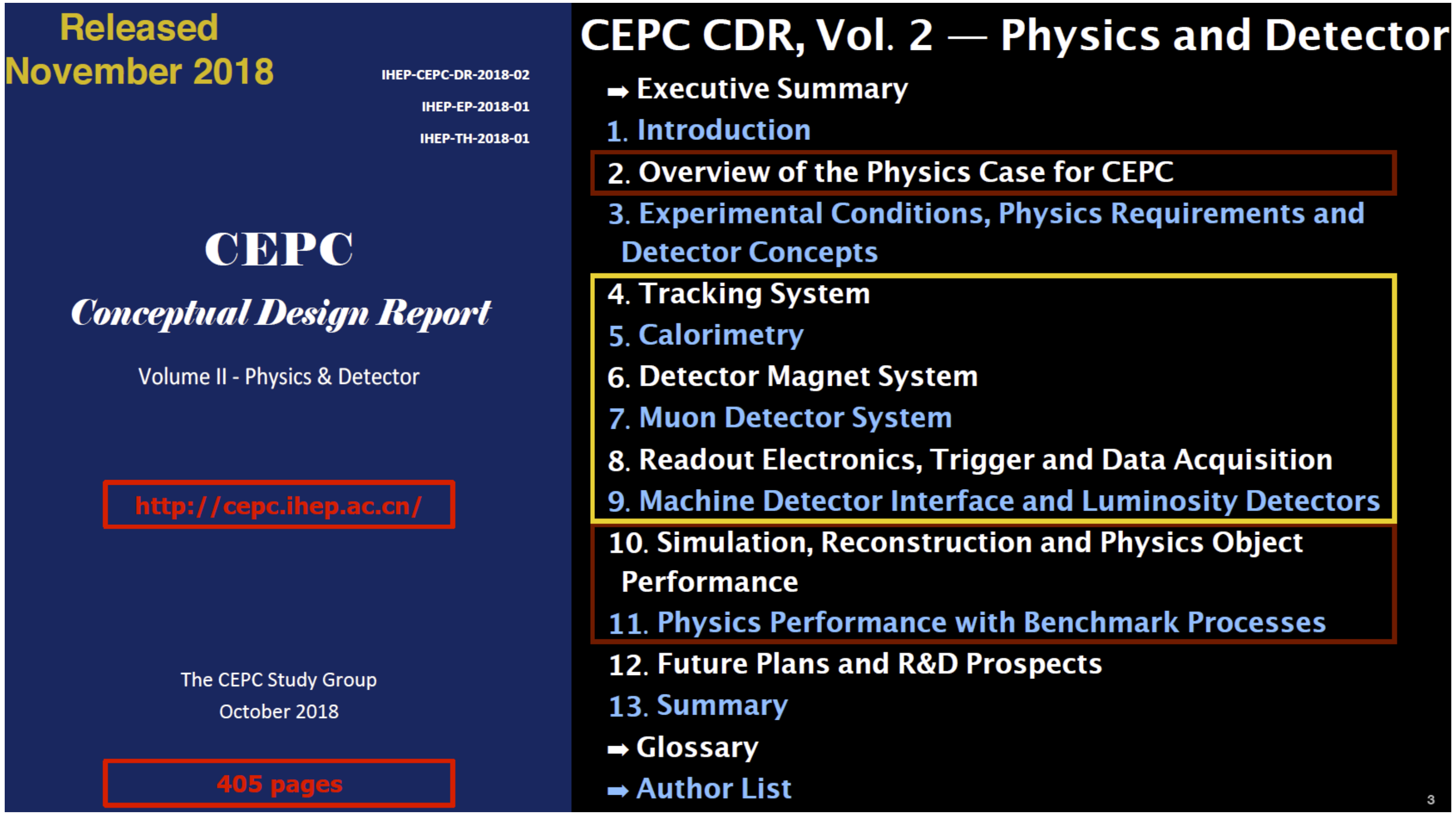
Highlights and future perspective of the CEPC detector

November 2019
2019 International Workshop on the High Energy Circular Electron Positron Collider

Sarah Eno

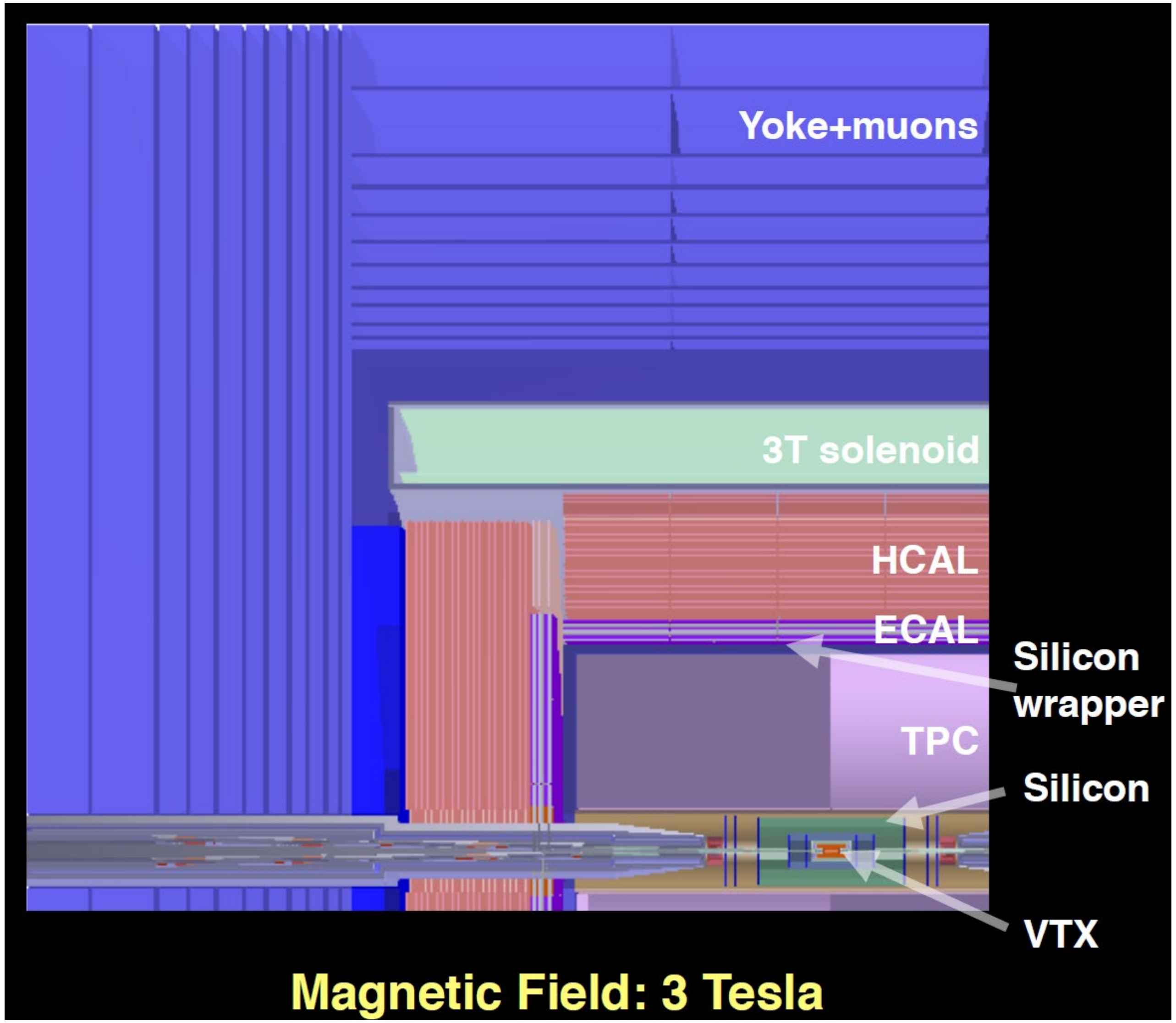
University of Maryland

About a year ago



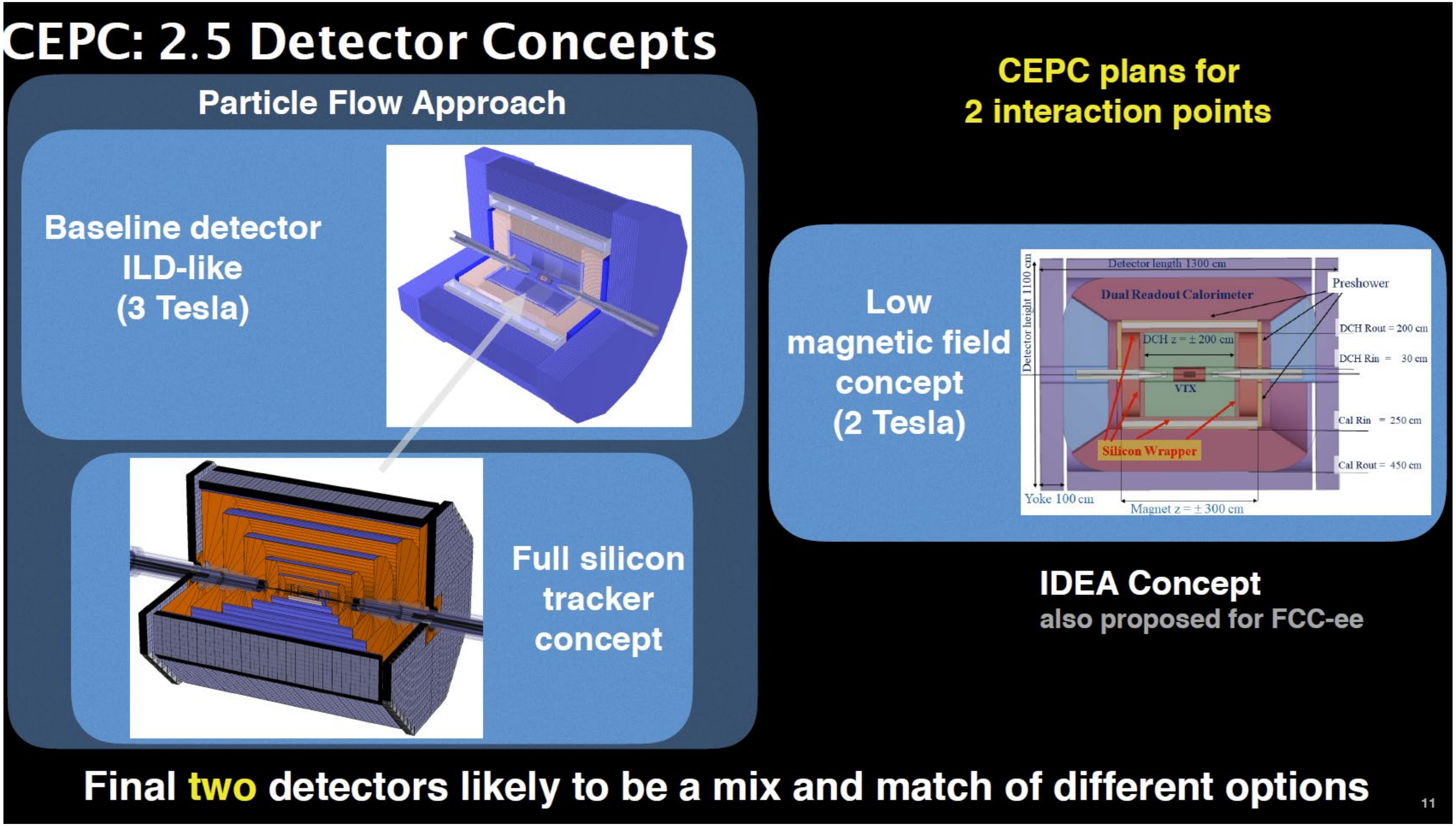
- Several detector options well matched to the physics of a Higgs factory.
- A well-developed detector simulation and particle reconstruction, including particle flow, for the baseline detector.
- Progress on simulation/reconstruction for the alternatives.

Baseline detector



- Low mass tracker with silicon vertex detector and TPC
- Imaging calorimetry à la CALICE
- High magnetic field
- Fully implemented in simulation and reconstruction

A few developed alternatives



themes

Very biased talk based on what caught my eye as a relative newcomer:

- Updating/re-affirming technical specs
- The challenge for Z running
- Exploration of novel "left field" possible detector options
- Continuing internationalization, learning/cooperating with other future machines
- Pushing the technology frontier

Look at these, and then blather about what this means about next steps

A very great many very interesting talks, some far from my areas of expertise. I apologize in advance for the many interesting things I did not include or did not properly understand. Many parallel sessions also makes summary challenging.

Updating/reaffirming technical specs

Physics requirements

We all know these

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

Challenging the specs

F. Bedeschi, this workshop

Physics process	Measurands	Detector subsystem	Performance requirement	From CDR
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$	Too tight?
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$	Not enough?
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV	Too tight?
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$	Not enough?

Important to do. While very stringent specs can inspire detector builders, when it comes time to build, too stringent specs can:

- can push one to immature technologies
- explode costs

Too loose specs can lead to missed physics opportunities

Nice session on Monday exploring this topic

Calorimetry requirements

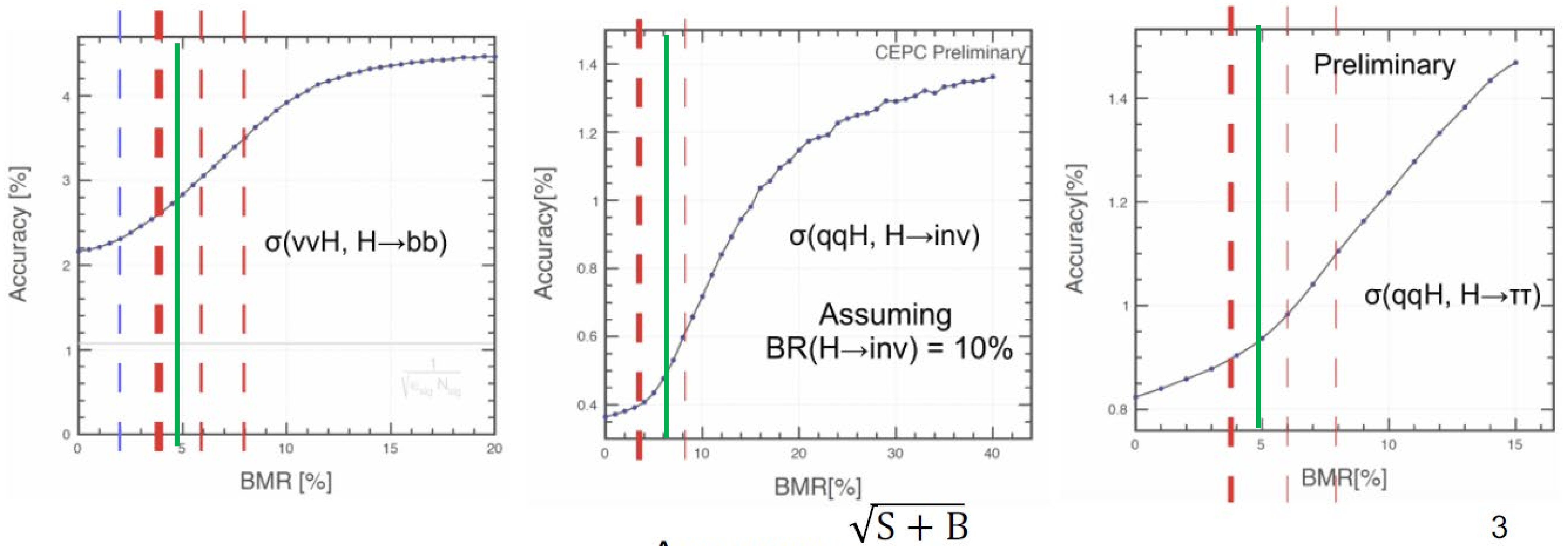
The CDR sets very challenging goals for jet resolution.
The CDR goals for electrons/photons are modest.

