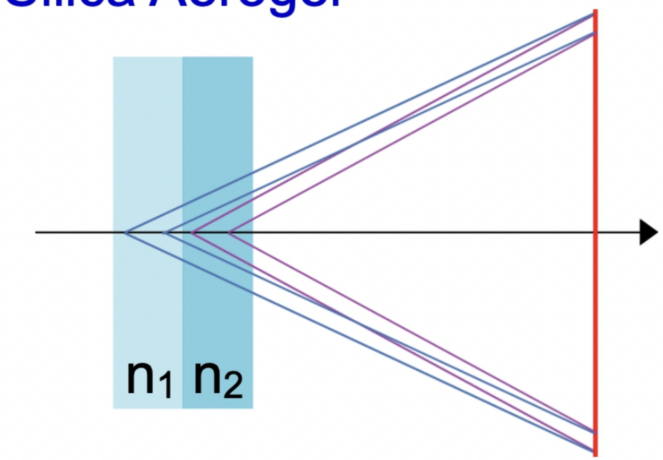




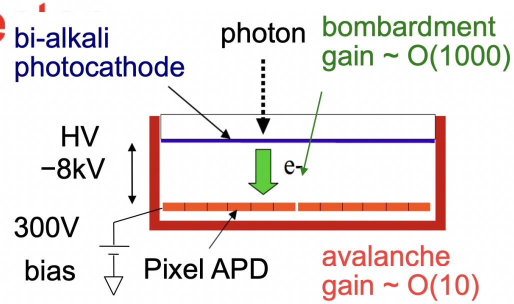


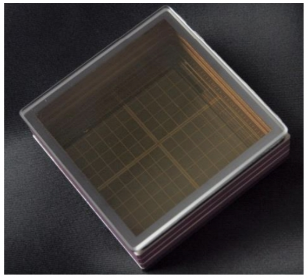
Silica Aerogel

Photodete

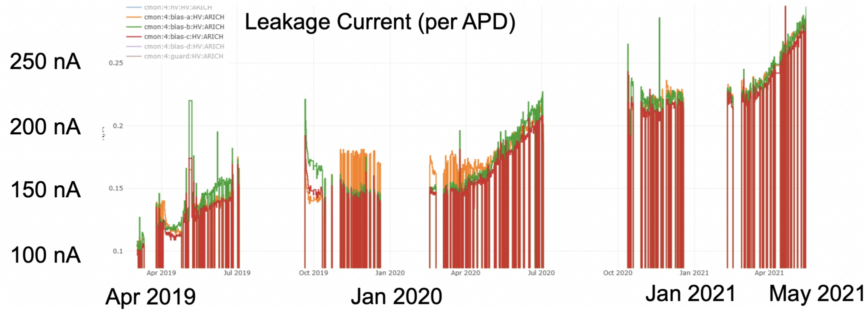


- $n_1 = 1.045$ and $n_2 = 1.055$

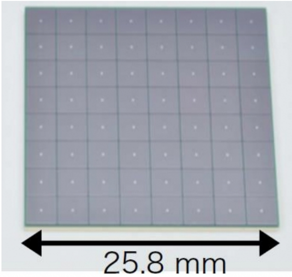




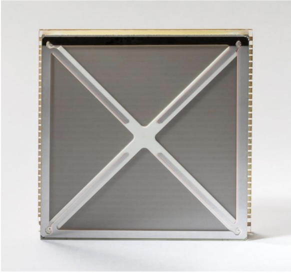
HAPD (Hybrid Avalanche Photo Detector)



64 (8 × 8) channel MPPC

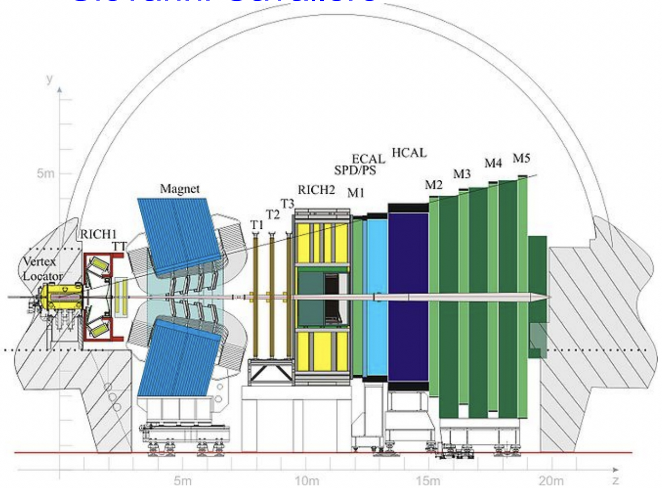


LAPPD (Large Area Picosecond PhotoDetector) : 200mm ×200mm

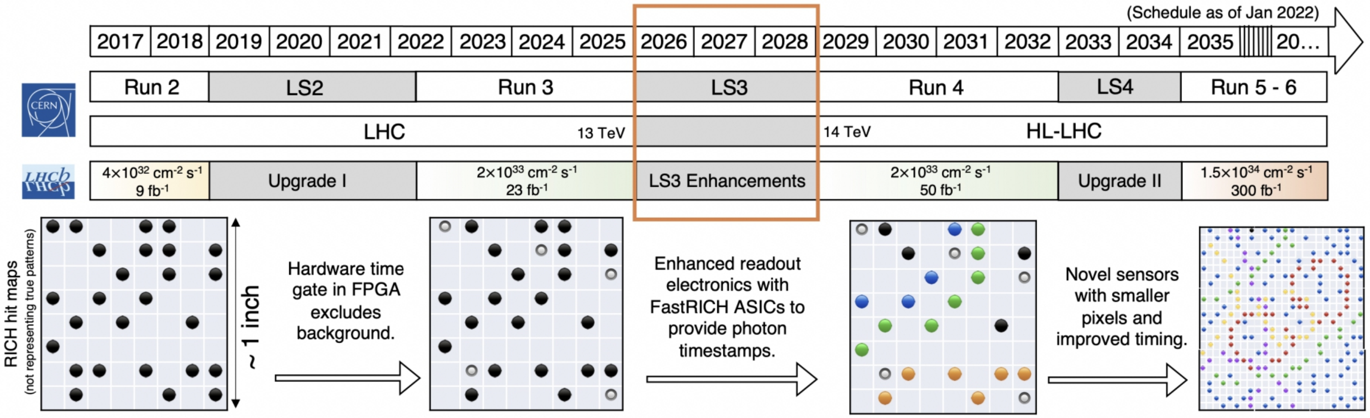


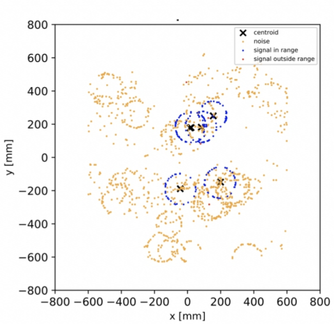
RICH @ LHCb

Giovanni Cavallero

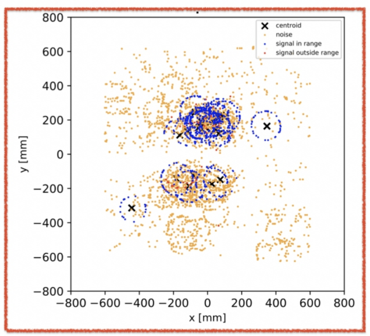


Relatively long period of LS3 central to the RICH evolution.

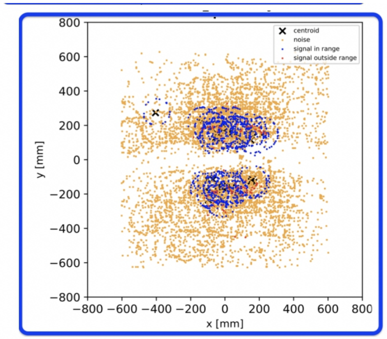




RICH1 rings with 1 PV

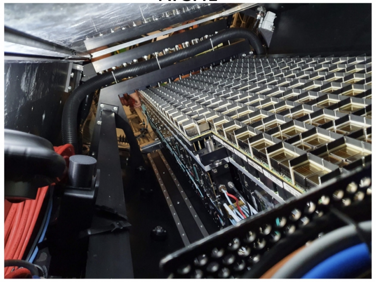


RICH1 rings with 5 PVs



RICH1 rings with 10 PVs

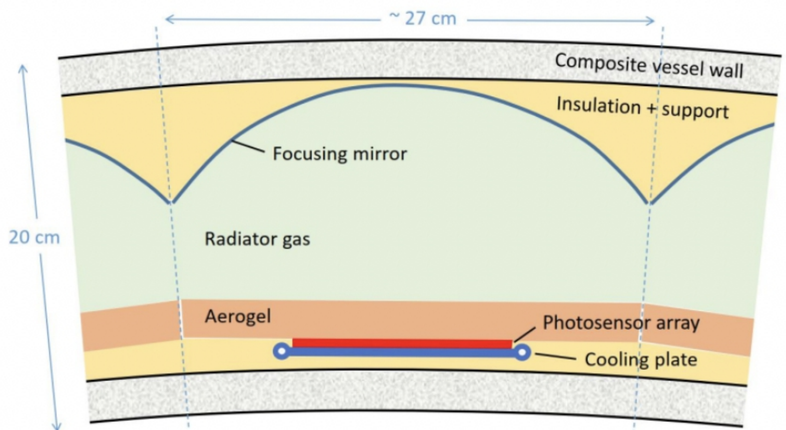
RICH1



RICH2

To address the challenges via fast electronics, high granularity & time measurement (LAPPD, MCP)...