Primarily for the Higgs physics program at CEPC

Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) = 2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta} (\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E = 3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E = \frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

Jet resolution is essential to e^+e^- Higgs factory calorimetry

Beautiful quantitative studies reasserting these themes



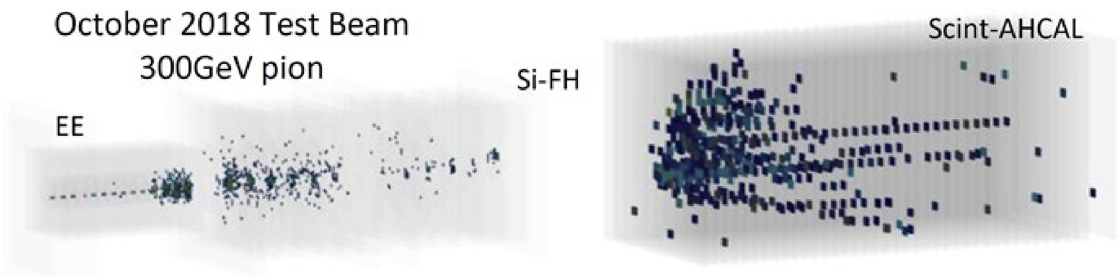
$$\text{Accuracy} = \frac{\sqrt{S+B}}{S}$$

For details, see Manqi Ruan's talk at Monday optimization session

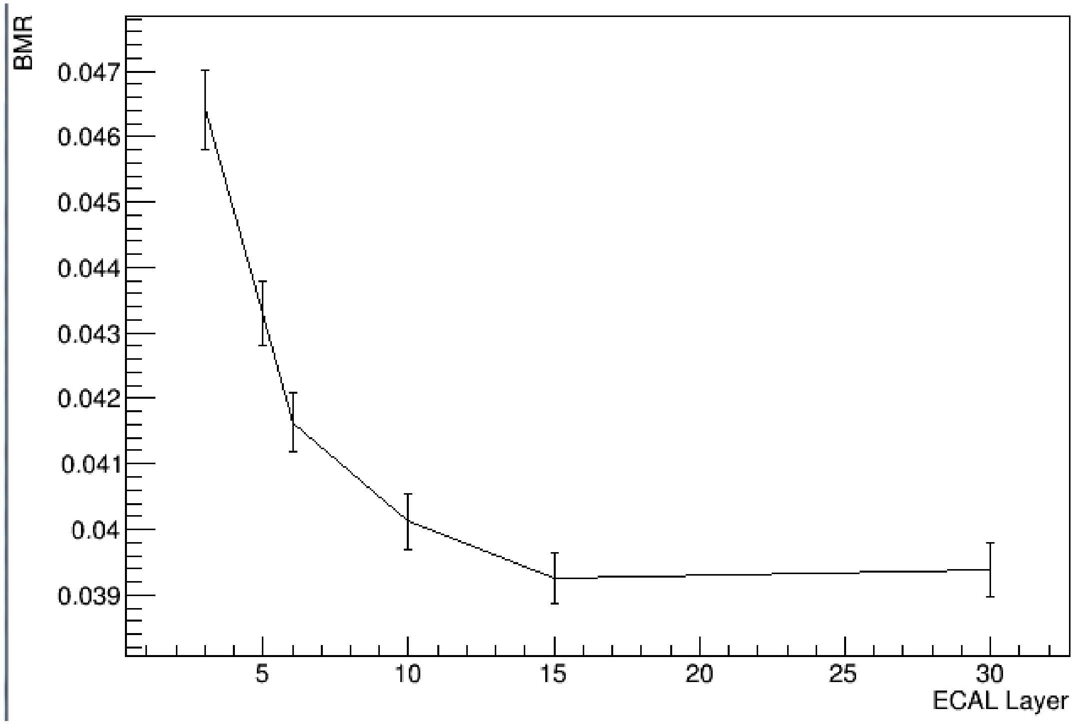
Jianming Qian: maybe could loosen to 5%? Accuracy still pretty good!

over specification?

Imaging calorimeters come with lots of readout segmentation. Pretty pics, but do we really need? They are expensive.



CMS HGCAL



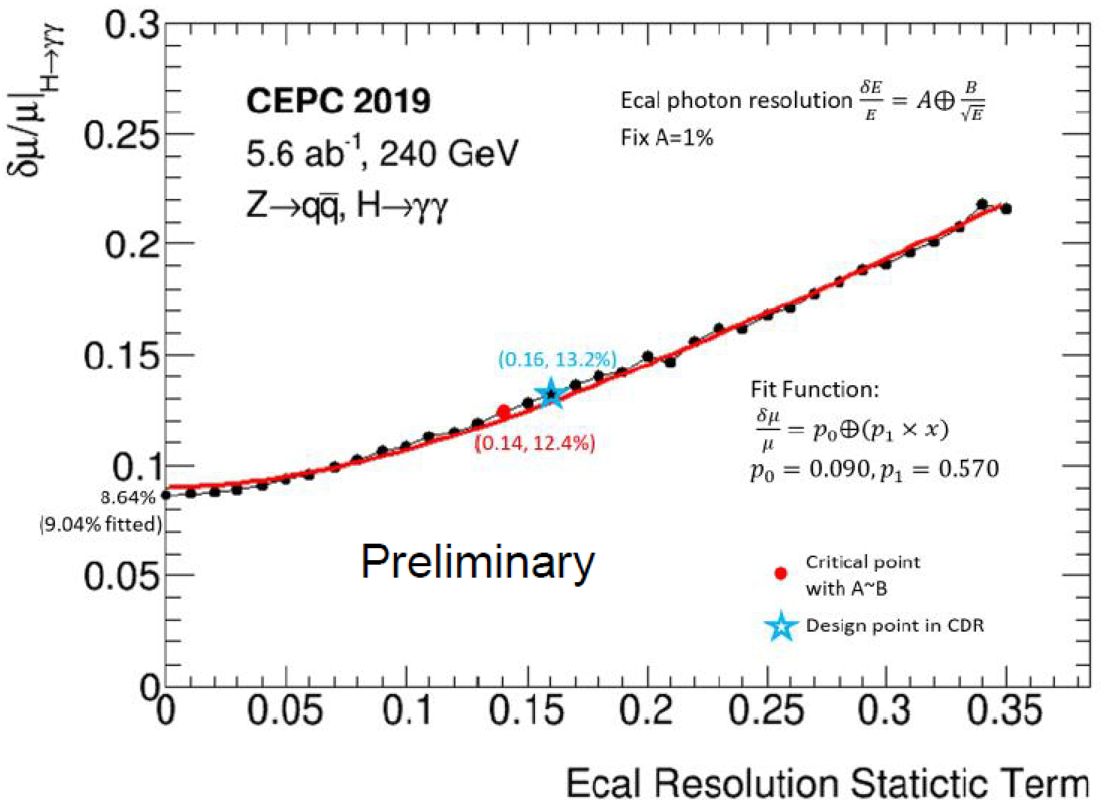
Boson Mass resolution as function of number of ECAL layers

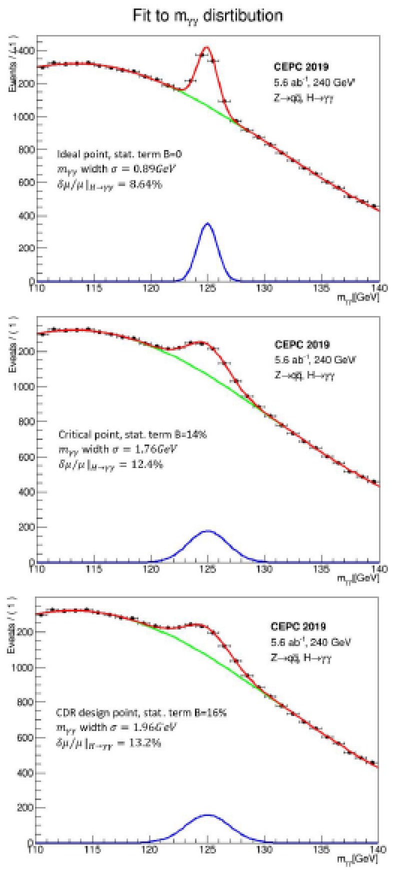
Maybe don't need separate readouts on all these layers? Or maybe we need better algorithms that actually need them and then get even better than 4%?

EM resolution: current benchmark

Manqi Ruan, this workshop

ECAL resolution benchmark on μ(H→γγ)





14% of statistic term is adequate to 1% constant term

18/11/19 CEPC WS@IHEP 9

If want contribution from constant term and stochastic term about the same, maybe should be 14%, not 20%?

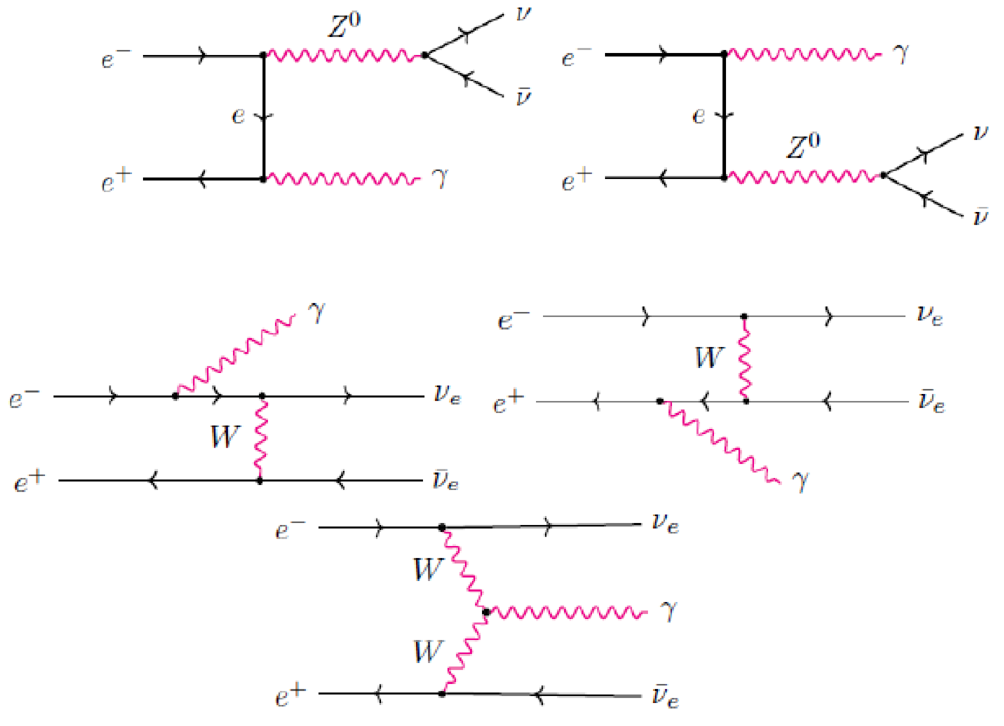
But how important is this anyway after the HL-LHC?

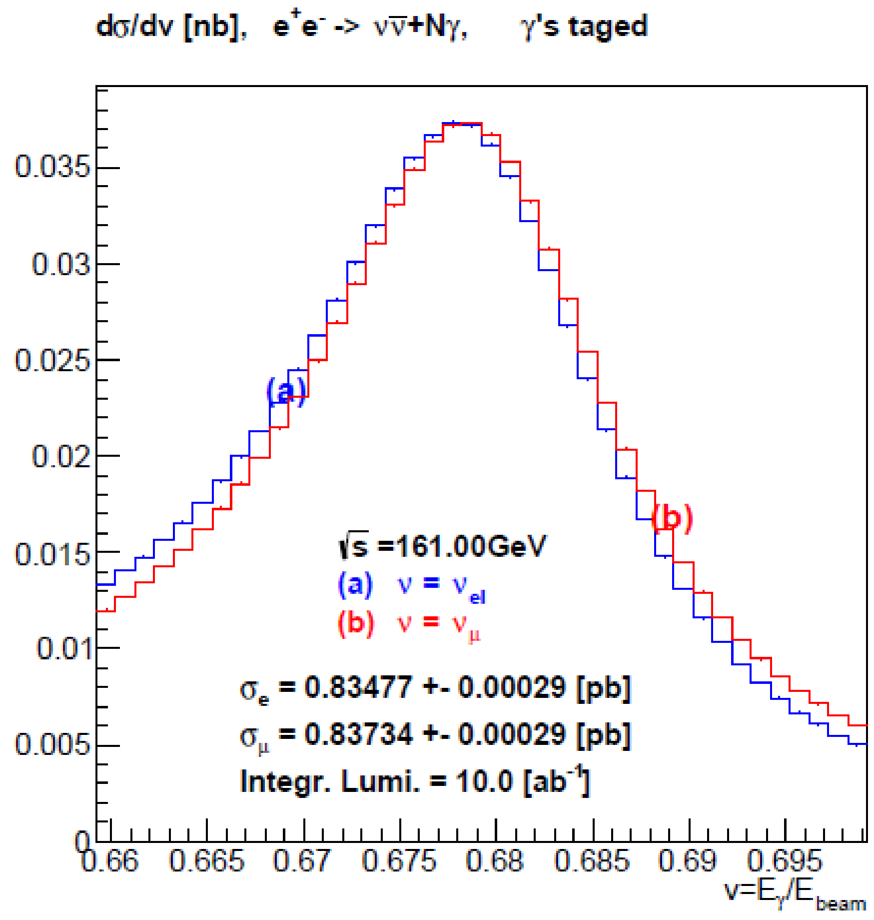
Can we find other benchmarks?

Coupling to electron neutrino

F. Bedeschi, this workshop

Could be first time that the coupling to an individual neutrino is measured?





Which do you prefer? This or more accuracy on Higgs couplings to b, tau, invisible? Or do we need complementary detectors?

Under specification?

From Manqi Ruan

- On top of what you summarized, I would like to add a small comment that the rich flavor program - might appreciate a better EM energy resolution. However, to identify a representative benchmark with clear physics impact is not trivial.

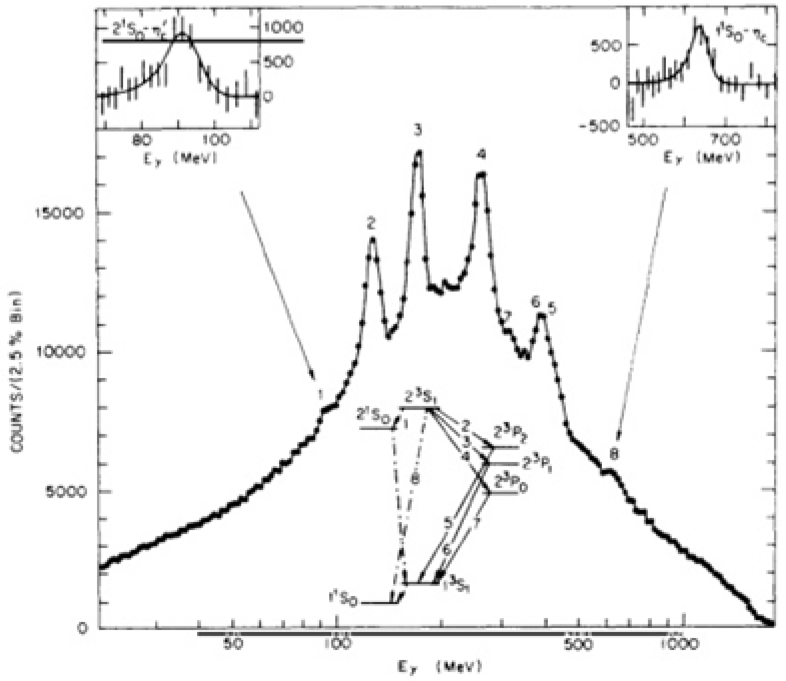
Lots of room to make an impact here!