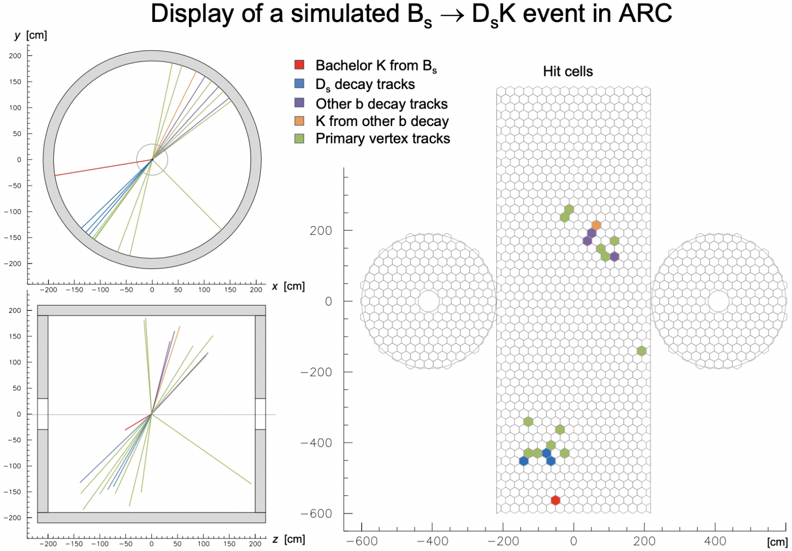
ARC (Array of RICH Cells)



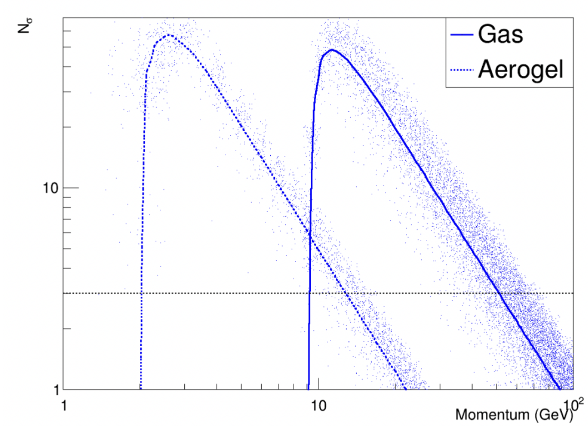
ARC detector (one cell)

Martin Tat

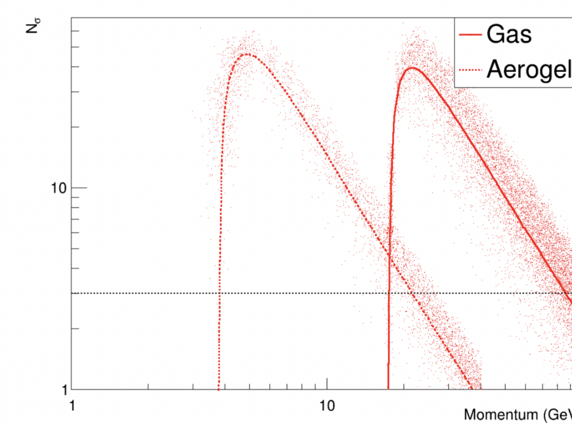
Display of a simulated $B_s \to D_sK$ event in ARC



Kaon-pion separation significance in ARC barrel

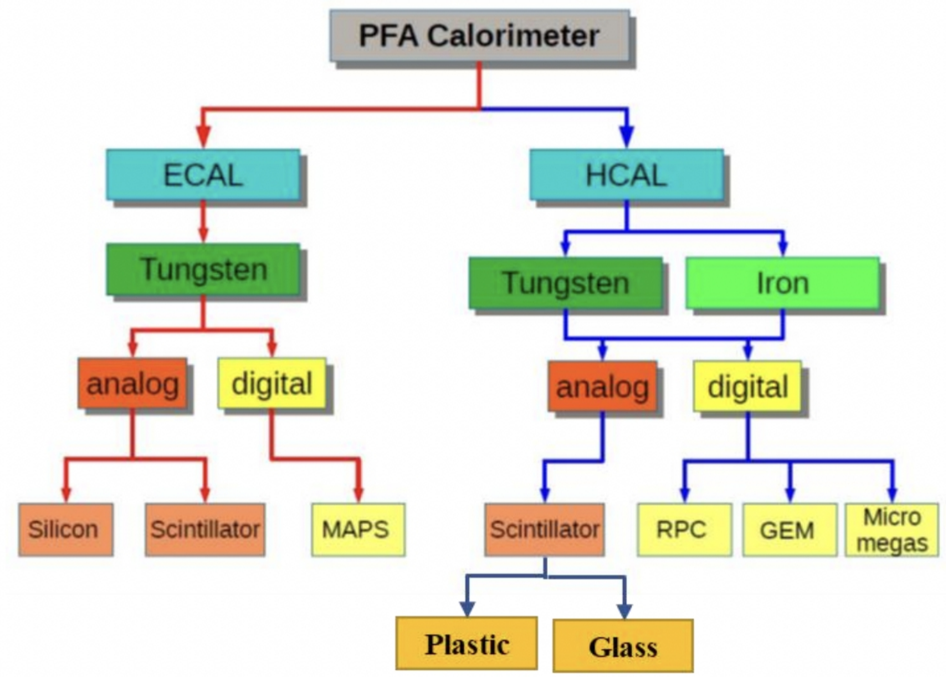


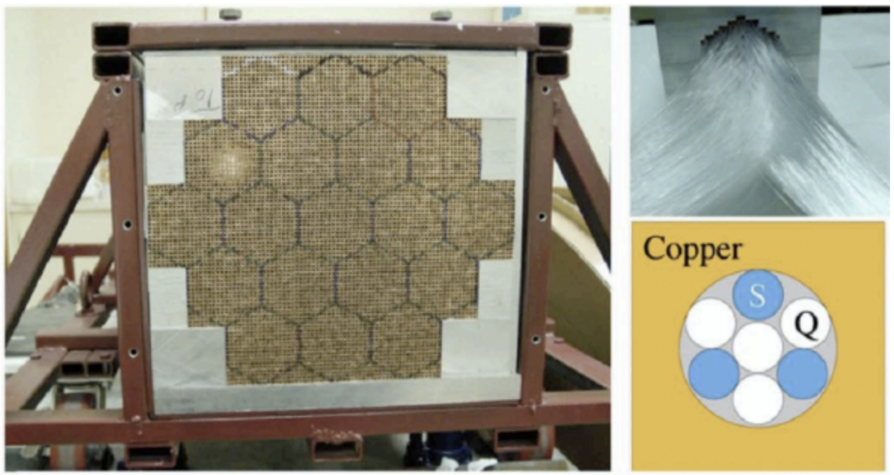
Kaon-proton separation significance in ARC barrel



- Lots to be explored(noise, PFA compatibility…) + promising performance up to 50 GeV!

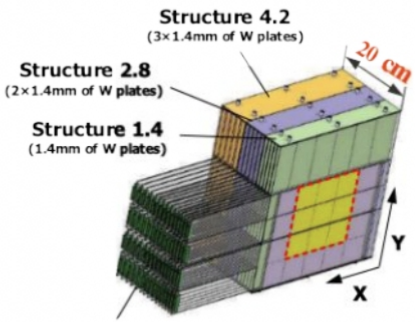
Calorimeter



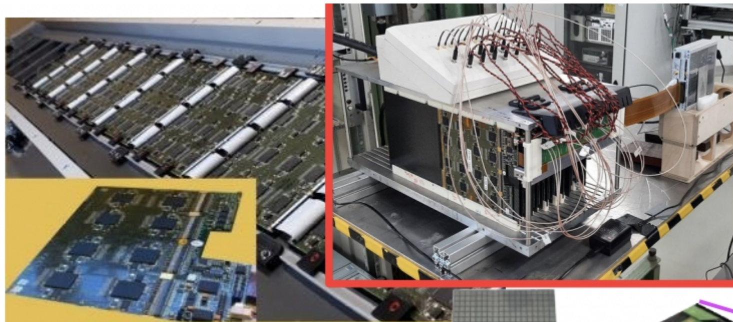


Si-W ECAL

Vincent Boudry

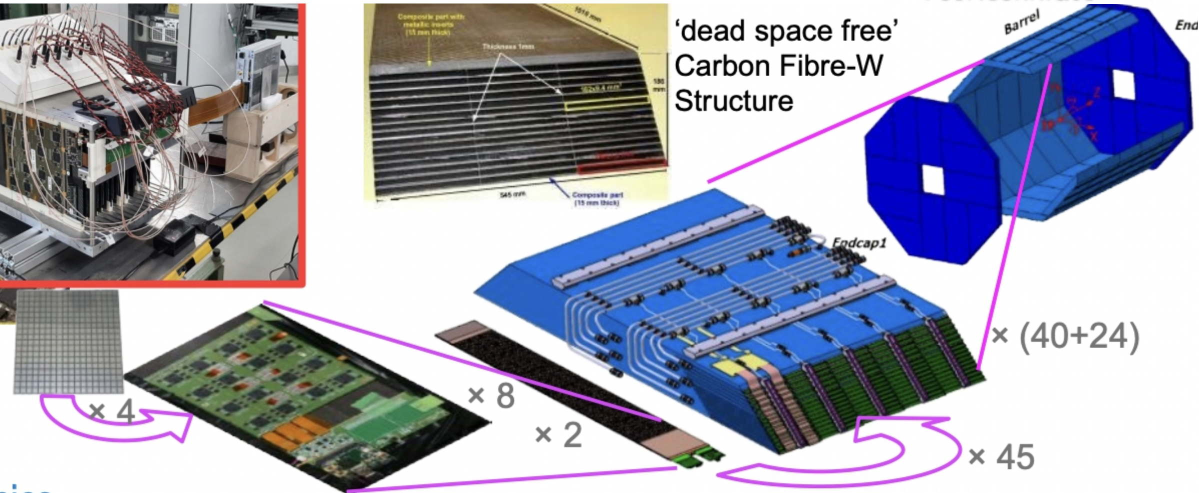


Physical (2005-11)



Technological (now)

– Embedded electronics



Pilote ➡ **Full Detector**

Electron

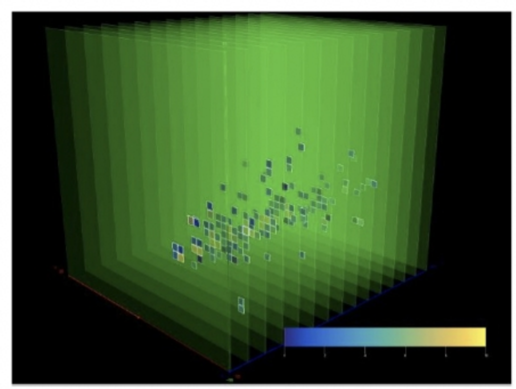


Fig. Simulation e- 10 GeV

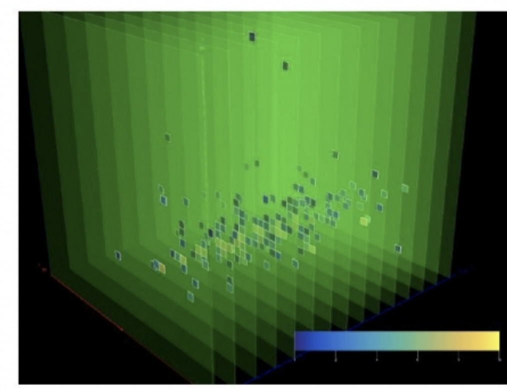
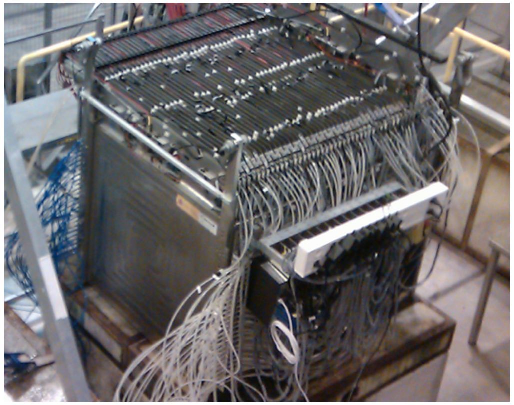


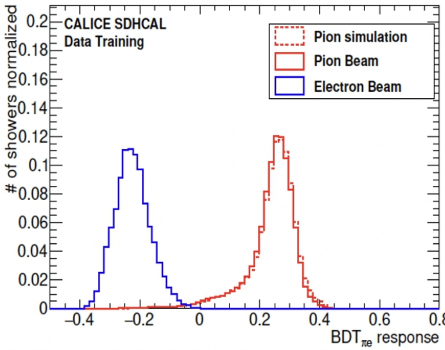
Fig. Reconstructed e- 10 GeV

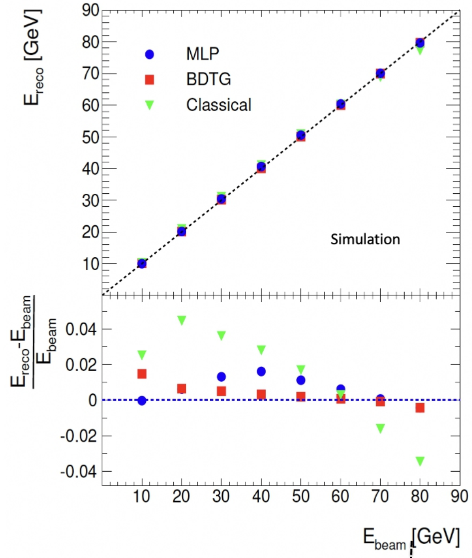
- Intensive technology & optimization studies, and reconstruction algorithm, i.e., energy estimation, PFA

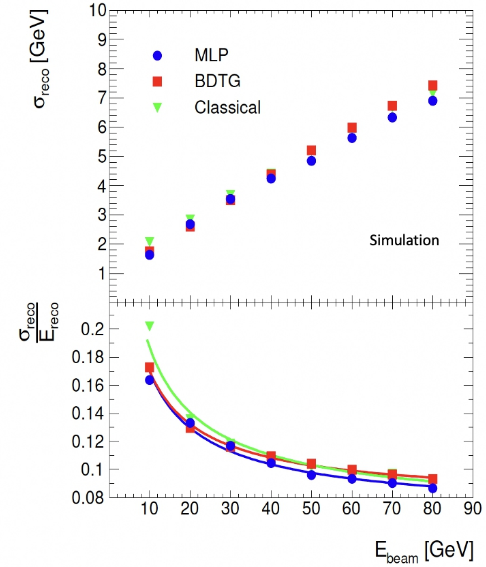
SDHCAL

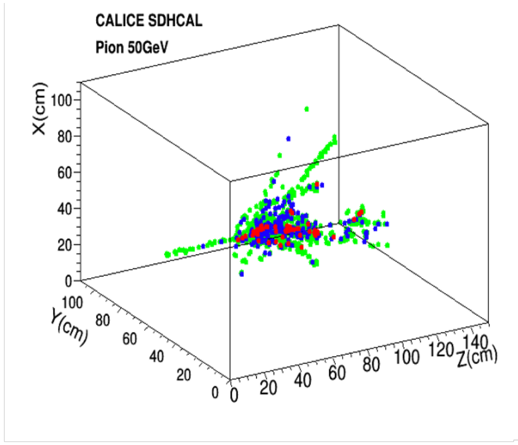
Imad Laktineh

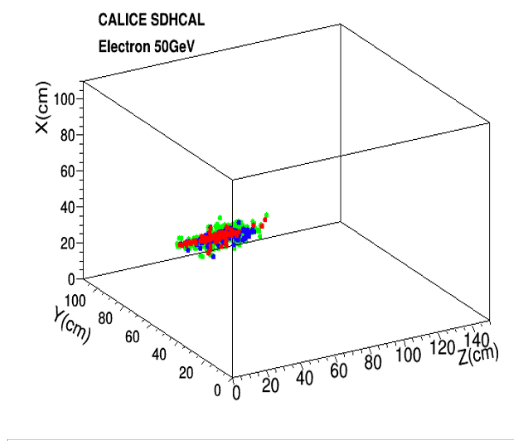


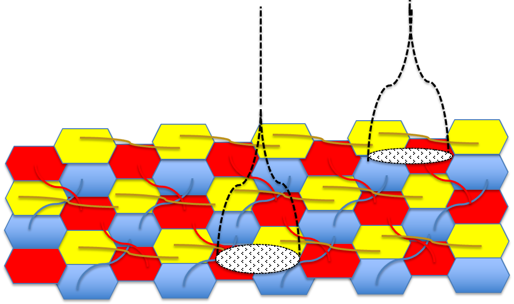


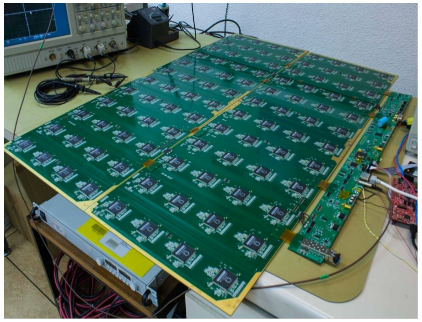








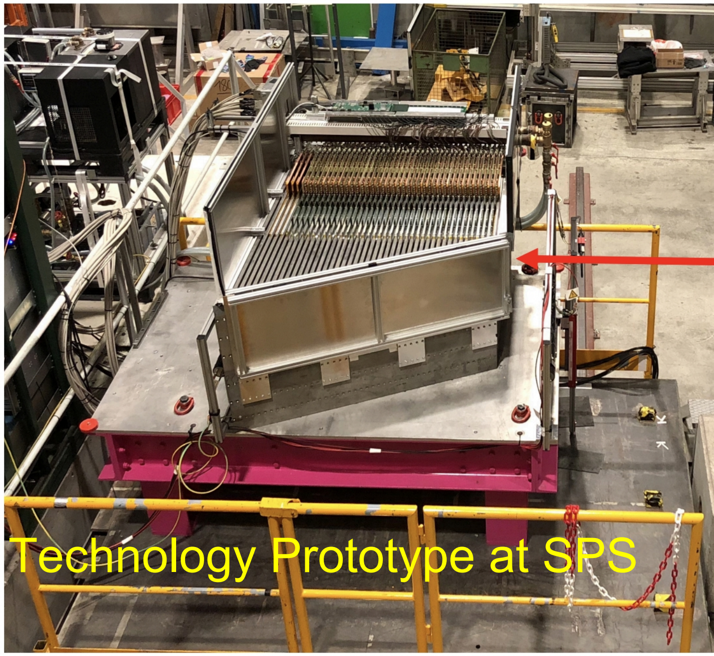




- Cubic meter prototype exposed intensively at CERN test beam
- Excellent granularity, excellent particle identification + decent resolution
- Lots of R&D towards usage at linear & circular collider