Most flavor physics will be done at the Z. “New” physics program needs careful bench marks

Nice program on theory motivated flavor physics here, but need to do detailed detector studies

Very important that we get the most physics we can out of this major financial investment

Crystal Ball



Tracking

- Very challenging requirement on track resolution
- Interesting that you need excellent track momentum resolution but not excellent electron/photon resolution. Muons play a special role at an electron collider due to reduced backgrounds, drive by two measurements: **Higgs mass and Higgs couplings to muons.**

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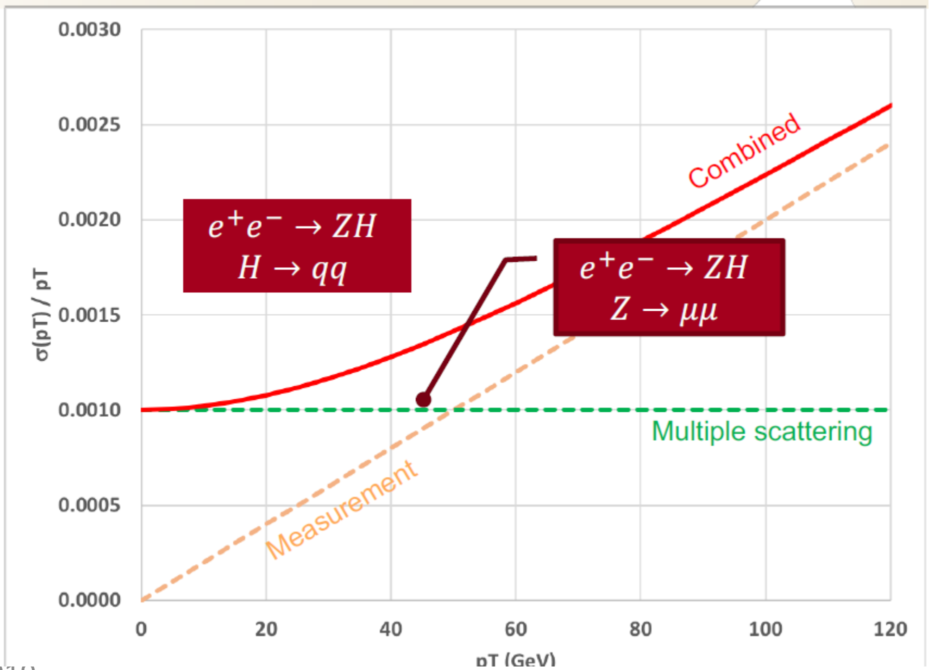
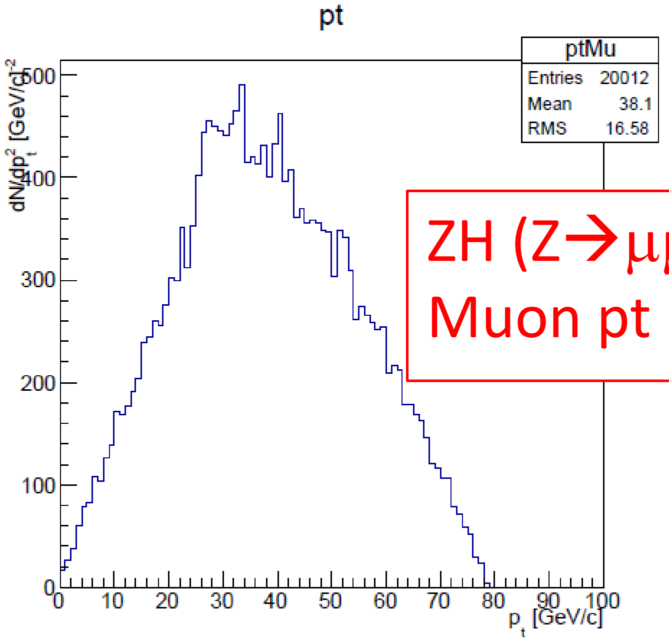
Charlie Young

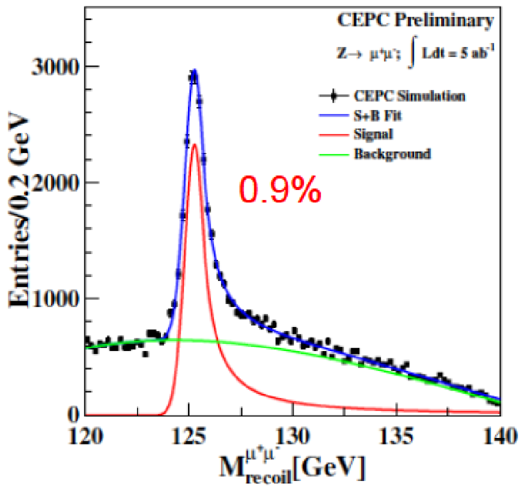


Transparency may be more important than hit position resolution? Can we relax the resolution specification?



muons

Zhenxing Chen & Yacine Haddad



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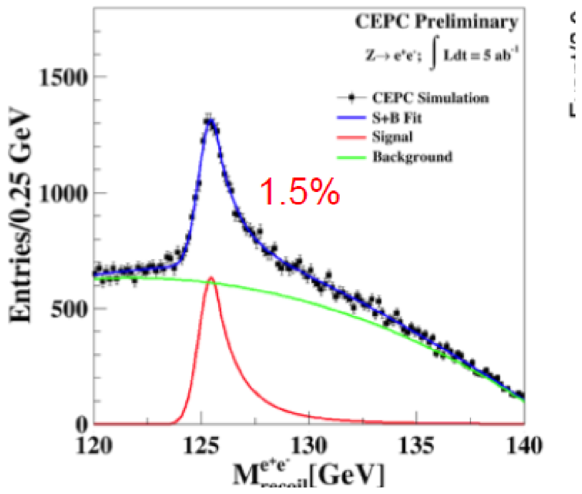
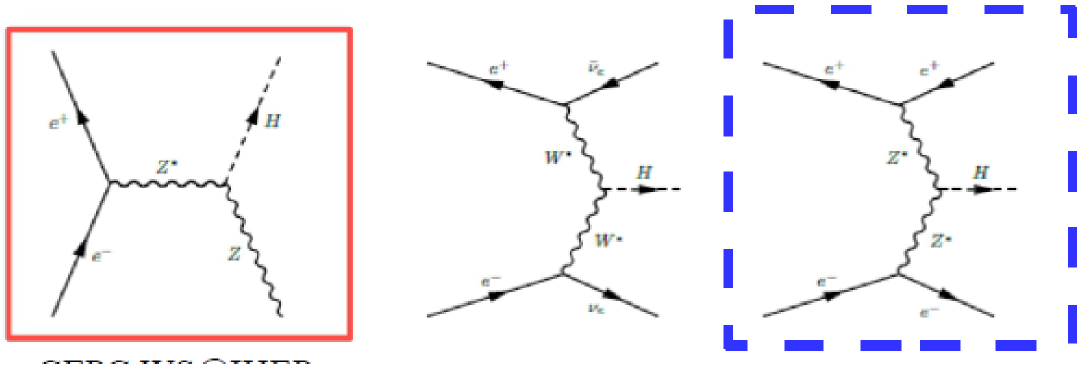
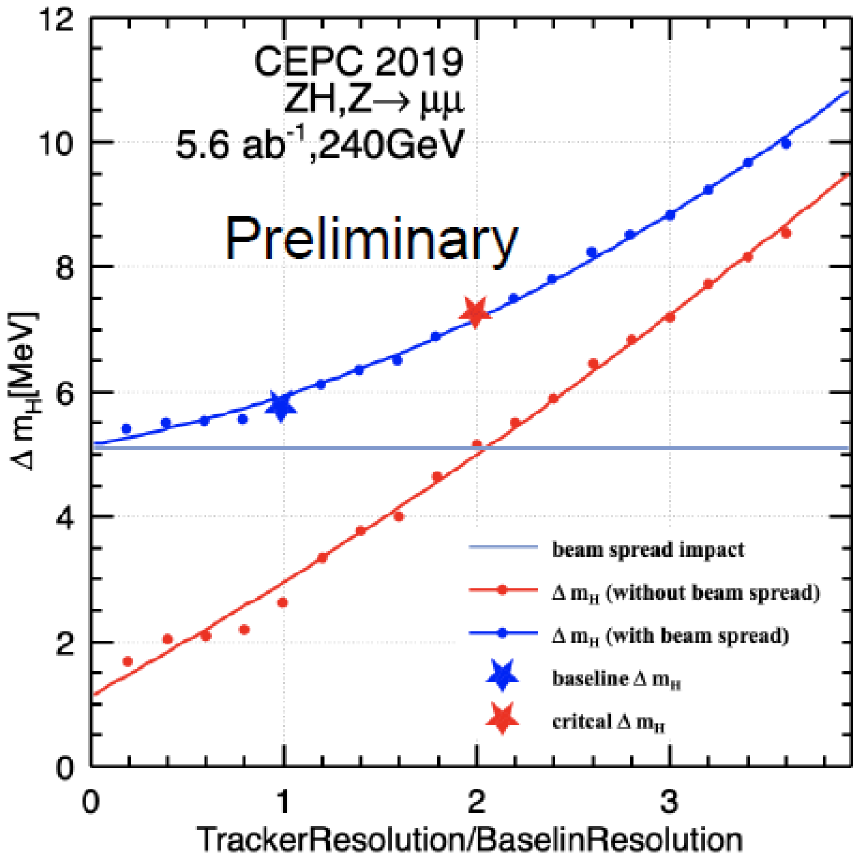




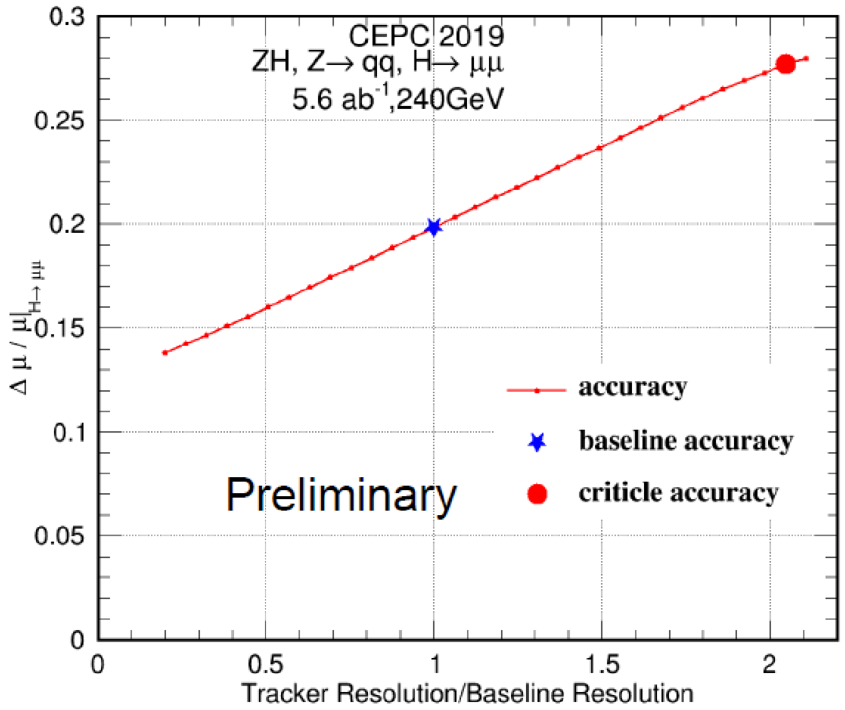


Maybe could relax by factor of 2?

Electron channel suffers from larger background even if sharpen up the peak with improved resolution

LianTao Wang: but who really cares about the Higgs mass precision?

μ(H→μμ) measurement at qqH event



- Degrading the tracking resolution by 2 times leads to a degrading of 40% in the signal strength measurement

Higgs to muon coupling

Would be nice to keep this low enough that CEPC improves over HL-LHC?

How much money should we pay for a challenging spec for 2 measurements, that that “is not so interesting” and the other that might be done at HL-LHC?

vertexing

Br(H->bb, cc) measurement

Zhigang Wu

- Br (H -> cc) is extremely sensitive to the vertex design
- Br (H -> bb) is less sensitive to the vertex design

Inner most hit radius most important

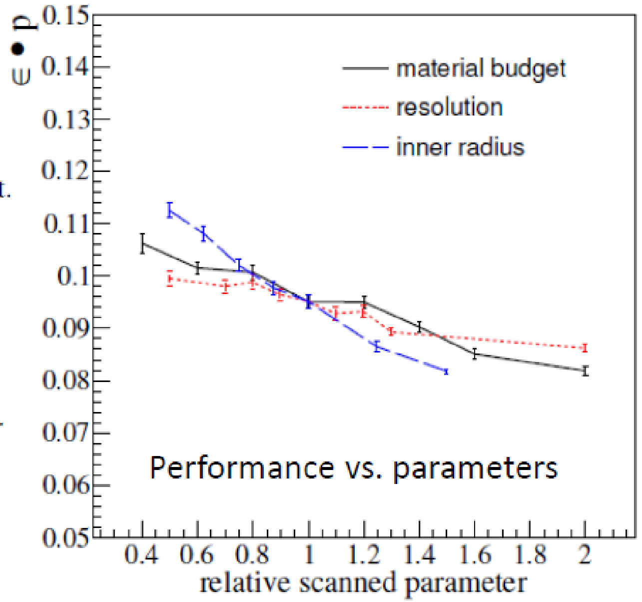
$$\frac{\delta_\mu}{\mu} \propto \frac{\sqrt{S+B}}{S} = \sqrt{\frac{1}{S}}\sqrt{\frac{S+B}{S}} \propto \frac{1}{\sqrt{\epsilon \cdot p}}.$$

Table 3. Maximum $\epsilon \cdot p$ value comparison for the $Br(H \to c\bar{c})$ measurement.

	Scenario A	Scenario B	Scenario C
$\epsilon \cdot p$	0.133 ± 0.002	0.095 ± 0.001	0.078 ± 0.001
	41%		-22%

Table 4. Maximum $\epsilon \cdot p$ value comparison for the $Br(H \to b\bar{b})$ measurement.

	Scenario A	Scenario B	Scenario C
$\epsilon \cdot p$	0.925 ± 0.001	0.914 ± 0.001	0.900 ± 0.001
	1%		-1.5%

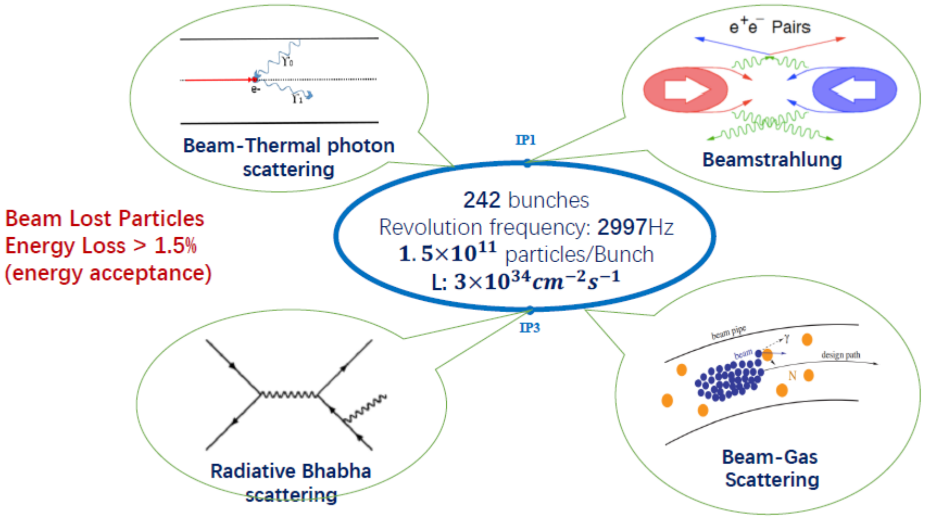


$$\epsilon \cdot \mathrm{p} = 0.095\left(1 - 0.14\frac{\Delta x_{material}}{x_{material}}\right)\left(1 - 0.09\frac{\Delta x_{resolution}}{x_{resolution}}\right)\left(1 - 0.23\frac{\Delta x_{radius}}{x_{radius}}\right)$$

Inner radius is the most sensitive parameter

7

Watch beam backgrounds

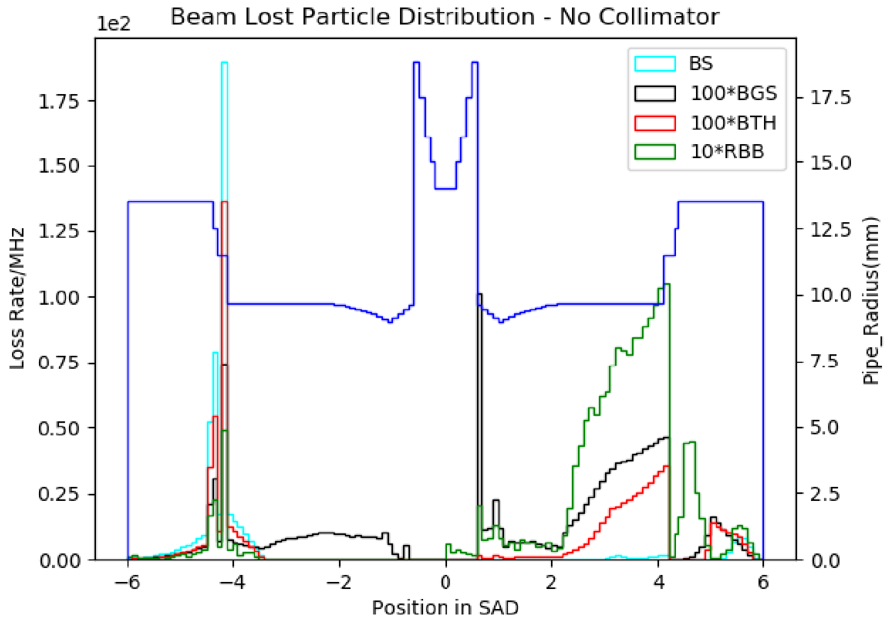


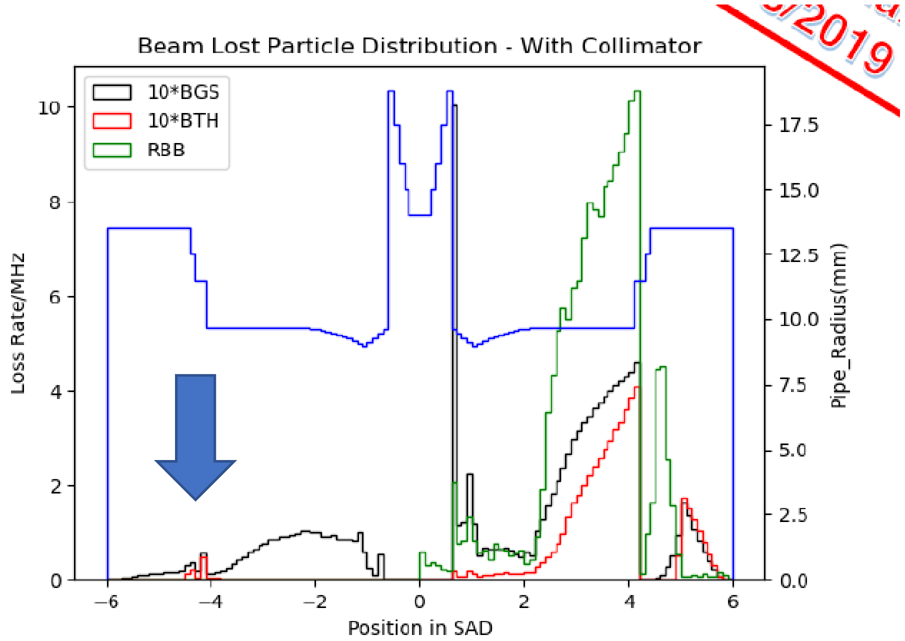
Haoyu Shi

Innovative work on shielding.
Something important to watch?