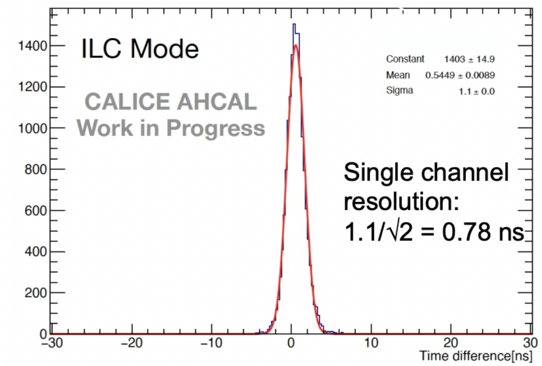
AHCAL

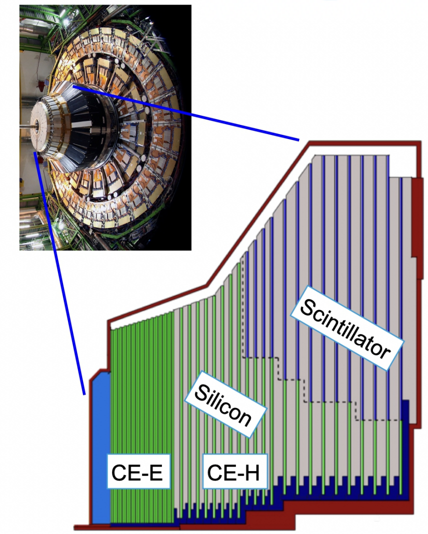
Katja Kruger

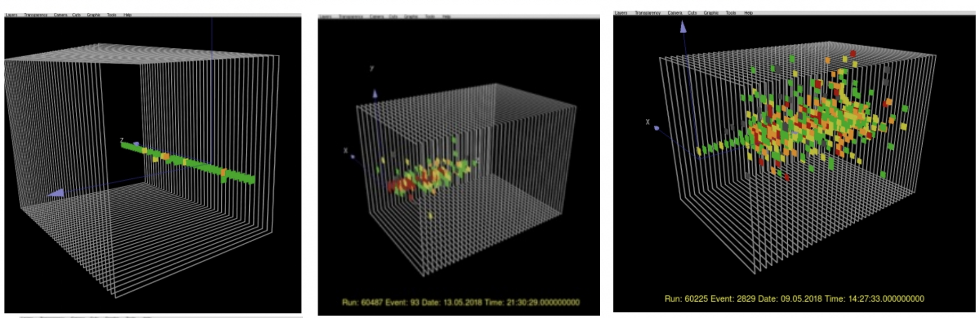


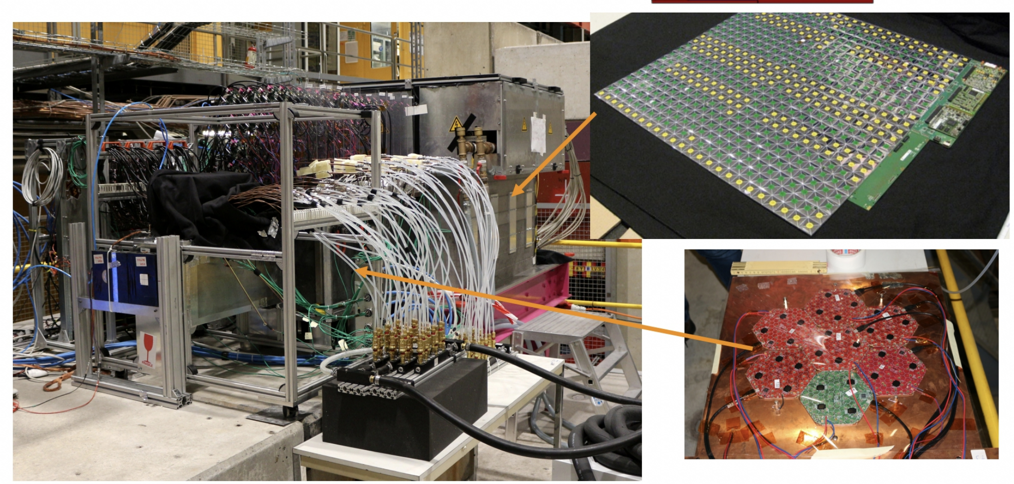
beam

With SPIROC2E



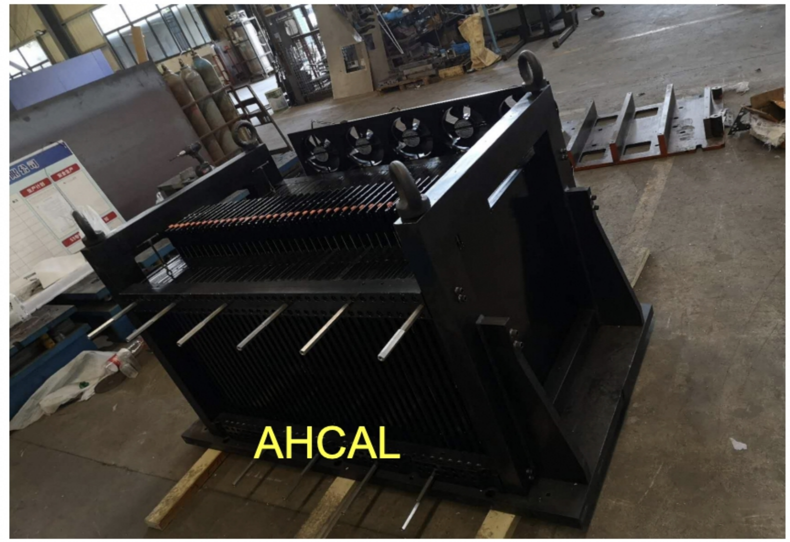




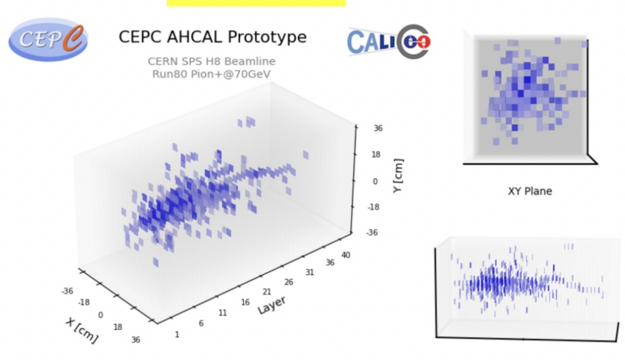


- CMS HGCAL will be first detector scale application of this technology

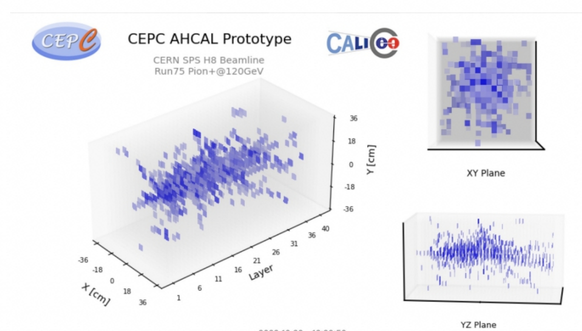
CEPC Calorimeter at SPS



70 GeV

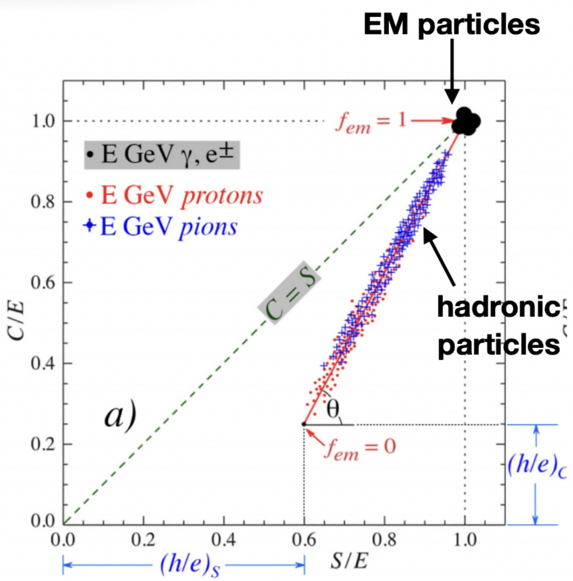


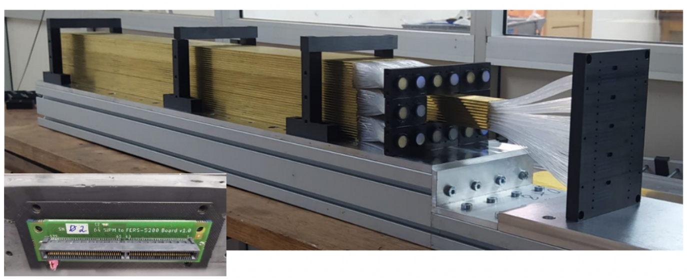
120 GeV

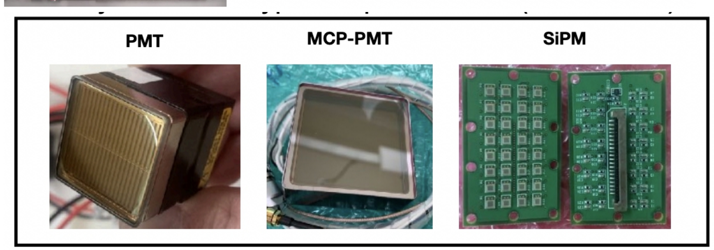


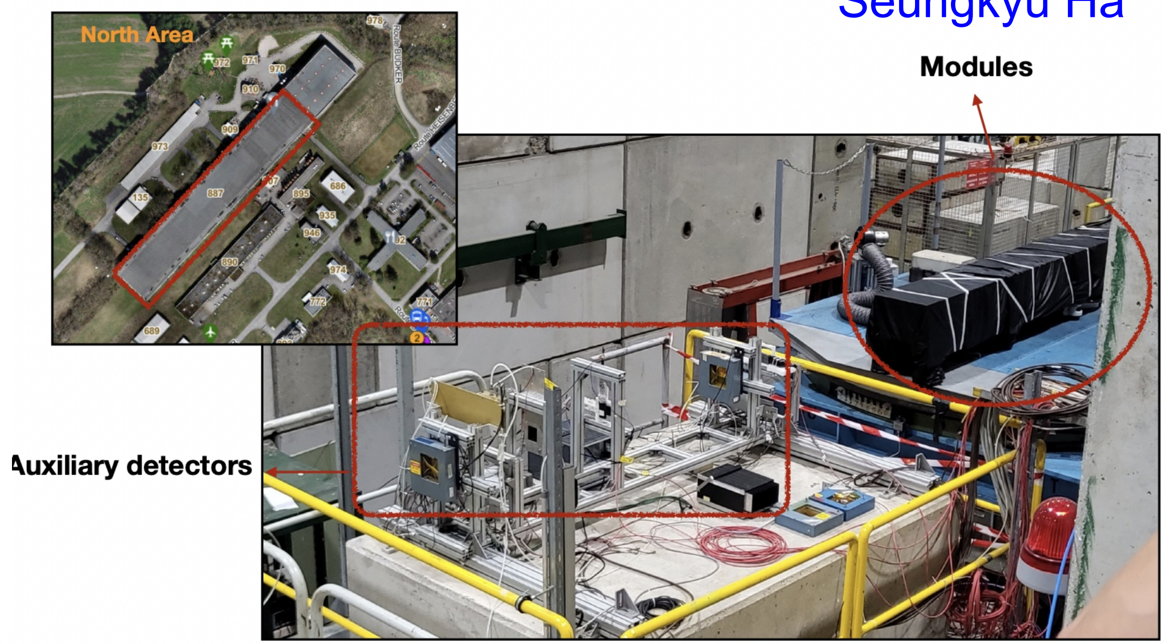
Dual readout calorimeter

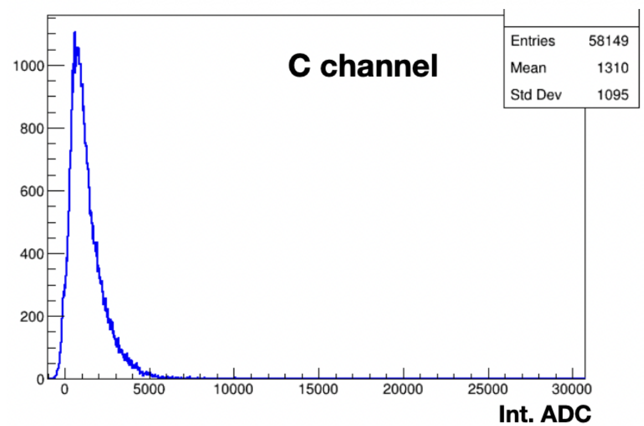
Seungkyu Ha

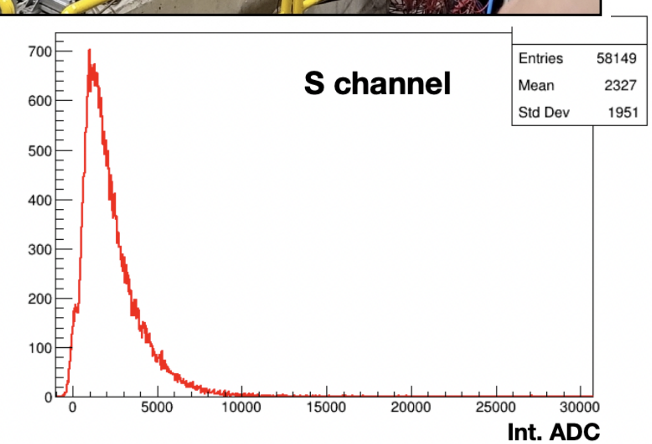






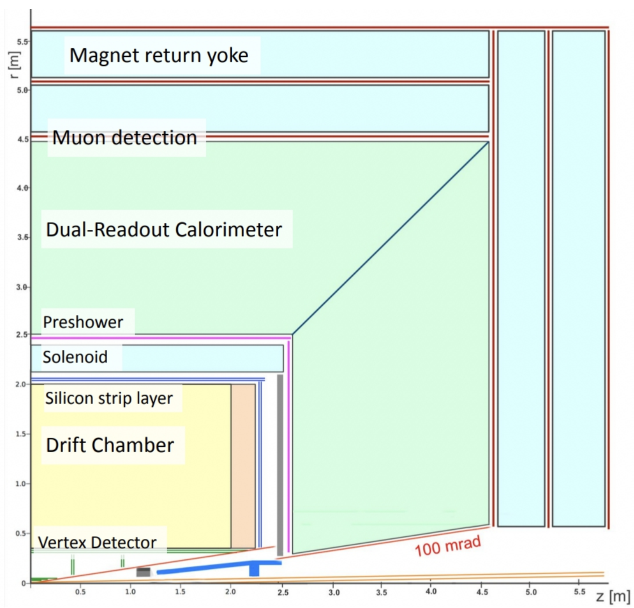


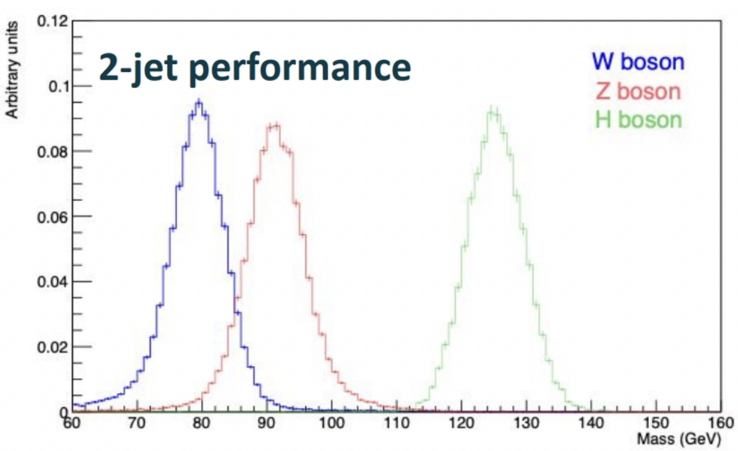




Dual readout calorimeter

Andreas Loeschcke, Adelina D'onofrio

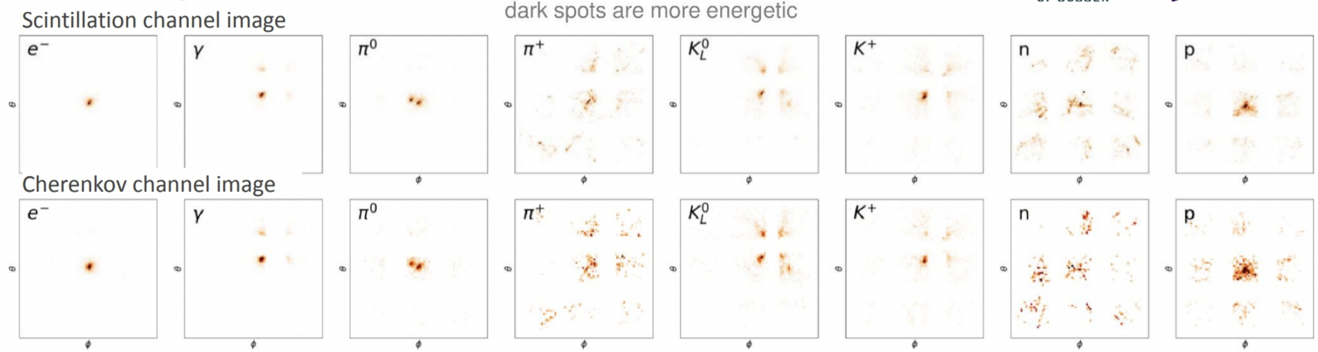


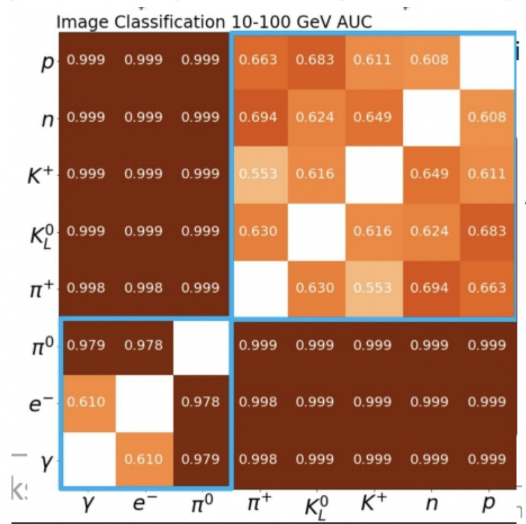


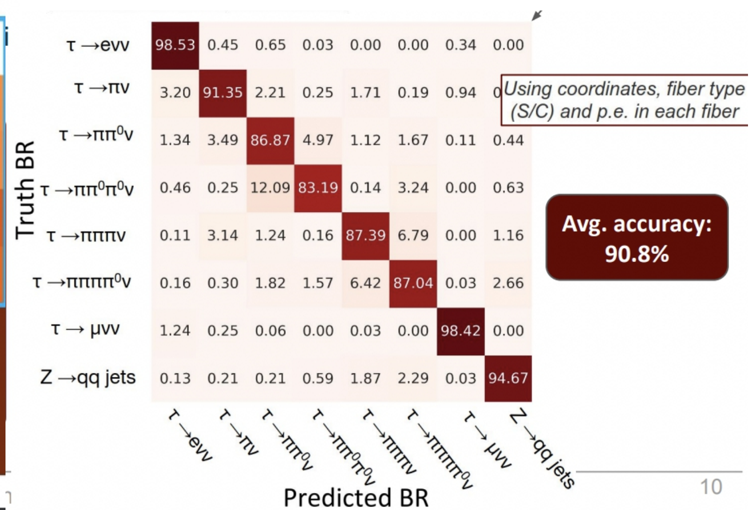
PID using Machine Learning [resource]

see also study with VGG and Residual NN

dark spots are more energetic





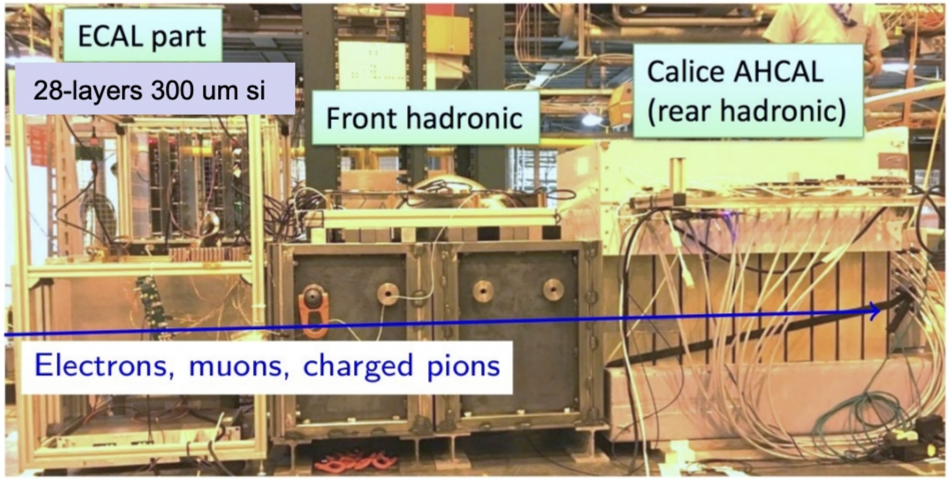


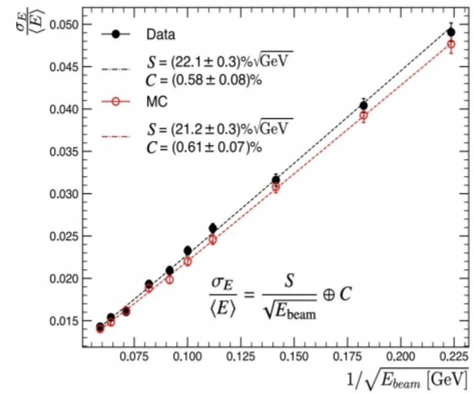
Good identification performance using Machine Learning...

Particle Flow for Dual Readout is also being studied

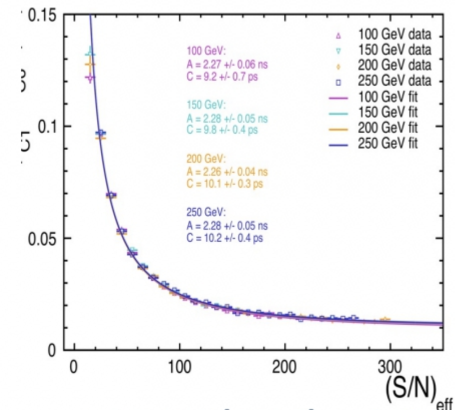
CMS HGC upgrade & IHEP

- **Beam tests in 2016–2018 using 6-inch silicon + SKIROC-cms modules and CALICE Sci. AHCAL**



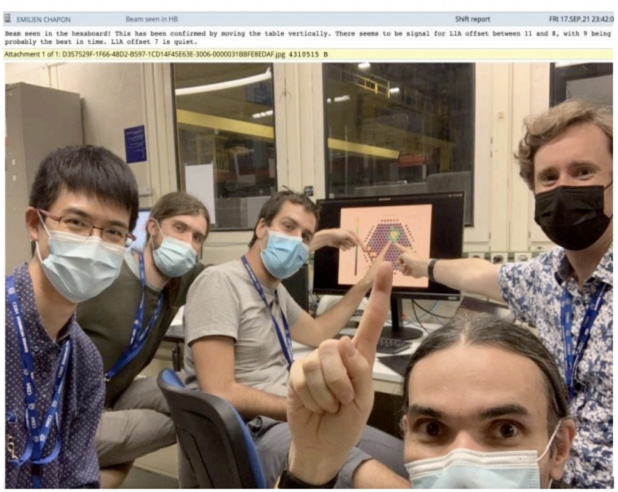


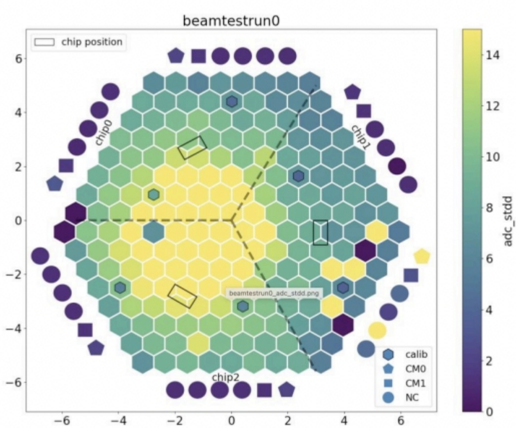
JINST 17 (2022) P05022



JINST 13 (2018) P10023

- **Switch to 8-inch silicon + HGCROC module at H2 beamline at CERN (SPS) Sept/Oct 2021**