Risk versus benefit?

- 4 types of Backgrounds
- Normalized to loss rate in MHz(one beam)
- BS contributes the most





The challenge of Z running

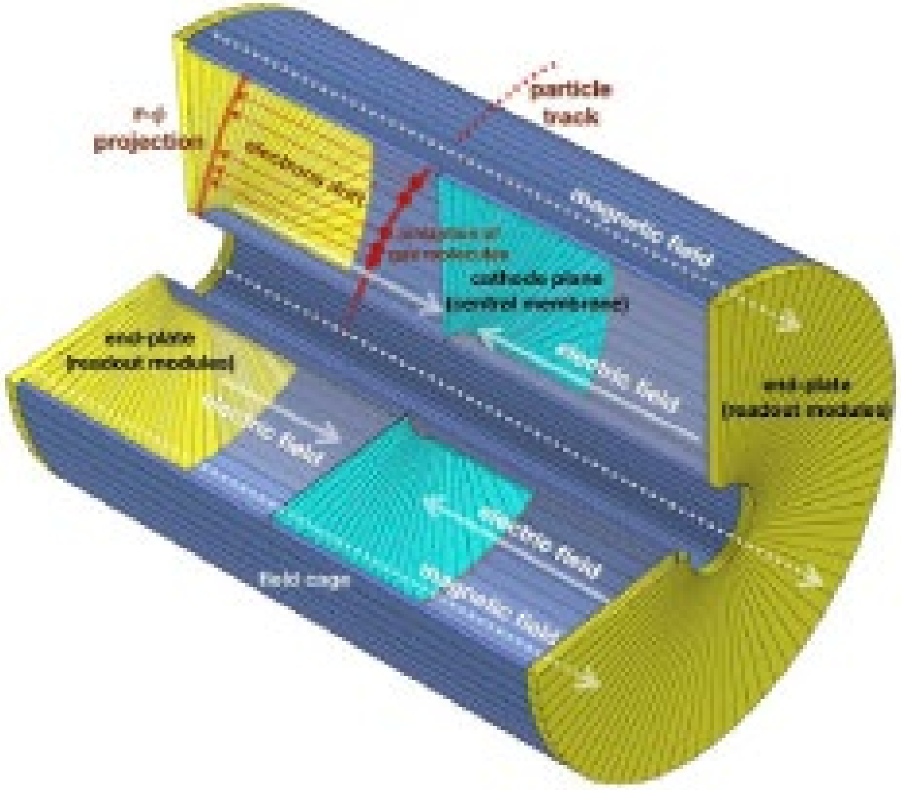
Challenges at Z

		CDR	New(*)	Ultimate(*)
ZH				
Luminosity	$cm^{-2}\ sec^{-1}$	3×10^{34}	5×10^{34}	
Bunch spacing	$nsec$	680	760	
Z, 3T solenoid				
Luminosity	$cm^{-2}\ sec^{-1}$	1.7×10^{35}	2.4×10^{35}	
Bunch spacing	$nsec$	25	25	
Z, 2T solenoid				
Luminosity	$cm^{-2}\ sec^{-1}$	3.2×10^{35}	3.8×10^{35}	1.0×10^{36}
Bunch spacing	$nsec$	25	25	25

from Jie Gao, Korea 2019

Int. Workshop, Beijing, Nov. 2019 8 F. Bedeschi, INFN

The ability to run on the Z is a very appealing feature of the circular machines. It is also a place where CEPC cannot stand on the giant shoulders of the work for ILC

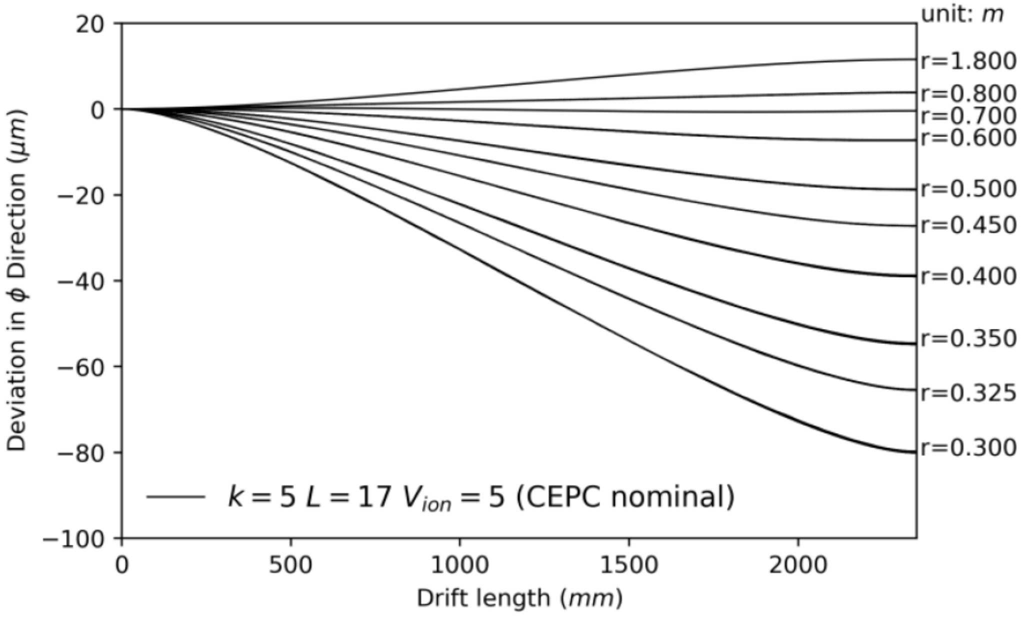


particle
track
projection
magnetic field
cathode plane
(central membrane)
end-plate
(readout modules)
electric field
end-plate
(readout modules)
electric field
electric field
field cage
magnetic field

Ion back flow

Huirong Qi

Simulation of deviation with IBF (k=Gain×IBF) @CEPC



Deviation in Φ at CEPC Z pole run with $17\times10^{34}cm^{-2}s^{-1}$ (Lumi.)

- 11 -

Idea: intermediate solution between pads and pixels for CEPC at Z

- Clusters contain the primary information of the ionisation
- Can we find a solution to resolve clusters?
- Some R&D for pixel TPC:
  - What is the optimal pad size to
    - – improve double hit and double track resolution
    - – do cluster counting for improved dE/dx?
    - → Pixel size:(200μm or large), significant reduce cost
- Almost without IBF (Gain< 2000)
- Micromegas + ASIC Chips (Our option)
- GEMs + ASIC Chips
  - → Some R&D at DESY
- There is a invitation to LCTPC collaboration and one response obtained.
- Kees from NIKEF will attend and discuss some possible collaboration.

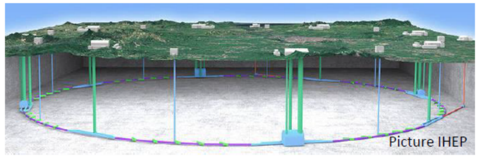
Ion back flow

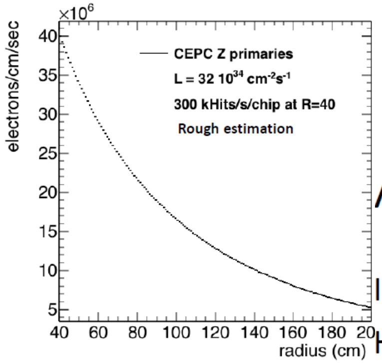
A GridPix TPC at the CEPC?

A GridPix TPC can deal with the high beam rates at the CEPC

- The CEPC with $L = 32\ 10^{34}\ cm^{-2}\ s^{-1}$ will produce Z bosons at ~10 kHz
- Link speed of Timepix3 (in Quad) is 80 Mbps: 2.6 MHits/s per $1.41 \times 1.41\ cm^2$
- Excellent time resolution: time stamping of tracks < 1.2 ns

- Power consumption ~2W/chip depending on hit rate
  - No power pulsing possible at the CEPC
  - Good cooling is important





18/11/2019 GridPix TPC Readout (Cornelis Ligtenberg) 17 / 19

Cornelius Ligtenberg

A GridPix TPC at the CEPC?

Ions are not limiting performance in the 240 GeV (Higgs) runs

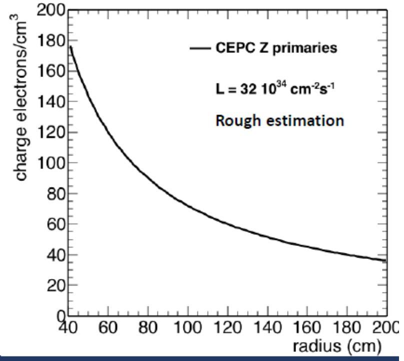
However, the number of Ions in the high luminosity 91 GeV run might be high

- Rough estimations at $L = 32 \cdot 10^{34}\ cm^{-2}\ s^{-1}$ indicate primary ionisation causes accumulated charge at an ILC250 level $\Rightarrow$ distortions < 5 μm (see backup slide)

Ion backflow (IBF) can give a lot of additional charge, so IBF must be controlled

- Measuring IBF for Gridpix is a priority, expected $\mathcal{O}(1‰)$
- Gating can greatly reduce IBF
  - At CEPC gating is possible because:

    max drift time of 30 μs < average Z interval 100 μs (10 kHz)
  - Will cause some leveling due to dead time

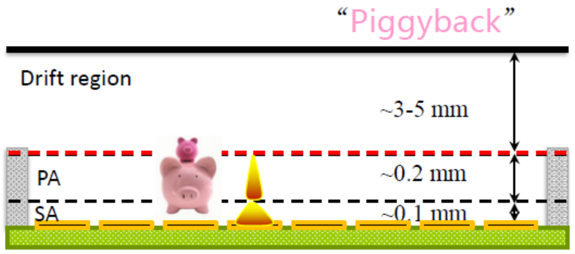


2019 GridPix TPC Readout (Cornelis Ligtenberg) 18 / 19

Ion back flow

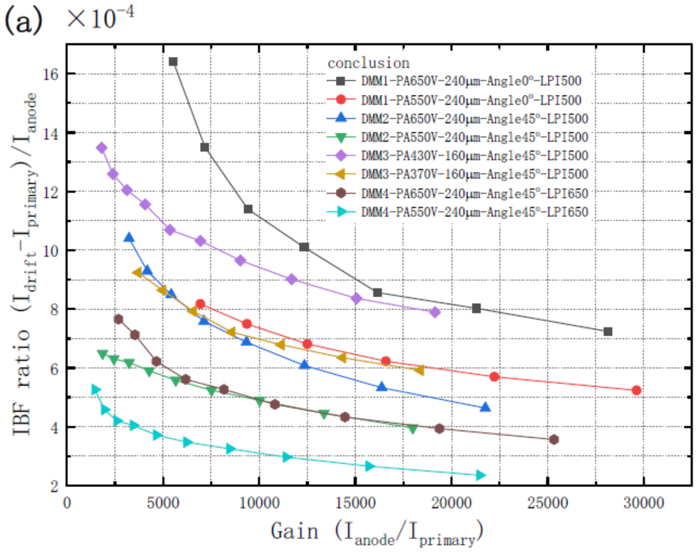
An interesting problem inspiring lots of intellectual work. Still time to play.

- DMM: Double Micro-Mesh gaseous structure
  - Hole-type → mesh-type : to strongly reduce IBF
  - Double mesh: cascading avalanche for high gain



Zhiyoung Zhang

Optimization Outcome For DMM



To push IBF down to an extremely low level:

- ✓ low PA electric field
- ✓ large PA gap
- ✓ high mesh density
- ✓ crossing mesh setting

A IBF ratio down to ~0.025%, which has been improved with a factor of 2 compared with that before optimization.

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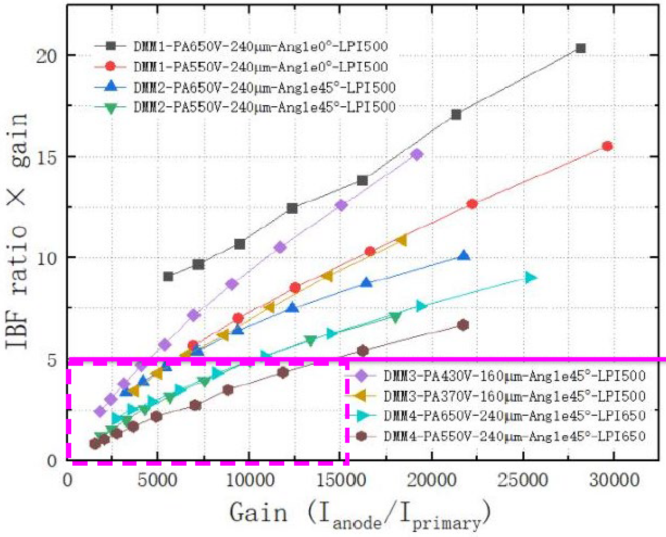

Define IBF ratio × gain as ε: ε = 5

This result fulfill the requirement of ε < 5 in the R&D of CEPC TPC, even operated in higher gain of >10000 is possible to improve the S/N.

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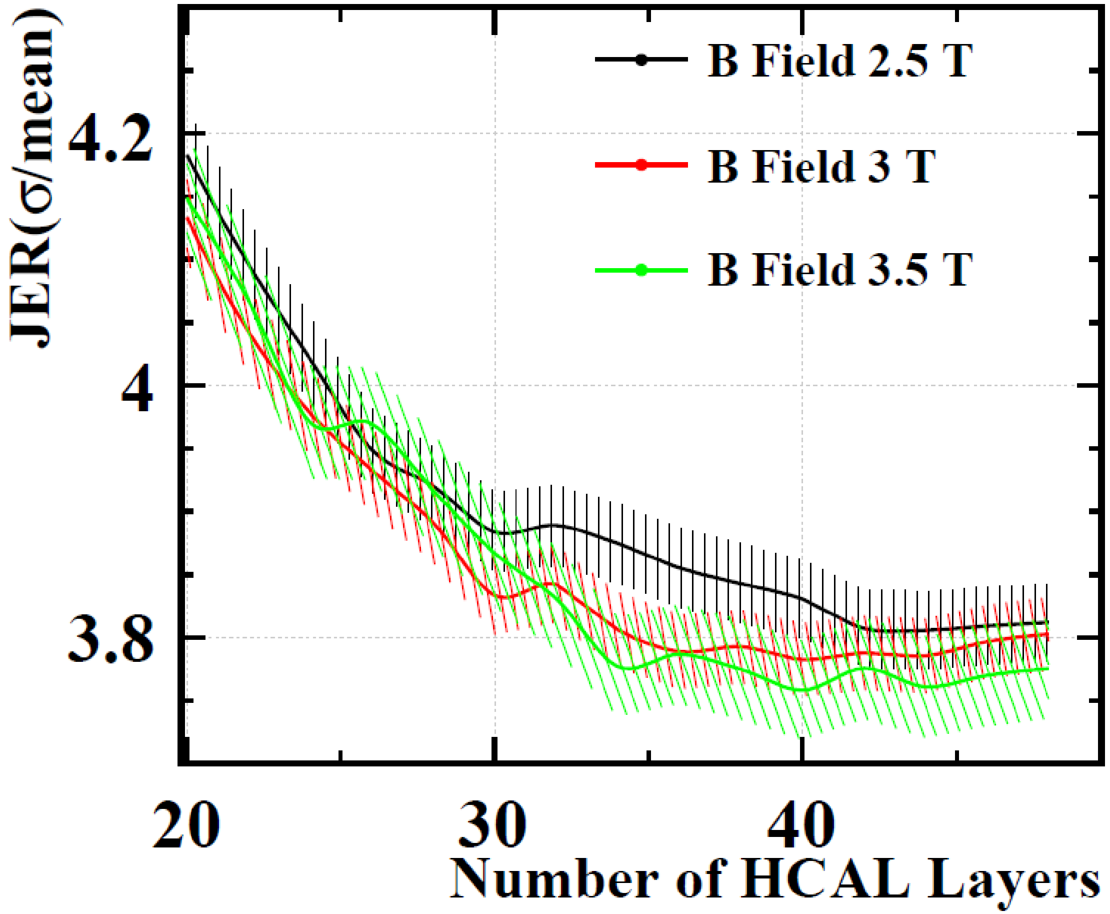
B field

- High inst lum at Z pole for 2T field appealing.
- How important to have the same field at Z and at Higgs?
- Lower momentum threshold at lower field? How important is low pT track reconstruction efficiency?

$$\frac{\sigma_{p_T}}{p_T} = \sqrt{\frac{720}{N+4}} \frac{\sigma_x p_T [GeV]}{0.3BL^2}$$

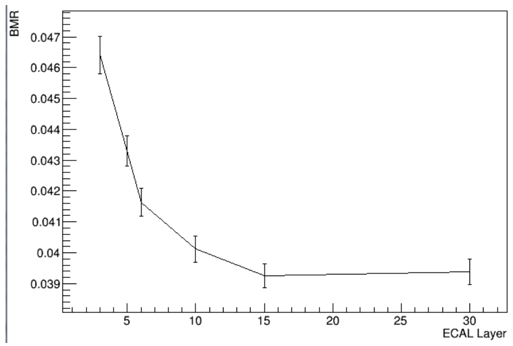


Relative importance of really nailing Higgs mass, Higgs coupling to muons versus easier transfer of calibrations from Z to Higgs?