IHEP LD Module with HGCROCv2, 300mm silicon in September 21 beam test

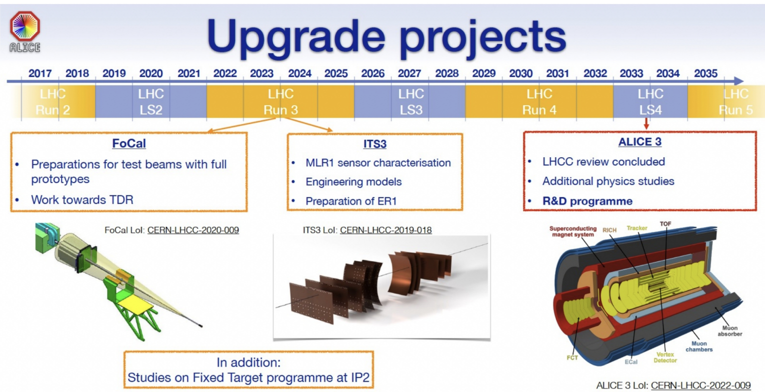
Noise/MIP response in realistic environment in Si modules ROCv2 (Sep), ROCv3 (Oct), explored a range of working parameters with e-beams

Analysis on going   Huaqiao Zhang

Lots of synergies...

Calorimeter upgrade for ALICE, ATLAS and LHCb

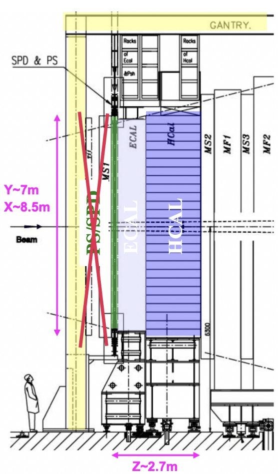
Hua Pei



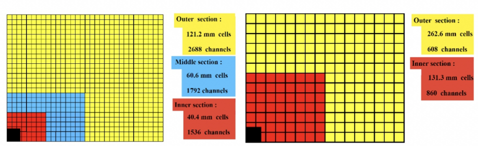
Summary

- Calorimeters at the ALICE and ATLAS experiments performed well throughout Run 1 and Run 2
  - Detailed operation and performance paper for Run 2 coming out
- Great physics output from all calorimeters: photon, hadron, charm/bottom, jet…
- Ready for Run 3: Many maintenance items taken care of over the long shutdown of last few years
- Exciting upgrades on the way: Run 3, Run 4, and beyond (2035-)

Eduardo Picatoste

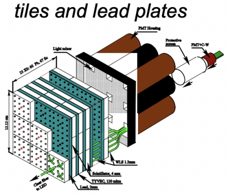


- 2 sub-detectors: ECAL, HCAL were kept
  - PS/SPD dismantled and not used in the Upgrade I
- Granularity
  - ECAL: 6016 cells
  - HCAL: 1488 cells

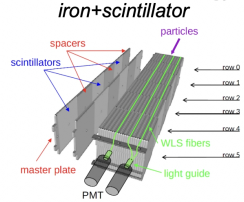


- Detection

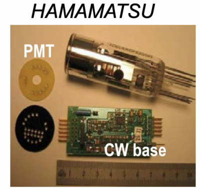
ECAL Shashlik: scintillator tiles and lead plates



HCAL: Tilecal technology iron+scintillator

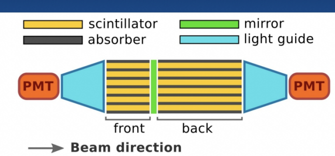


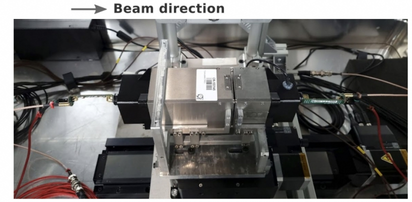
PMT R-7899-20, HAMAMATSU



25 October 2022 CEPC – CMS and LHCb Calorimeters Run3 and Phase-II Upgrades status and plans ICCUB

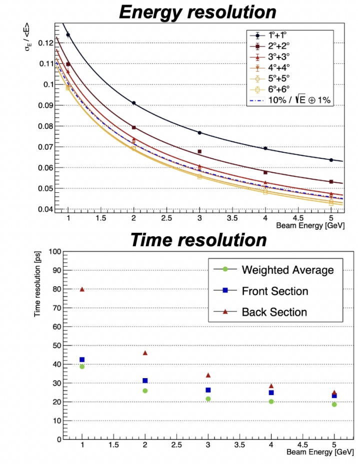
LHCb ECAL Upgrade II: SpaCal-W channel prototype



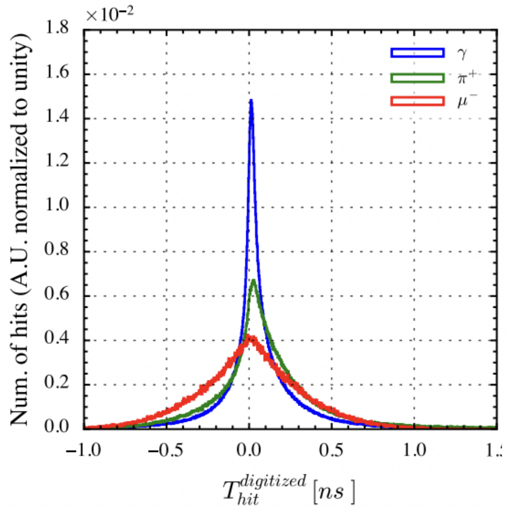


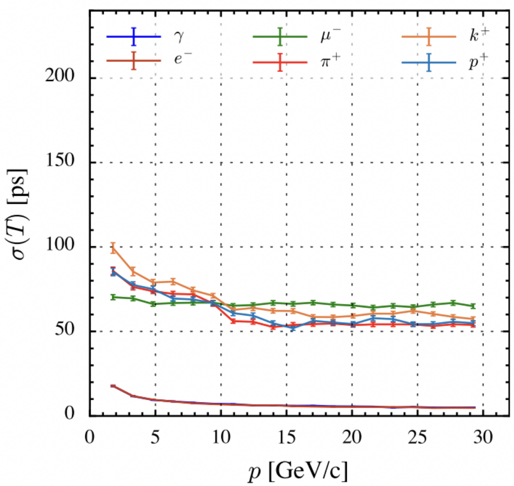
- SpaCal prototype module with W absorber and garnet crystal fibers:
  - Pure tungsten absorber with 19 g/cm^3
  - 9 cells of 1.5x1.5 cm^2 (RM ≈ 1.45 cm)
  - 4+10 cm long (7+18 X_0)
  - Reflective mirror between sections

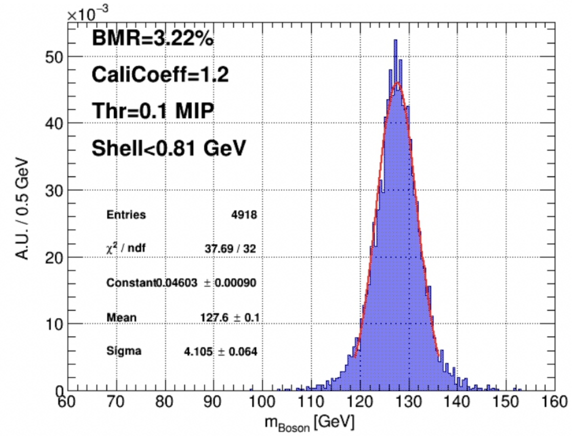
DESY 2020 Test beam result

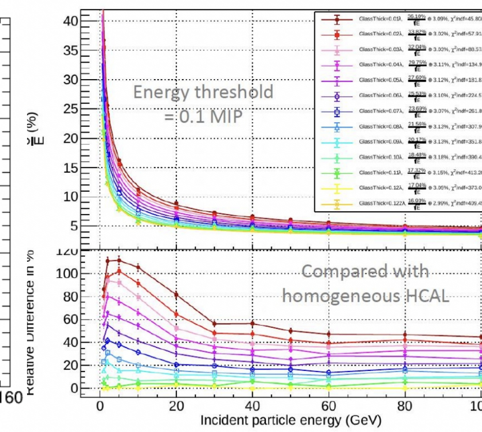


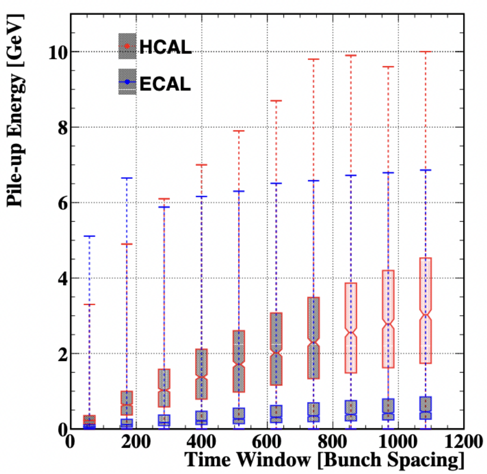
Performance

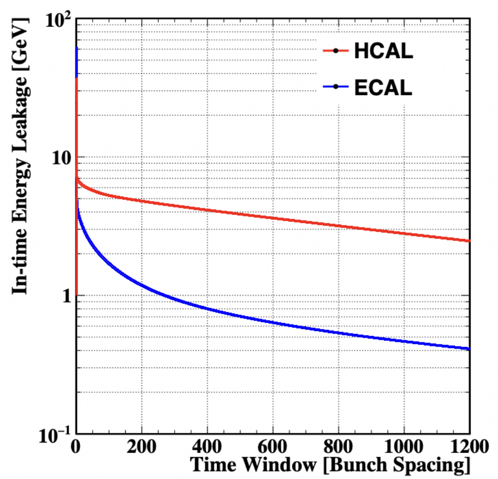


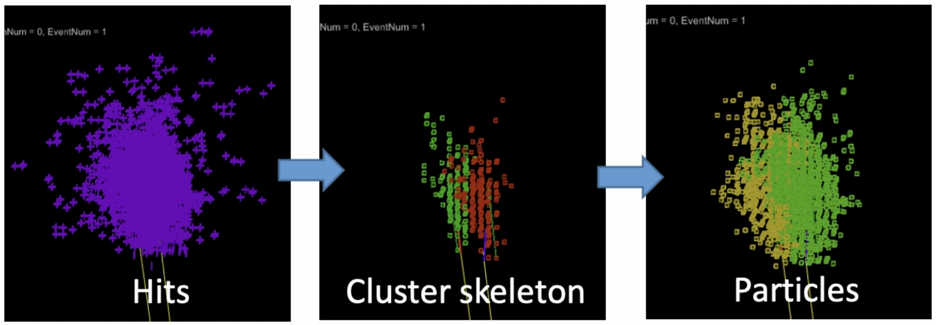


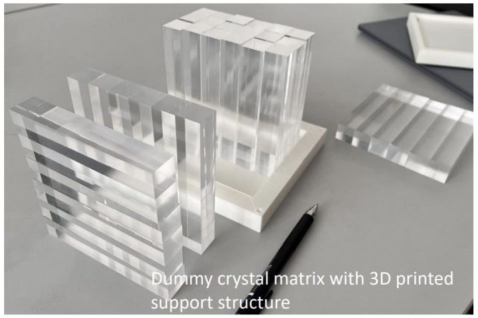


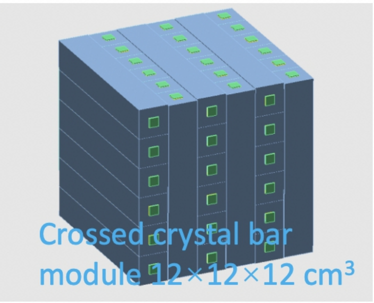






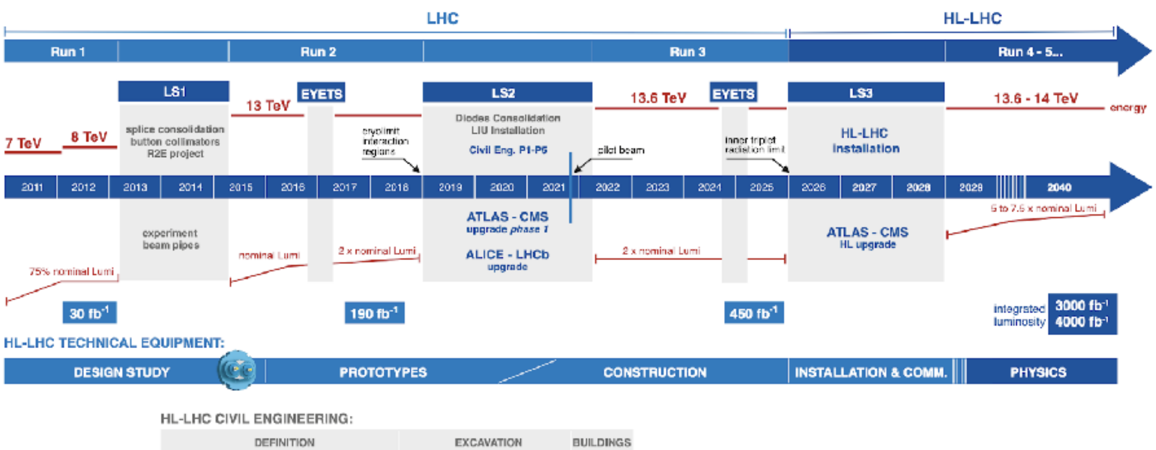


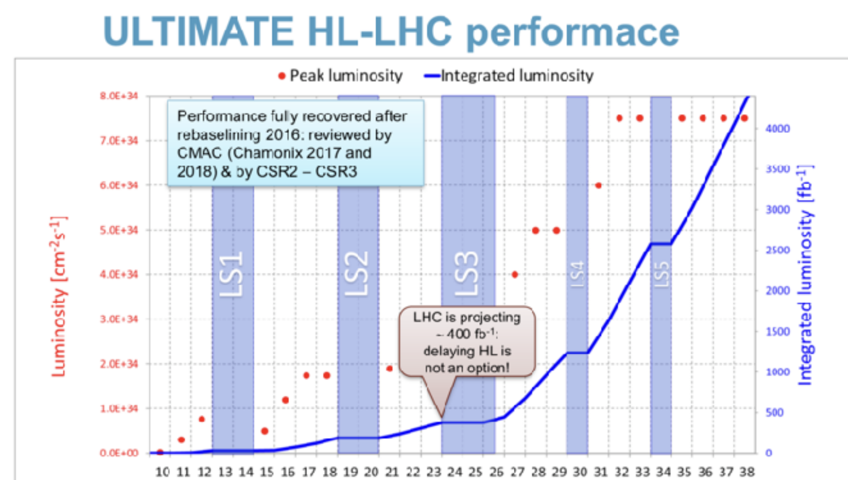




Yuzhi Che, Peng Hu, Baohua Qi, Zhiyu Zhao

TDAQ & Software





The CMS Level-1 Muon Trigger focusing on the RPC system

Ecs Asilar

Ready for Run 3

Conclusion

As a result of successful performance at CERN 904 Lab, GIF++ and at the CMS cavern, currently, demonstrator iRPCs are getting ready for taking data during Run3 to further validate the performance for Phase II operations.

Phase-2 Upgrade Of Level-1 Trigger

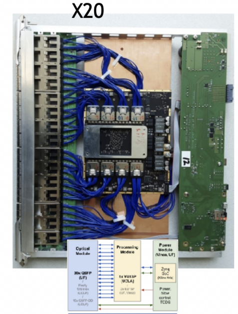
Vladimir Rekovic

nca Institute, University of Belgrade

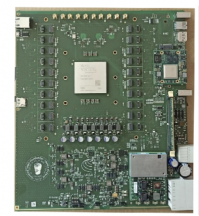
Hardware demonstrators

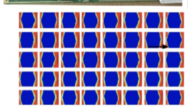
- ATCA boards hosting powerful Xilinx Ultrascale+ FPGAs with high I/O are designed
- Prototypes vailable in different flavors for Phase-2 L1-Trigger (optics Firefly or QSFP)
  - “X2O” for OMTF, EMTF, GMT (moving from Ocean in TDR)
  - BMTL1
  - “Serenity” for GCT, Correlator, GT
  - “APx” (GCT)

X20



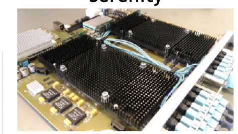
BMTL1





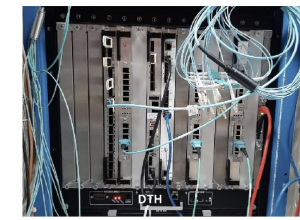
E llent results of optics tests

Serenity



APx

Ongoing Slice Test of FW with hardware connecting multiple boards of different flavors.



Progressing well towards electronics readiness review in Q1/2 2023.

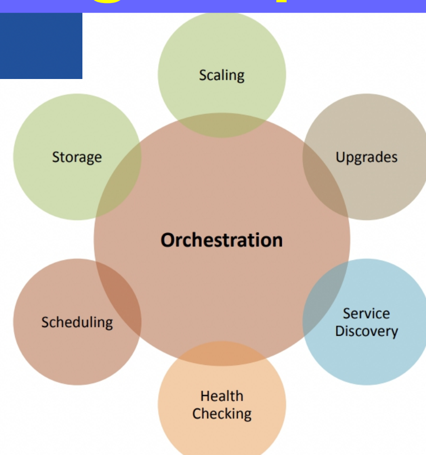
ATLAS Data Acquisition Phase 2 Outlook

Preparing for phase 2

Matías Bonaventura, CERN
On behalf of ATLAS TDAQ Collaboration

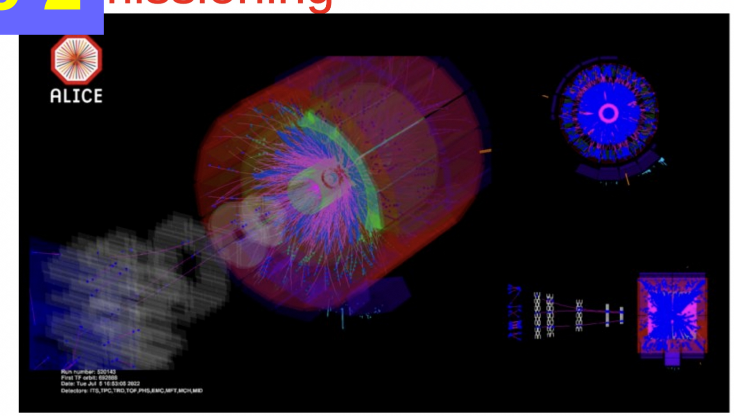
Conclusions

- HL-LHC upgrade requires a major upgrade of all components of the ATLAS TDAQ
- Impact of technology evolution
  - Full event building thanks to network improvements
  - Persistent storage design on hold due to increased storage cost and endurance u
  - RDMA-based readout network
  - Management of processing farm with Kubernetes orchestration
- Upcoming challenges
  - Close interaction with industry to track technology updates
  - Incorporate experience from run 3 operations



missioning

Sylvain Chapeland



5 July 2022: ALICE first 13.6 TeV collisions of LHC Run 3.

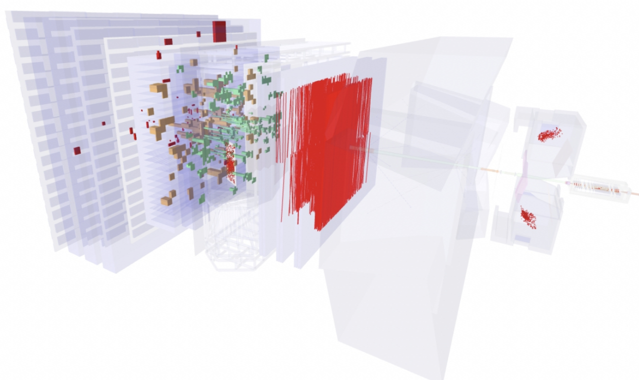
- ALICE started Run 3 with success
  - Actively taking p-p physics data
  - Exercising data flow and processing with p-p at high rates
  - Waiting for HI collisions

See also talk of M. Boulais

LPNHE Paris · Sorbonne Université · LHCb · erc European Research Council, Established by the European Commission

LHCb HLT1
Tracking and vertexing at 30 MHz with GPUs

Marianna Fontana



Conclusion

- LHCb is currently undergoing its first major upgrade in order to increase its instantaneous luminosity by x5
- Major changes in the trigger strategy:
  - Remove L0 hardware trigger, read-out full detector at 30 MHz
  - New first level trigger run on GPUs
- Partial event reconstruction and trigger selection lines implemented with excellent physics performance expected
- The system can be realised with ~200 GPUs (throughput ~170 kHz)
- GPUs are installed in the EB server and the commissioning is ongoing
- LHCb is almost ready to start collecting physics data with the brand new detector

ALICE

ALICE Trigger System Run3

R. Lietava for the ALICE Collaboration

The University of Birmingham

Summary

- Most of the detectors take data in **triggerless** mode: read out data of all interactions (**50kHz Pb-Pb and > 500kHz pp**)
  - – Compress these data by online reconstruction
  - – One common online-offline system
- Central trigger system:
  - – Distributes clock and HB frame delimiter
  - – Provides Minimum Bias trigger when needed
  - – Provides Continuous/Triggered Mode as required
- Operation
  - – Trigger system providing clock, HB and triggers since October 2021

Highly relevant, & encouraging experience for CEPC, etc.