Exploration of novel "left field" possible detector options

- Detector technology is always moving
- There is still time to consider new ideas, if they can strengthen the physics program
- Be careful not to ossify to the baseline???? Challenging (discussed more later)

Left field calorimetry



Boson recoil mass versus number of ECAL layers

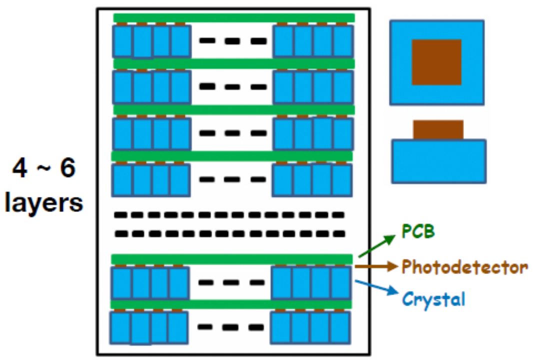
Can we have PFLOW and good EM resolution and a reasonable cost?

Yuexin Wang

Ideas on Homogeneous Crystal ECAL

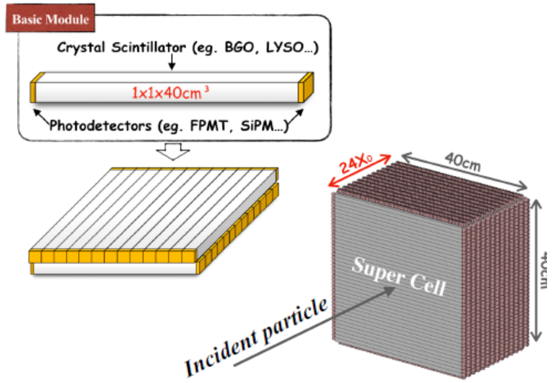
2 basic geometries

Geometry 1:



- *Similar to baseline ECAL;*
- *Finely segmented transverse, 1cm×1cm cell;*
- *Limited number of longitudinal layer.*

Geometry 2:



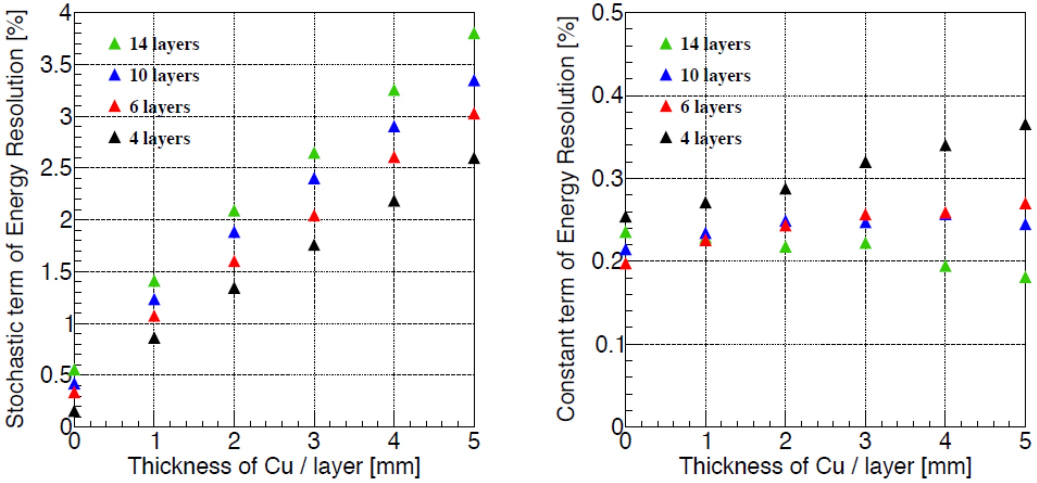
- *Finely segmented longitudinal, 1cm/layer;*
- *Transverse cell, long crystal bar, 1cm×40cm;*
- *Cross structure*
  - *crystal bar perpendicular to adjacent layer*
- *Time measurement for hit positions*
  - *compensating for transverse granularity.*

4

Dead Material and Layer Number

Model: (Crystal + PCB + Cu) / layer

Crystal, total radiation length = $24X_0$
PCB, 2mm/layer
Cu, represents the dead material between layers (cables, cooling, etc.)
Varying thickness of Cu per layer and longitudinal layer number



Note: digitization not implemented yet, so energy fluctuations and leakages dominate

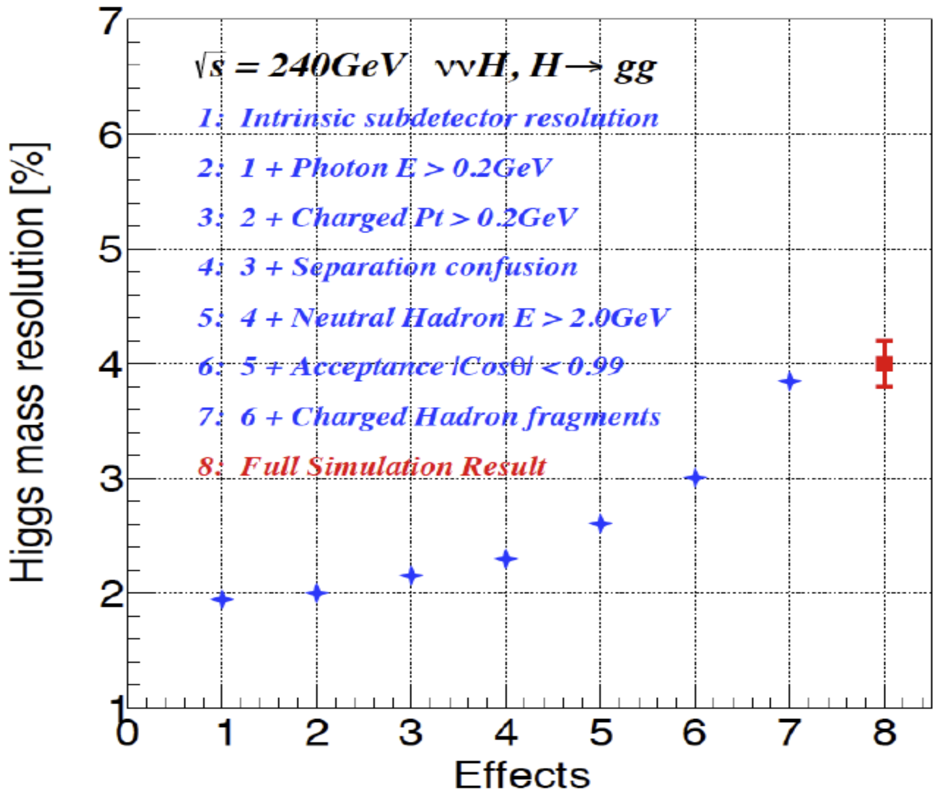
6

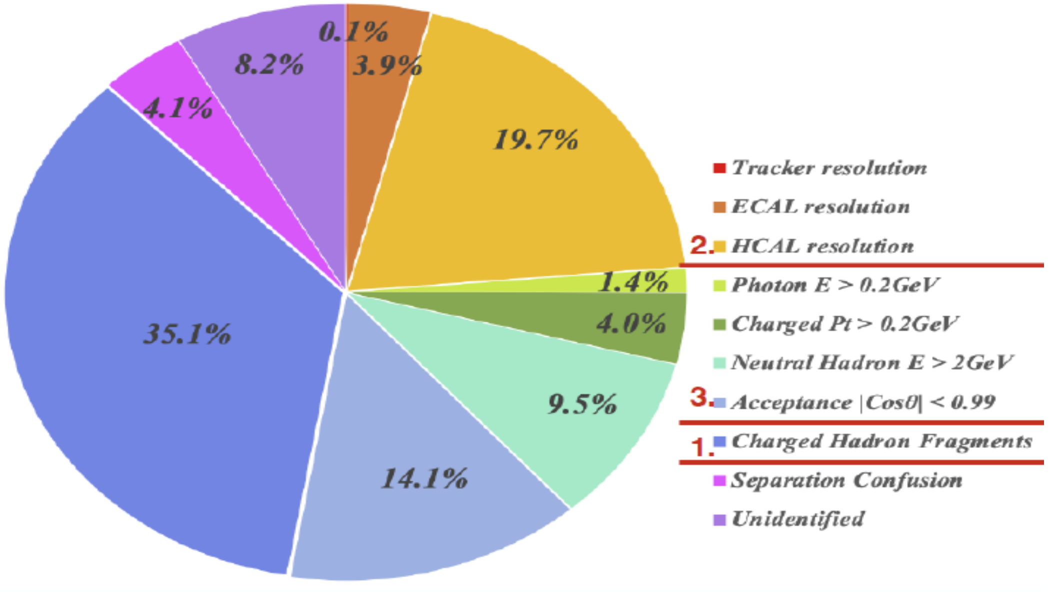
Can we do better?

My current favorite slide

PFA Fast simulation (Preliminary)

From Manqi Ruan

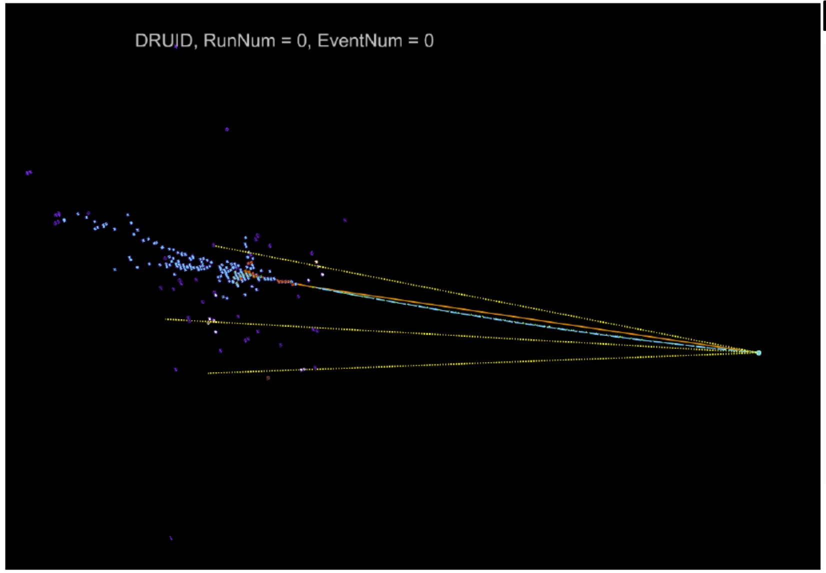




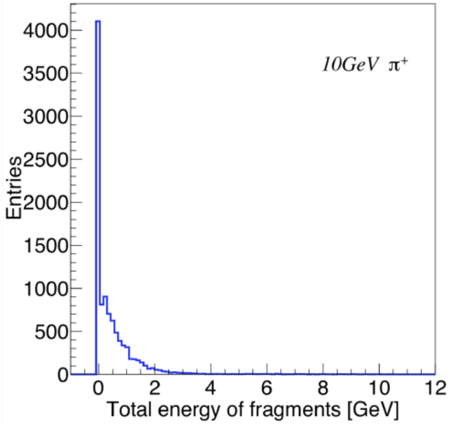
YX. Wang

Fast simulation reproduces the full simulation results, factorize/quantifies different impacts
Same cleaning condition as in the Full simulation applied
Early phase of modeling/tuning

28/10/19 LCWS 2019 17



From Manq Ruan's talk



Time/pattern recognition may help a lot, in identify the charged cluster fragmentations without arise the threshold for the neutral hadron significantly...

Room for new algorithms, timing information, even physical signal to help get rid of these?

- Number 2 is hadronic resolution.
- Number 3 is acceptance. Impossible to improve?
- Neutral hadron energy threshold not negl. Any chance to go lower?

Very thin Silicon

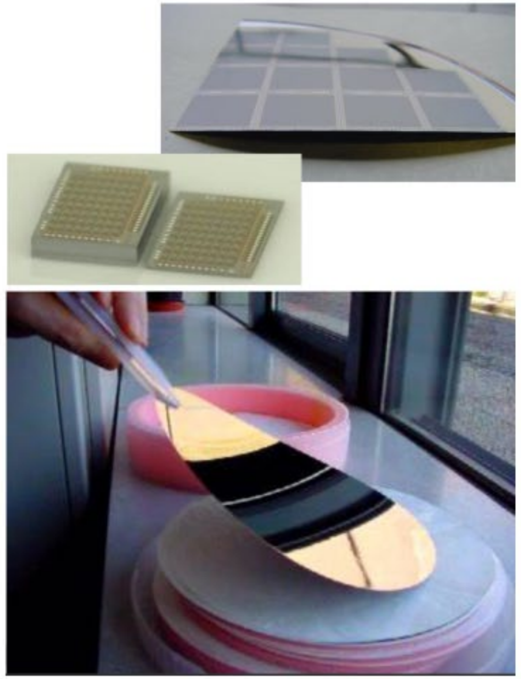
Trending up: Thinner Silicon

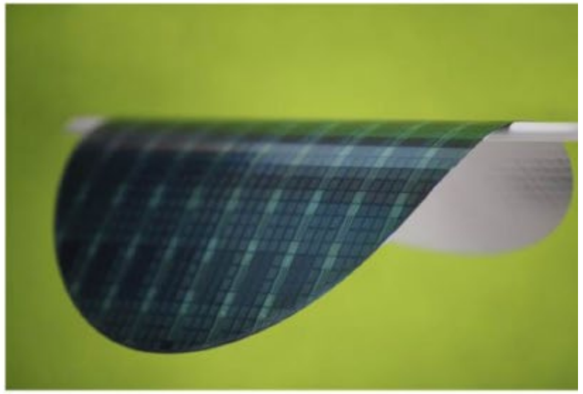
INFN

Manual da Rocha Rolo

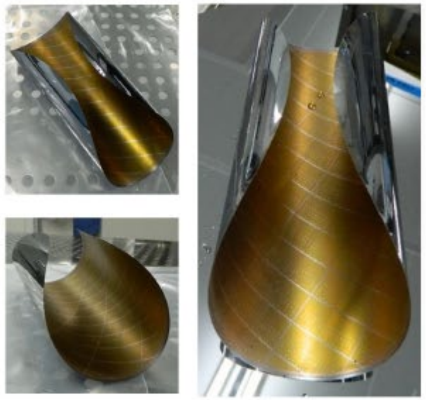
- Technology:
  - Course + fine grinding
  - Critical: thinning damage, impact on devices
- Wafer handling:
  - Very thin wafers (< 100 um): use of carrier wafers and temporary wafer (de-)bonding technology
- IMEC results:
  - Thinning down to 15 um
  - Total thickness variation ~ 2 um on 200 mm wafer

P. De Moor (IMEC)





50 μm thin 300 mm Silicon Interposer Wafer with Cu-RDL metallisation. Source: Fraunhofer IZM



Magnus Mager, VERTEX2019

Wafer-scale ultra-thin (< 20 μm) stitched MAPS could bend into a cylindrical mechanically stable self-supporting shape:

☑ *purely Si based collider detector for tracking and PID with a VERTEX with an unprecedented low material budget of < 0.05 % X_0 per layer*

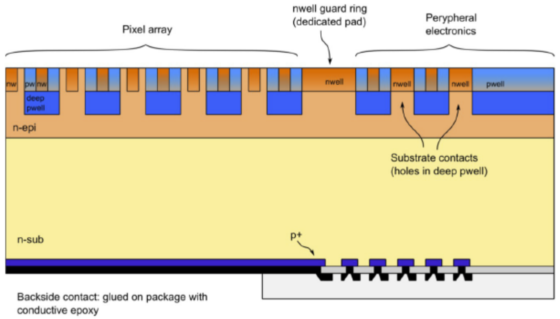
6 Manuel Da Rocha Rolo (INFN) — darocha@to.infn.it CEPC Workshop IHEP, Beijing, 2019-11-18

Left field tracking

Huirong Qi

Recent new developments

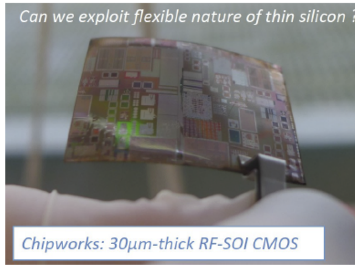
- There are significant advances in technologies from the upgrades of Belle II, LHC/LH-LHC experiments (low-mass, fast-timing, radiation hardness).
- It makes sense to re-optimize the CDR detector designs to take the advantage of these new developments and new ideas, for example:
  - Low-mass CMOS vertex detector from ALICE
  - Fast timing LGAD detector from HL-LHC
  - TORCH/RICH PID from LHCb
- ARCADIA project (Advanced Readout CMOS Architectures with Depleted Integrated sensor Arrays):
  - Help to facilitate R&D for low-power high-density pixel matrix CMOS monolithic sensor.

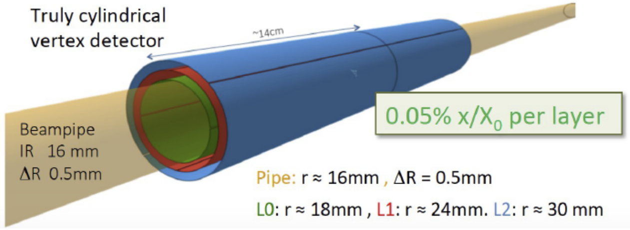


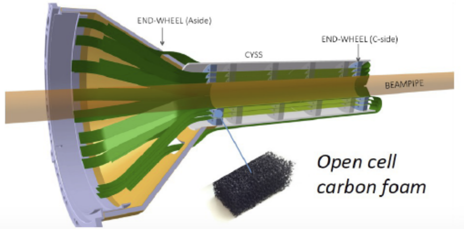
8

ALICE ITS-3 Upgrade

- ALICE proposed to upgrade the inner barrel with a nearly 0-mass tracker in LS3. (cds.cern.ch/record/2644611)
- Improve track precision with smaller pixels, close to IP, less material(0.05% X0 per layer).
- Thinned sensor arranged in a perfect cylindrical.
- No electrical substrate if sensor covers full stave.
- Eliminate active cooling if power < 20 mW/cm^2.

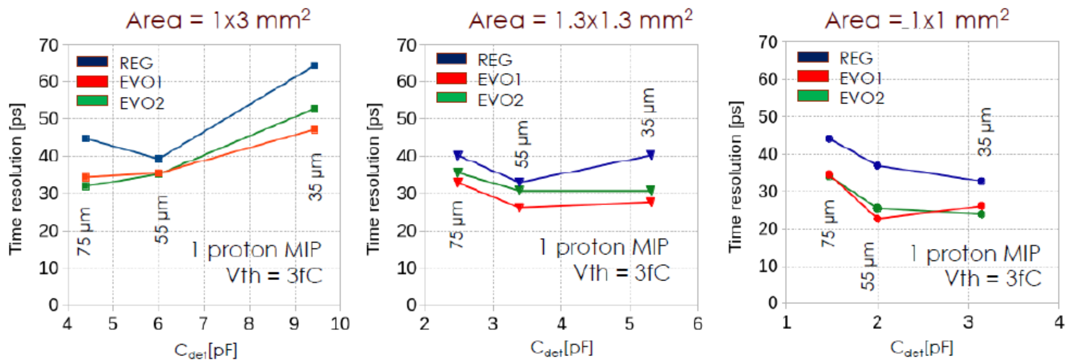






New capabilities: Particle id

Marco Costa



Everybody is doing timing these days. Why not CEPC?

Particle identification for CEPC

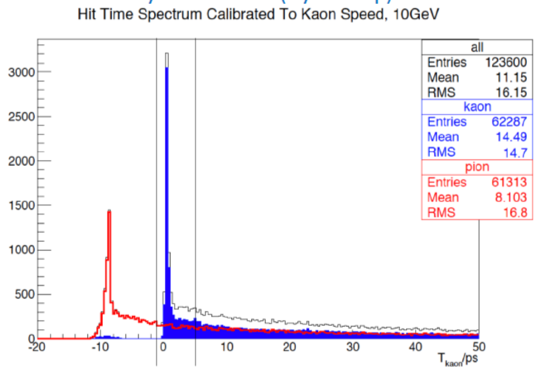
- K/pi separation for CEPC flavor physics for full silicon concept
  - 10ps time solution can provide 2~3 sigma K/pi separation at 5~7GeV

$$\Delta t = 0.5*L/c*(\gamma_1^{-2} - \gamma_2^{-2}) = 0.5*L/c*E^{-2}(m_1^2 - m_2^2)$$

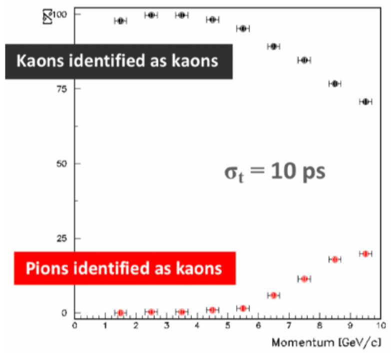
mass(pion) = 139 MeV; mass(Kaon) = 493 MeV;

$$\Delta t = k*LE^{-2} = 380*L/m*(E/GeV)^{-2}\ ps$$

Study from CEPC (by Manqi)



Study from Topside



PID capabilities driven by flavor program. Really need to develop detailed benchmarks to make sure this important part of the program gets the detector it needs.

LGAD sensor R & D in China：NDL LGAD sensor

- LGAD sensor with Epitaxial layer
  - NDL is foundry for SipM. They started at LGAD R & D with IHEP in 2019.
  - Three batches LGAD sensor fabricated in 2019.
  - Thickness of epitaxial layer: 33um
    - epitaxial layer Resistivity: 100 Ohm.cm or 300 Ohm.cm

http://www.ndl-sipm.net/contacteng.html

NDL can provide reliable and cost effective SiPMs with typical delivery time from 1 week to 3 months.

Novel Device Laboratory（NDL）
Address: XueYuan Nan Lu No.12
Hai Dian District, Beijing, China,100875
Tel: +86-10-62207419, Fax：+86-10-62207419
Email：info@ndl-sipm.net

Photoelectric Instrument Factory of Beijing Normal University
Address: 1st floor in block B of Dormitory 4 Xin Wai Da Jie No.19, Hai Dian District, Beijing, China
Tel: 010-58807630
Email: 58807630@163.com
Web: http://www.peifbnu.com/plus/view.php-aid=72.html

Continuing internationalization, learning/cooperating with other future machines

In this together

Talks by:
- CALICE
- ALICE
- HGCAL
- LHCb
- MEG2
- CMS
- ATLAS
- Mu3e
- SoLID

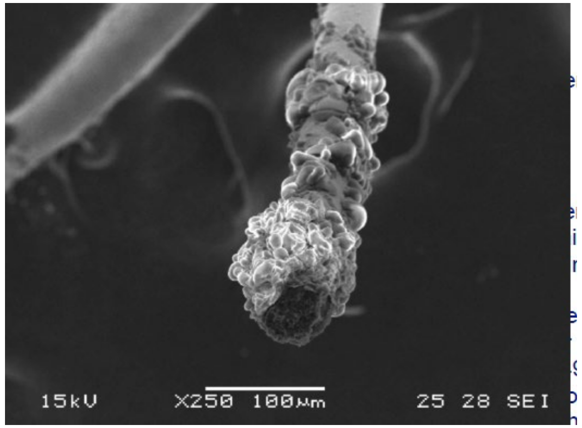
F. Grancagnolo

A short history of wire problems

A short history of wire related problems

1. March 2016 (wiring started Nov. 2015)
   many field wires mounted on the chamber, found broken due to unsuspected extreme sensitivity to humidity. Detailed analysis revealed a corrosion pattern.
   September 2016 restarted wiring and assembly from scratch
2. October 2016 human error caused a few wire breakings.
   Procedures revised and wiring and assembly resumed in December 2016.
3. July/August 2017 14 wires found broken inside the chamber. Removed. Improved environmental conditions and air dryness. Assembly resumed in September 2017. Decided to limit wiring to 9 layers with a slightly de-tensioned (-1 mm) chamber to avoid excessive stress to weak wires.
4. Wiring and assembly completed in December 2017.
5. October 2018, found a broken cathode during operation. Again due to earlier initiated corrosion.
6. After partial engineering run in Nov. 2018, extract chamber from COBRA. Chamber reopened and extra-tensioned (+1.2 mm) to eliminate wires with corrosion process in progress. 49 more wires eliminated. All showed clear signs of corrosion. Chamber kept under extremely low humidity for the whole summer at extra-tension. No sign of further damage ever since. Tension partly released. Chamber closed.

The future e+e- community cannot afford to fail. This is best ensured by working closely together.



China-Japan

Additional Introduction

- Two efforts on Sci-W ECAL
  > Chinese group for CEPC
  > Japanese group for ILC (ILD)
- Collaboration between two efforts and Joint studies together
  > Monthly meeting
  > Optimization of sensitive unit (scintillator & SiPM)
  > A technological Sci-W ECAL prototype --- Chinese group
  > Two layers double-side readout prototype --- Japanese group

China-France

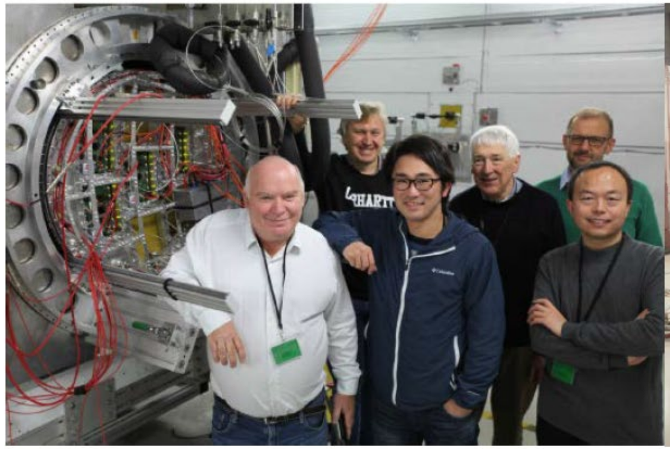
International cooperation

- CEA-Saclay IRFU group (FCPPL)
  - Three vidyo meetings with Prof. Aleksan Roy/ Prof. Yuanning/ Manqi and some related persons (2016~2017)
  - Exchange PhD students: Haiyun Wang participates Saclay's R&D six months in 2017~2018
  - Bulk-Micromegas detector assembled and IBF test
  - IBF test using the new Micromegas module with mor 590 LPI
  - UV+ laser tracker

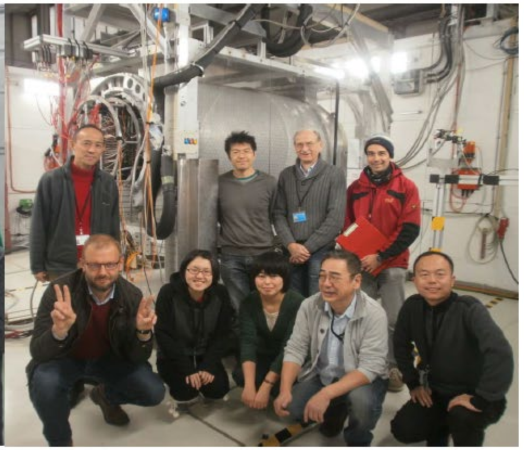
- 27 -

International cooperation

- LCTPC collaboration group (LCTPC)
  - Singed MOA and joined in LC-TPC collaboration @Dec. 14,2016
  - As coordinator in ions test and the new module design work package
  - CSC funding: PhD Haiyun jiont CEA-Scalay TPC group(6 months)
  - Joint beam test in DESY with Micromegas detector module in 2018



Beam test in 2018



Beam test in 2016

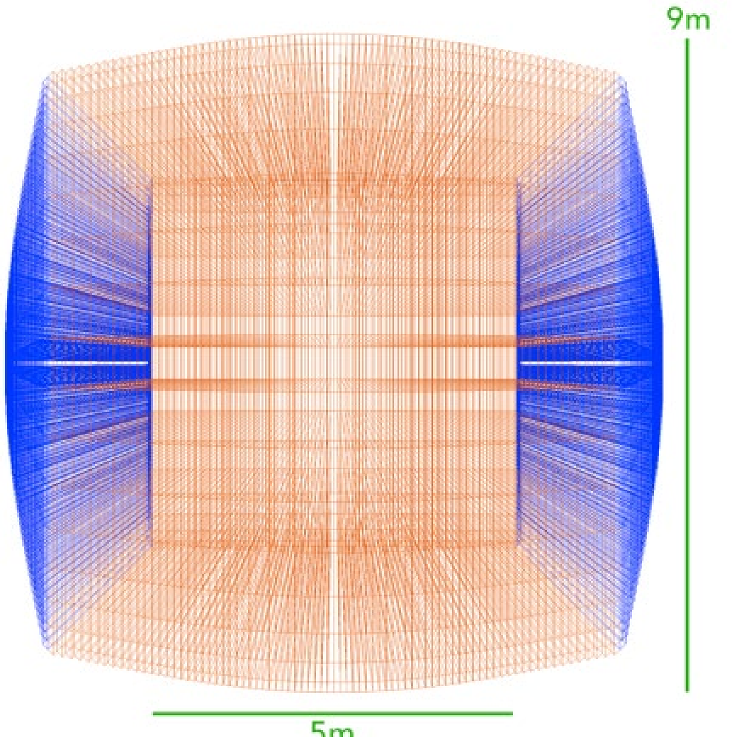
- 28 -

China-Italy


EU program participation
INFN
Istituto Nazionale di Fisica Nucleare
CREMLIN+ (JINR,BINP, DESY, GSI/FAIR, INFN
LE, BA with BINP (Novosibirsk)
totype drift chamber for
the Super Tau-Charm factor
Rescaled version of the IDE
chamber.
FE, LNF and BINP collaborate on a cylindrical μRell chamber.
ATTRACT:
Neutron detector with
BO, FE, LNF, Lund U
and industrial partners TECHTRA and ELTOS
FEST (RISE 2019): call involving
LNF, ……)
Covers stay at IHEP for CE
26 man months in 2020
NSF Grant "AccelNet: Future Research Software for HEP"
BO, FE, LE, MI, PD, PI, PV with endorsement of
CSN1 and person in charge of INFN scientific computing
APPROVED
APPROVED
APPROVED
GOOD – WAITING FOR DECISION
CEPC plenary meeting, November 6, 2019
2
F. Bedeschi, INFN-Pisa

China-S. Korea??

IDEA calorimeter



You know you want to work on this state of the art calorimeter!!!