We need to better understand the requirements stemmed from sys. control

Offline & Computing (1)

- Recent development of CEPCSW focus on the core software, simulation and reconstruction to support the 4th concept detector design.
- Highlights
  - **R&D on advanced computing technologies in framework**: heterogeneous computing with TRACCC from ACTS, integration of ML using ONNX, RDataFrame based analysis toolkit, Gaussino based simulation framework.
  - **Extension of EDM4hep for dN/dx and completed chain of dN/dx study.**
  - **Support multi-track fitting with silicon detector and drift chamber.**
  - **New reconstruction algorithms for long crystal bar ECAL**: clustering, shower recognition, energy splitting and energy/time matching.
  - **Sharing computing resources between CEPC and ILC**: adding 640 CPU cores in 2022

10:00	Status of CEPC Simulation Software	A415, IHEP	Tao LIN	10:00 - 10:24
	Tracking in CEPC Silicon Detector	A415, IHEP	Chengdong FU	10:24 - 10:48
	Status of Drift Chamber Software	A415, IHEP	Yao Zhang	10:48 - 11:12
11:00	Updated Progress in a New PFA for Crystal Bar ECAL	A415, IHEP	Yang Zhang	11:12 - 11:36
	CEPC Computing	A415, IHEP	Dr Xiaomei Zhang	11:36 - 12:00

	Status of CEPC Core Software	A415, IHEP	Teng Li	13:30 - 13:54
14:00	Key4hep Status Report	A415, IHEP	Andre Sailer	13:54 - 14:18
	ATLAS Fast Calorimeter Simulation	A415, IHEP	xiaozhong huang	14:18 - 14:42
	Generative Models for Fast Simulation of Electromagnetic and Hadronic Showers in Highly Granular Calorim...		Peter McKeown	
15:00	Status of IDEA Software for Simulation and Reconstruction	A415, IHEP	Lia Lavezzi	15:06 - 15:30

Talks could be found in https://indico.ihep.ac.cn/event/17020/sessions/10728/#20221028

Offline & Computing (2)

- Four invitation talks on Key4hep, ATLAS fast simulation, ILD ECAL/HCAL fast simulation, IDEA software

Time	Contribution	Speaker / Location	Time slot
	Status of CEPC Core Software	Teng Li	
	A415, IHEP		13:30 - 13:54
14:00	Key4hep Status Report	Andre Sailer	
	A415, IHEP		13:54 - 14:18
	ATLAS Fast Calorimeter Simulation	xiaozhong huang	
	A415, IHEP		14:18 - 14:42
	Generative Models for Fast Simulation of Electromagnetic and Hadronic Showers in Highly Granular Calorim...	Peter McKeown	
15:00	Status of IDEA Software for Simulation and Reconstruction	Lia Lavezzi	
	A415, IHEP		15:06 - 15:30

Summary

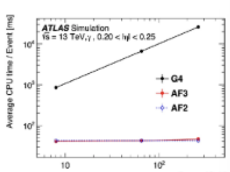
- A lot of developments in the plumbing of Key4hep:
  - Preparations for better multi-threaded processing
  - Spack build system maintenance, improvements and up-scaling
  - Event Data Model refinements and Quality-of-Life improvements
- Integration of new features: reconstruction, event display
- Important investments for future maintainability and synergies!

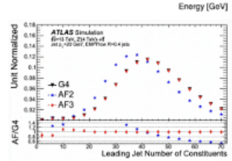
A. Sailer | Key4hep: Status and Plans - CEPC WS, October 28, 2022 | 14 / 14

Key4hep

Conclusion

- AF3: next generation of fast simulation in ATLAS
  - FastCaloSimV2: classical parameterization
  - FastCaloGAN: machine learning
  - Muon punch-through: fake muon
- Similar CPU consumption as AF2, improved modeling, especially for jet substructures
- Default simulator for Run3 and HL-LHC
  - Run3: >50%, targeting 70%
  - HL-LHC: 90%





20

Conclusion

Achieved

- Generative models hold promise for **fast** simulation of calorimeter showers with **high fidelity**
- Demonstrated high fidelity simulation of **hadronic** showers with generative models
- Demonstrated high fidelity simulation of **photon** showers with **angular and energy conditioning**
- Initial investigation into generative model performance after **reconstruction**

Next Steps

Hadron Shower Simulation

- Simulation of hadronic showers combining **ECAL and HCAL**

Photon Shower Simulation

- Benchmark performance after **reconstruction** and **timing**
- Develop strategy for dealing with **arbitrary incident positions**

DESY. | CEPC Workshop 2022 | Peter McKeown | 28.10.2022 Page 16

Fast simulation based on generative models

NEXT FUTURE

Grid Infrastructure

- Virtual Organization created for FCC
  Admin: G. Ganis
- Setup (user interface, computing element, storage) for FCC Virtual Organization @
  - T1 CNAF
  - T2 ReCaS Bari
- Disk space on the storage @ CNAF = 100 TB
  - TB2021 and TB2022 for DCH (@ CERN)
  - TB2022 for DRCalo (@ DESY & CERN)

Forecast for 2023

- Preliminary full simulation & reconstruction of IDEA by Fall 2023
  - Inside Key4hep and with tools provided by it (ACTS, Pandora ...)
- Organization of hands–on tutorial/school for physics analyses & software
- Group growing as the software becomes more mature and easier to use

CEPC WS, 2022/10/24–28 LL - IDEA SOFTWARE

IDEA software

Talks could be found in https://indico.ihep.ac.cn/event/17020/sessions/10728/#20221028

Summary

- Lots of excellent talks/reviews
- Significant progress, with indispensable international collaboration
  - Delivered prototypes + promising results
  - New ideas + advanced technologies
- CEPC poses stringent requirement, has strong synergies with other projects
  - Successful operation & detector upgrade at LHC, SuperKEKb, etc
  - Common R&D for other Higgs factories & beyond
- Multiple IPs: multiple detector with optimized design & different technologies
- To pursuing new ideas, better performance, & new technologies via significant R&D with in-depth international collaboration - to benefit not only CEPC/HEP research, but also other disciplines & on society

Thank you

to speaks, conveners, and enthusiastic participants

to my colleagues helped prepare the slides: Yiming Li, Tao Lin, Huirong Qi, Yaquan Fang, Zhijun Liang, Haoyu Shi, etc

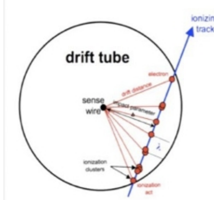
Hope to see you in person, and work together soon!

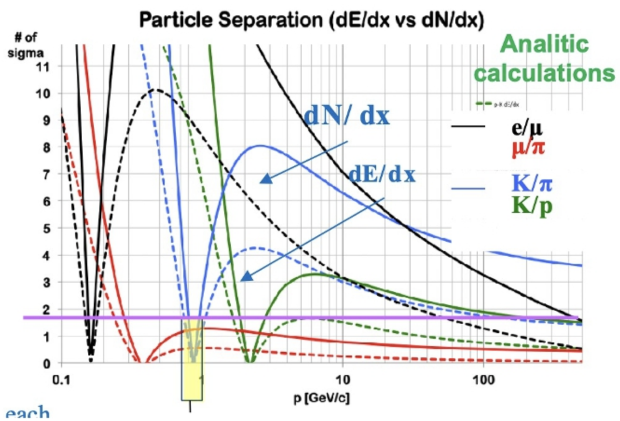
Backup

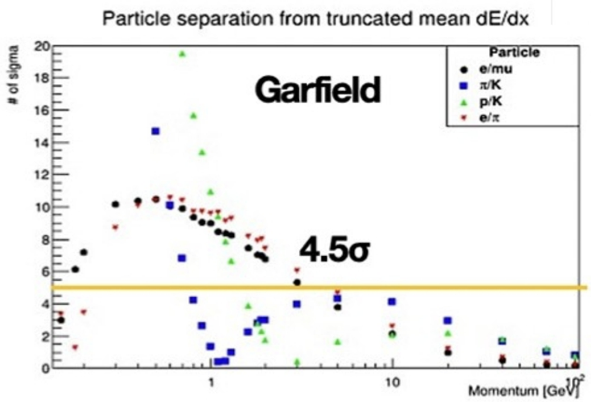
IDEA drift chamber: improved PID w/ cluster counting

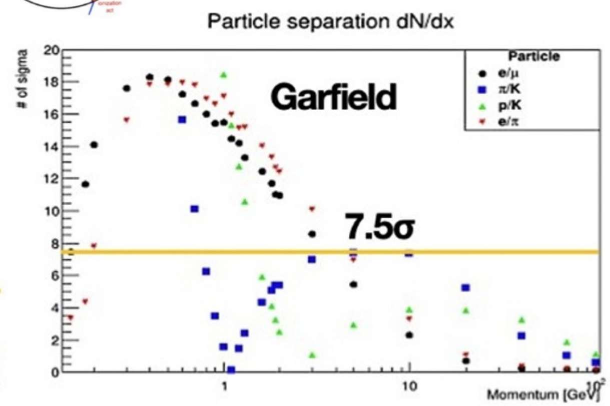
Gianluigi Chiarello

- Particle identification with ionisation loss measurement: significant improvement expected in resolution and K/π separation from cluster counting rather than dE/dx









- Beam test at CERN in 2021 with 165 GeV muon beam to tune algorithms for cluster identification and counting

- Beam test at CERN in 2022 with muons of 40, 80 and 180 GeV, analysis in progress

- **Next:** beam tests foreseen at PSI and Fermilab to cover wide range of βγ