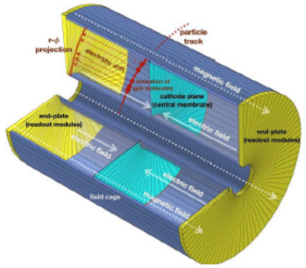
- Express interest and want to join this project in near future
  - Korea:
    - Korea Univ.: Suyong Choi
    - KNU: Chang-Seong Moon, Hwanbae Park Hyunseok Cho
  - Japan
    - University of Tokyo: Yuji Enari
  - China
    - ?
  - Taiwan
    - NTU: Rong-Shyang Lu
    - NCU: Chia-Ming Kuo

Pushing the technology frontier

MPGDs applied in CEPC

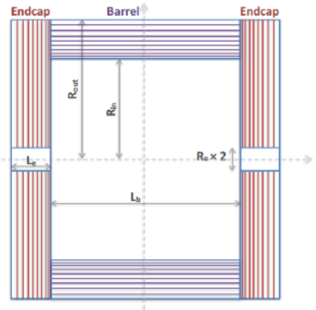
◆ Gas amplification detector module for CEPC TPC readout

- Baseline detector: GEM & MM
- Gain: 10^3–10^4
- Spatial granularity: 1 mm^2
- Position resolution: 100 μm in r - ϕ



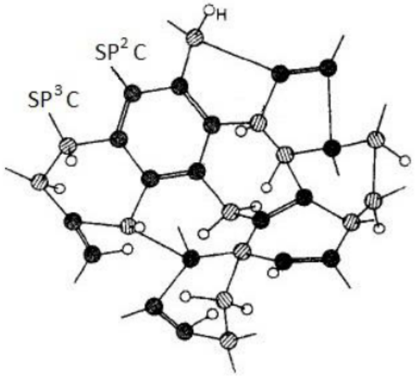
◆ CEPC muon detector system

- Candidate MPGD detector: μ-RWELL
- Sensitive area: 8600 m^2
- Time resolution: 1-2 ns
- Detector efficiency: 95% (P_μ >5GeV)
- Rate capability: ~ 60 Hz/cm^2

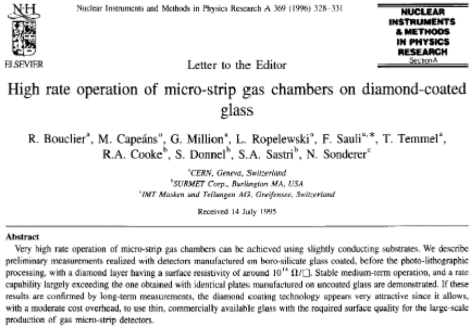


Diamond-like Carbon

Diamond-like Carbon (DLC): a class of metastable amorphous carbon material that contains both the diamond-structure and graphite-structure.



Atom structure of DLC



Nuclear Instruments and Methods in Physics Research A 369 (1996) 328–331

NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A

ELSEVIER

Letter to the Editor

High rate operation of micro-strip gas chambers on diamond-coated glass

R. Bouclier[a], M. Capeáns[a], G. Million[a], L. Ropelewski[a], F. Sauli[a,*], T. Temmel[a], R.A. Cooke[b], S. Donnel[b], S.A. Sastri[b], N. Sonderer[c]

[a]CERN, Geneva, Switzerland
[b]SURMET Corp., Burlington MA, USA
[c]IMT Masken und Teilungen AG, Greifensee, Switzerland

Received 14 July 1995

Abstract

Very high rate operation of micro-strip gas chambers can be achieved using slightly conducting substrates. We describe preliminary measurements realized with detectors manufactured on boro-silicate glass coated, before the photo-lithographic processing, with a diamond layer having a surface resistivity of around 10^{14} Ω/□. Stable medium-term operation, and a rate capability largely exceeding the one obtained with identical plates manufactured on uncoated glass are demonstrated. If these results are confirmed by long-term measurements, the diamond coating technology appears very attractive since it allows, with a moderate cost overhead, to use thin, commercially available glass with the required surface quality for the large-scale production of gas micro-strip detectors.

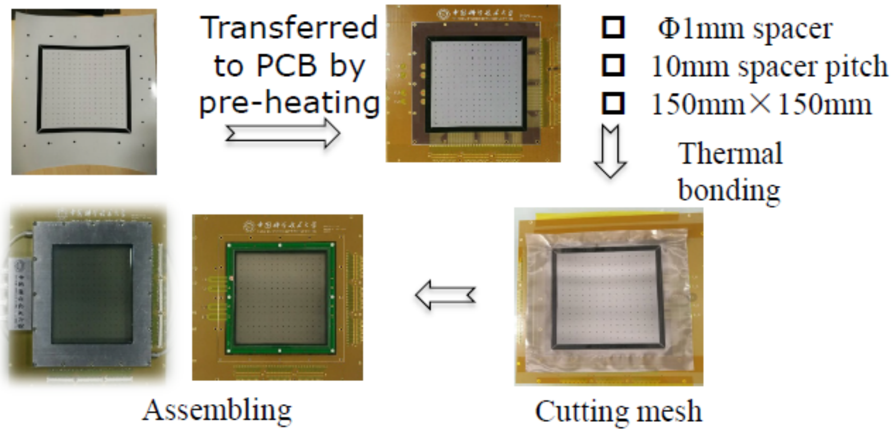
DLC coating was firstly used in MSGC in 1995 to resolve the charging-up effect

- DLC coating shows good stability in surface resistivity and good chemical stability.
- Resistive electrodes based on DLC are very resistant to discharge and radiation, and able to withstand chemical or physical manufacturing processes.

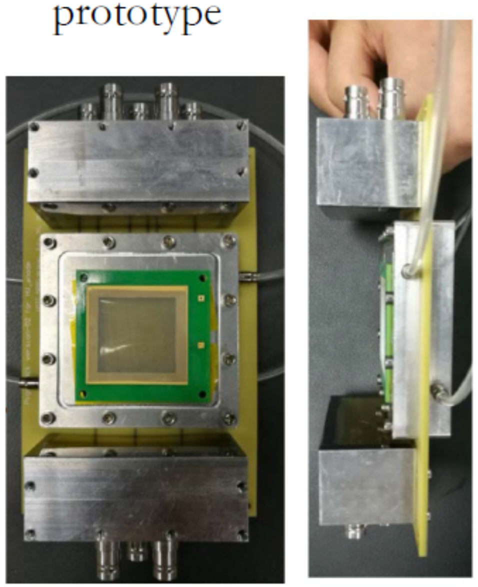
DMM Fabrication

- DMM is fabricated with the thermal bonding technique that has been developed at USTC.

Micromegas fabrication process with thermal bonding technique



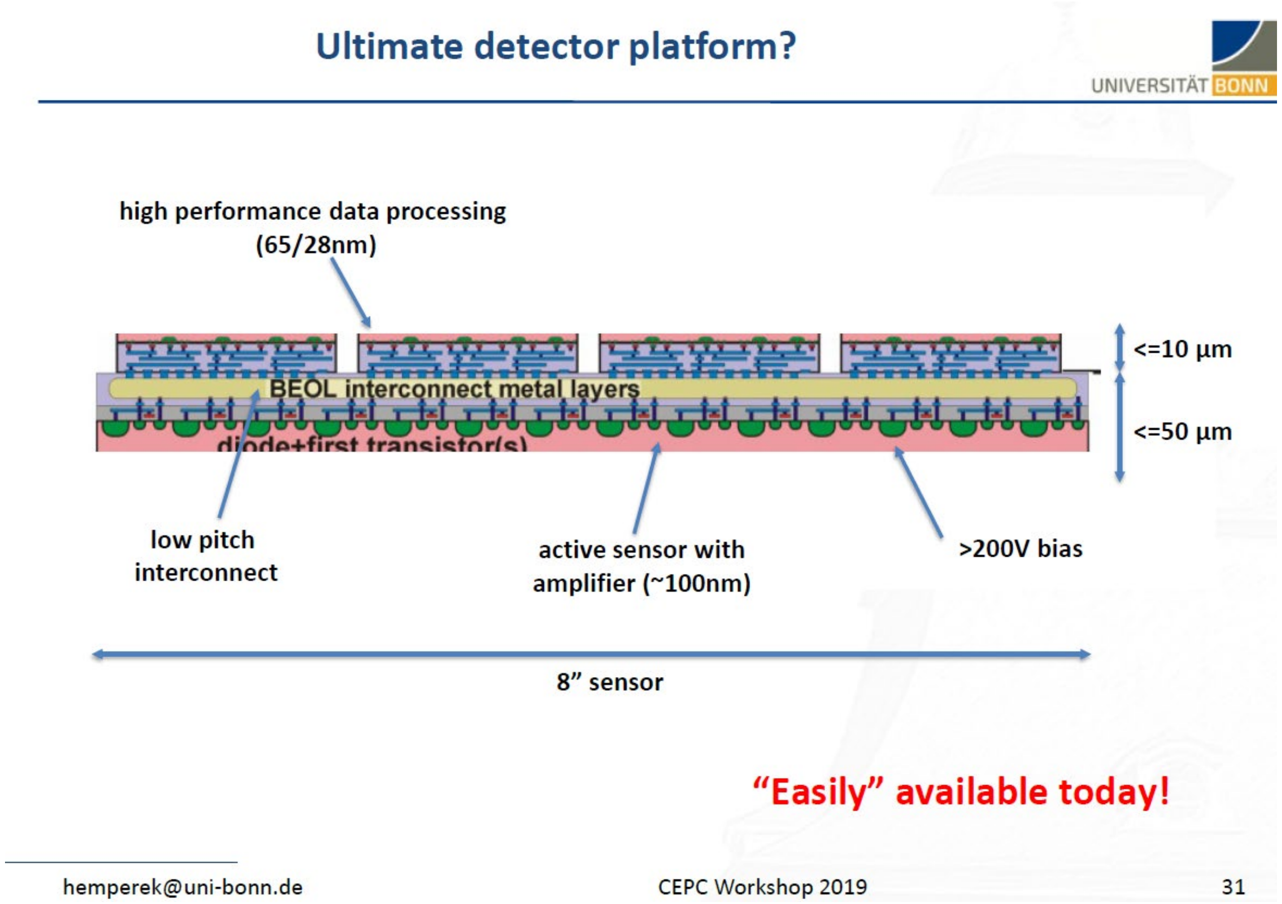
A 2.5cm×2.5cm DMM prototype

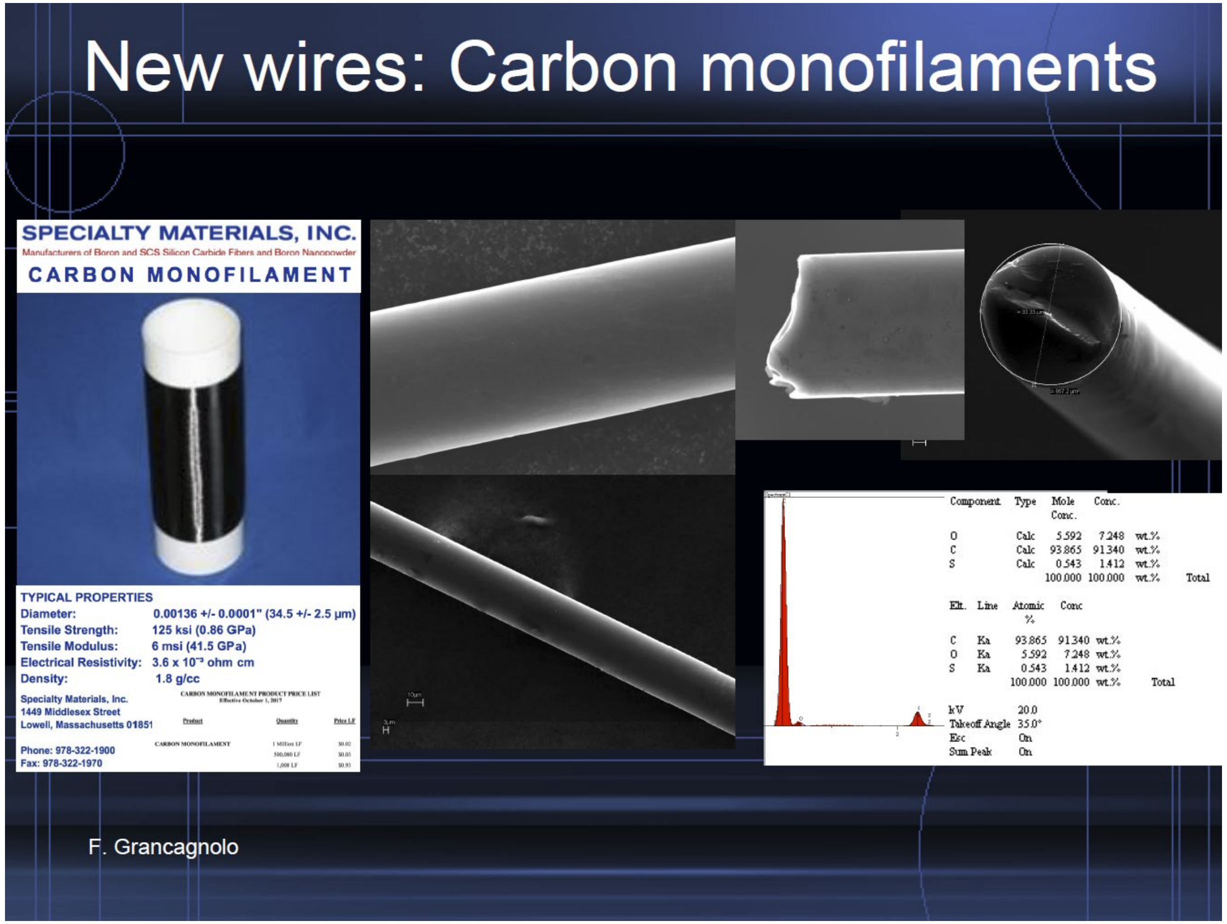


More details:

- *Thermal bonding method for fabricating Micromegas detectors and its applications (arXiv:1910.03170)*
- *A Thermal-Bonding Method for Fabrication of Micromegas and its applications, MPGD2019, 5-10 May 2019, La Rochelle, France.*

2019/11/18 CEPC2019, Zhiyong Zhang (USTC) 6


Ultimate detector platform?
UNIVERSITÄT BONN
high performance data processing (65/28nm)
BEOL interconnect metal layers
diode+first transistor(s)
<=10 µm
<=50 µm
low pitch interconnect
active sensor with amplifier (~100nm)
>200V bias
8" sensor
"Easily" available today!
hemperek@uni-bonn.de
CEPC Workshop 2019
31

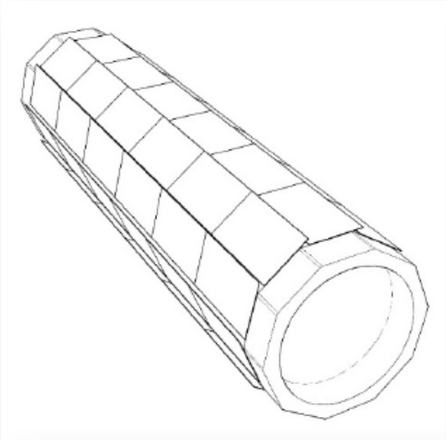


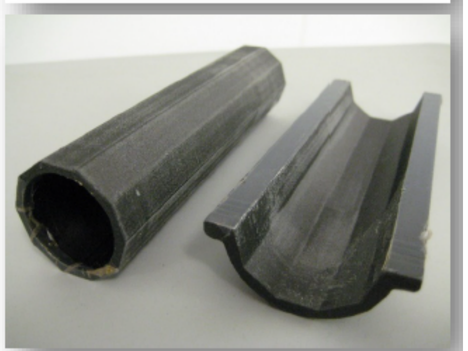
How to keep mass down. Drift chamber wire replacement?

UNIVERSITY OF LIVERPOOL

Single-shell Vertex Layer Support

- Commercial spread-tow weave too large for vertex layer & use low modulus & poor thermal conductivity fibre
  - Develop manufacture of custom spread-tow woven pre-preg with weave ~ 5mm
  - OK for vertex-scale – too laborious for larger scales – would need commercial solution
- Single woven layer of K13C2U/EX-1515
  - Thickness ~ 80µm
  - $\%X_0$ ~ 0.03%
- Fabrication
  - 3D printed master mould tool
  - CFRP mould made from 70°C cure tooling pre-preg followed by 130°C post cure
  - Production part made from K13C2U/EX-1515 using CFRP mould
  - Spread-tow laminate oriented at +/-45°
- First prototype under evaluation





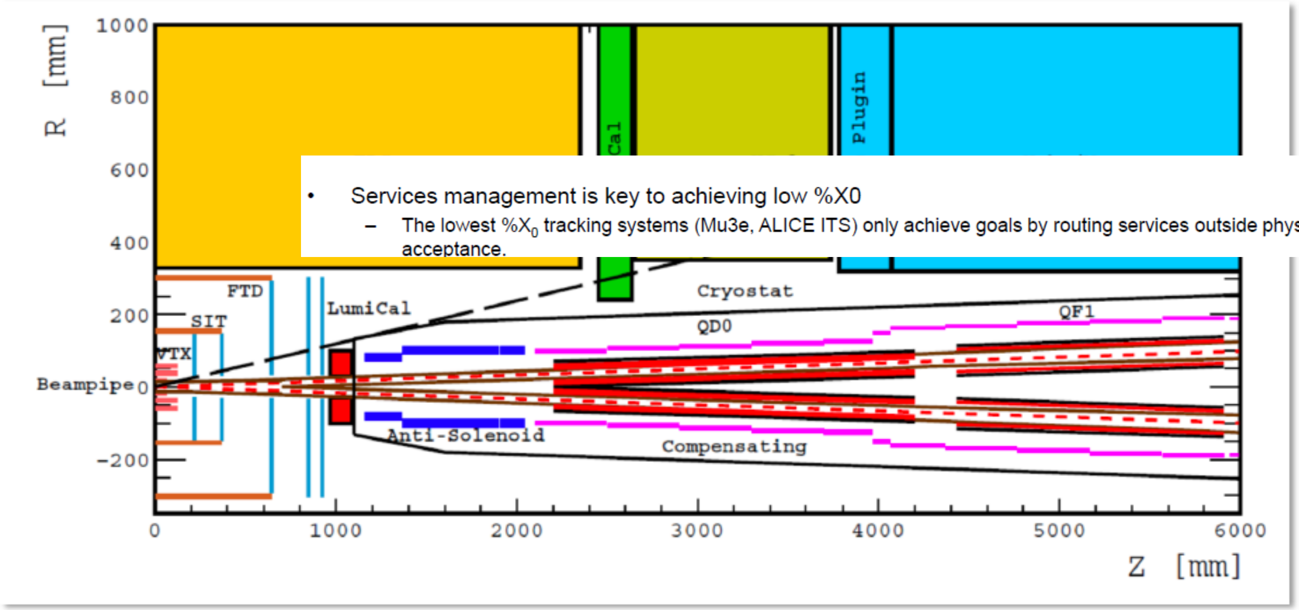
19/11/2019 CEPC Workshop - Beijing - November 2019 17

In the hallways

Tim Jones Liverpool

- What will the cabling plant look like?
- Can you actually build the supports for that calorimeter?

Not only need to think about these things. With these stringent specs, and the huge interdependencies induced by particle flow, they need to be put into the simulation and their impact assessed.



- Services management is key to achieving low %X0
  - The lowest $\%X_0$ tracking systems (Mu3e, ALICE ITS) only achieve goals by routing services outside physics acceptance.

- Lots to discuss ….
  - How are VTX, SIT & FTD supported ?
  - How are their services (plus LumiCal) routed ?
  - If the central silicon system is cooled by gas what is the required cross-section of the cooling inlet/outlet ?
  - How is the performance of the TPC affected by high (30°C plus) and possibly varying temperatures ? (eg drift velocity)

Future thoughts

The detector needs of an e^+e^- Higgs factory has been pondered since at least 1886, when the JLC was proposed as a next step for the KEK program. When I got my Ph.D. on AMY in 1989, and I moved on to the Tevatron, some of my fellow postdocs/students moved on to work on JLC. There is probably also even older history. Thinking about the “next steps” is therefore daunting.

Any future e+e- collider has a deep debt of gratitude to ILC (including the ILC itself)

But we still have time before the final design and construction of the detectors begins. Physics is always moving, and it is important to reassess and challenge conventional wisdom on the design needs.

to LO

- To LO, CEPC needs to keep doing what we are doing. Things look very good!
- An exciting, state-of-the art, set of detectors well matched to the physics program is emerging.
- Great moves towards international collaboration
- Balance of risk and performance is being considered

Things are looking rosy!

Particle flow

It is essential that we can easily try different alternative geometry with particle flow. Any change in geometry could affect our extremely challenging jet resolution. Without the ability to play with alternatives quickly/easily, we will always have to take the safe route, not just on calorimetry, but on everything.

Can we have a person dedicated to implementing the GEANT into the software? Do we have detailed documentation on the PF code to make it quicker for new people trying new ideas to adjust it?

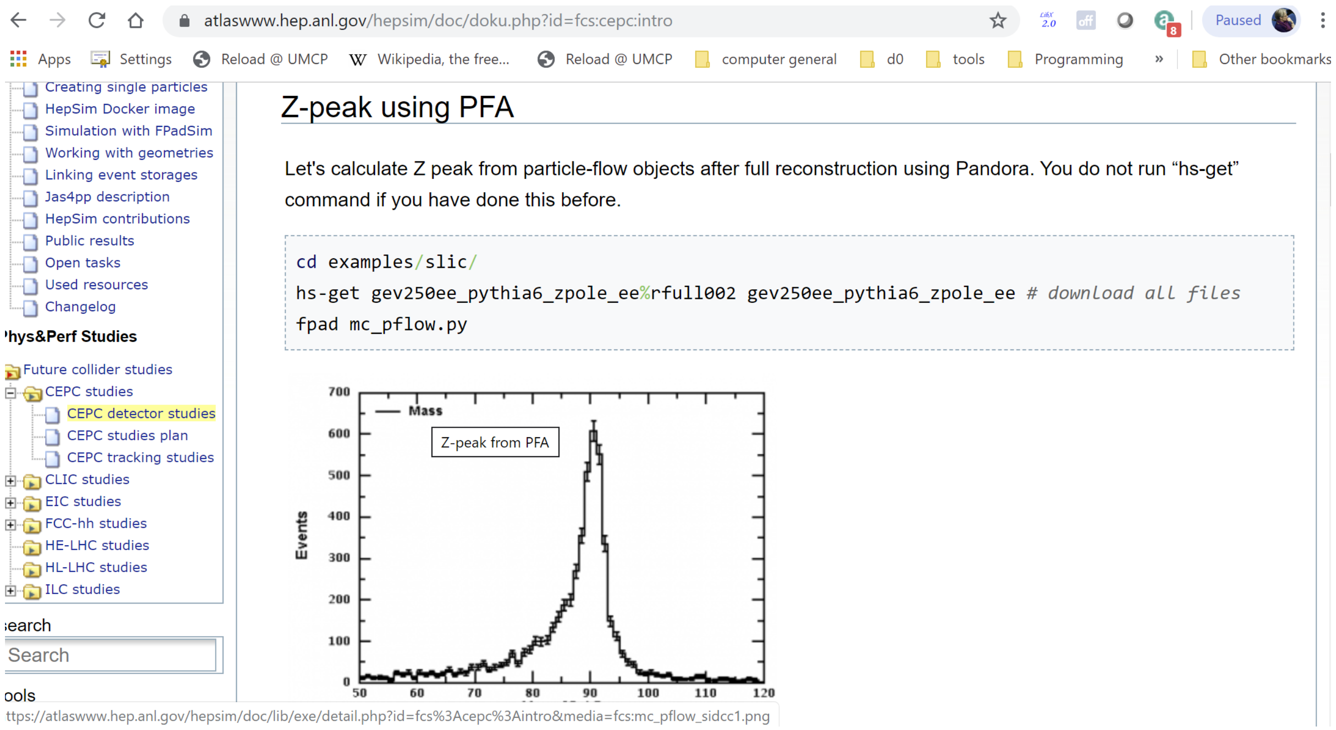
- Use the W-Cu alloy instead

$$\frac{1}{X_0} \equiv \sum_i \frac{w_i}{X_i}$$

W:Cu	100:0	85:15	75:25
X_0 (mm)	3.5	4.4	5.1

Is this in the simulation? How does this affect transverse segmentation optimization? Hadron fragmentation? Separation confusion conrobution to resolution in PFA?

hepsim: https://atlaswww.hep.anl.gov/hepsim/#
Generic, which is politically useful. Use it to study crystal detector with full PF



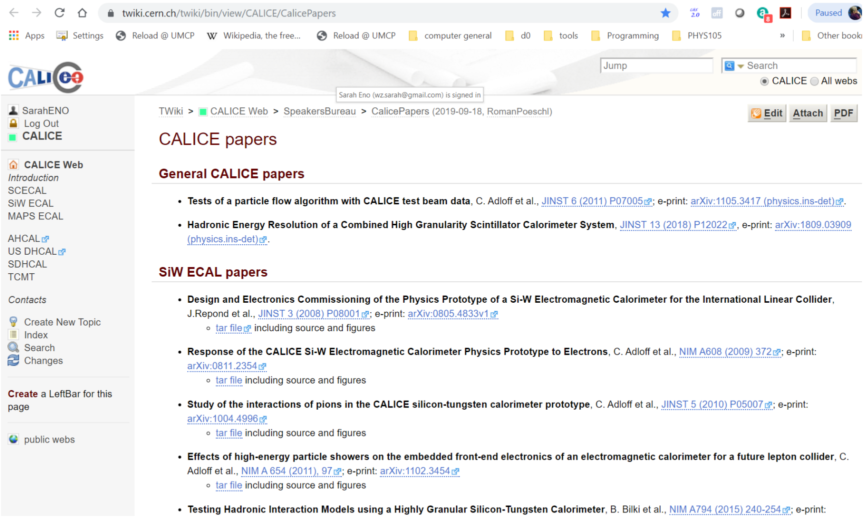
Conclusions

- Great progress on two beautiful detectors
- Flexibility leading to better and better design
- Collaboration growing to match important physics program
- Time to get serious about benchmarks for the flavor program at the Z?

But maybe need to make sure we don’t become too attached to baseline.
Maybe need more optimization tools (beyond the base line detector).
Definitely need to remember all the future machines are in this together.

backup

Calorimetry



twiki.cern.ch/twiki/bin/view/CALICE/CalicePapers

TWiki > CALICE Web > SpeakersBureau > CalicePapers (2019-09-18, RomanPoeschl)

CALICE Web
Introduction
SCECAL
SiW ECAL
MAPS ECAL
AHCAL
US DHCAL
SDHCAL
TCMT
Contacts

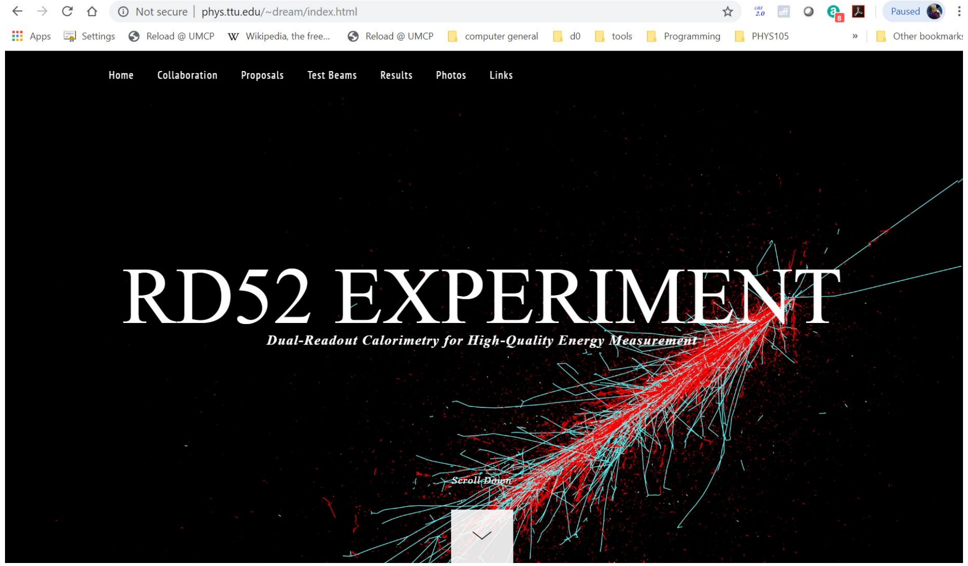
CALICE papers

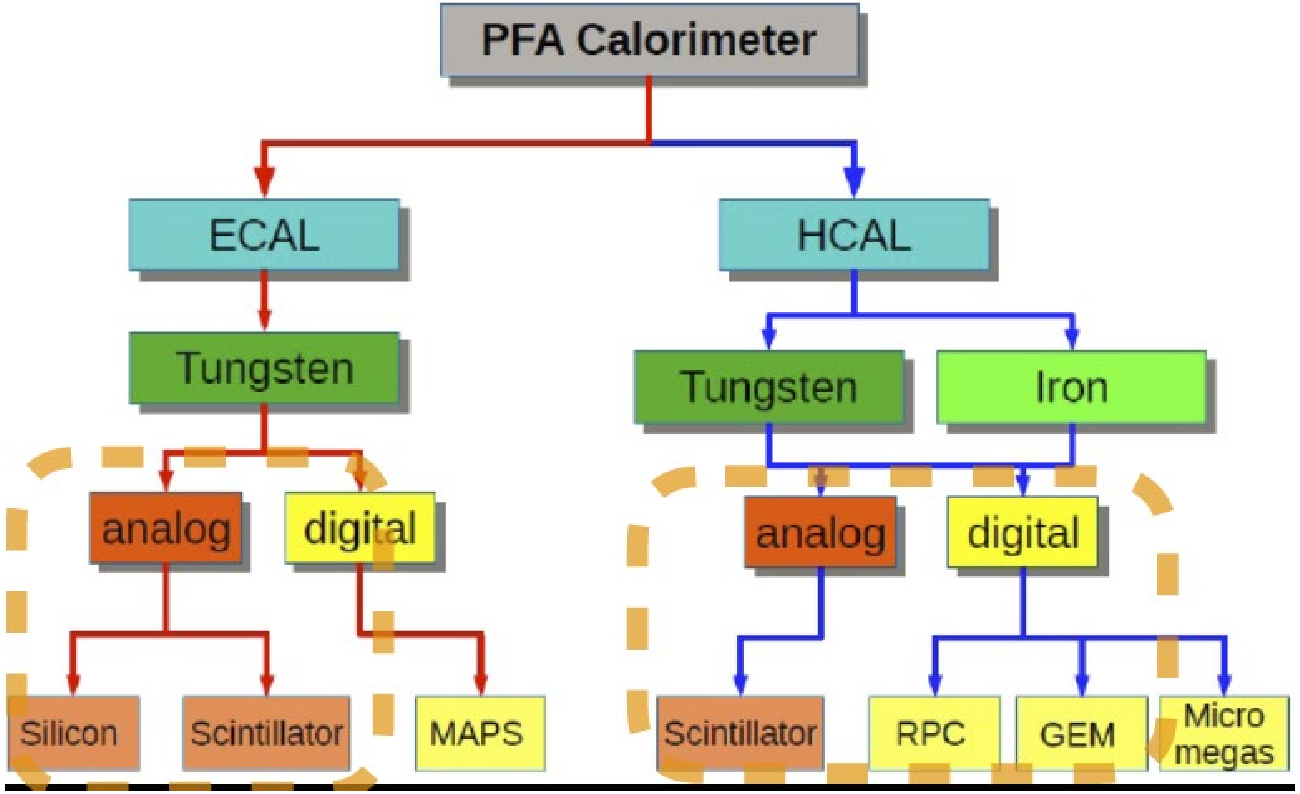
General CALICE papers

- **Tests of a particle flow algorithm with CALICE test beam data**, C. Adloff et al., JINST 6 (2011) P07005; e-print: arXiv:1105.3417 (physics.ins-det).
- **Hadronic Energy Resolution of a Combined High Granularity Scintillator Calorimeter System**, JINST 13 (2018) P12022, e-print: arXiv:1809.03909 (physics.ins-det).

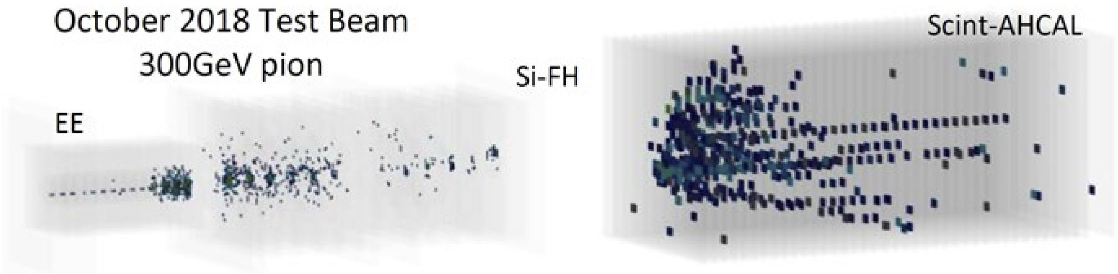
SiW ECAL papers

- **Design and Electronics Commissioning of the Physics Prototype of a Si-W Electromagnetic Calorimeter for the International Linear Collider**, J.Repond et al., JINST 3 (2008) P08001; e-print: arXiv:0805.4833v1
  - tar file including source and figures
- **Response of the CALICE Si-W Electromagnetic Calorimeter Physics Prototype to Electrons**, C. Adloff et al., NIM A608 (2009) 372; e-print: arXiv:0811.2354
  - tar file including source and figures
- **Study of the interactions of pions in the CALICE silicon-tungsten calorimeter prototype**, C. Adloff et al., JINST 5 (2010) P05007; e-print: arXiv:1004.4996
  - tar file including source and figures
- **Effects of high-energy particle showers on the embedded front-end electronics of an electromagnetic calorimeter for a future lepton collider**, C. Adloff et al., NIM A 654 (2011), 97; e-print: arXiv:1102.3454
  - tar file including source and figures
- **Testing Hadronic Interaction Models using a Highly Granular Silicon-Tungsten Calorimeter**, B. Bilki et al., NIM A794 (2015) 240-254; e-print:



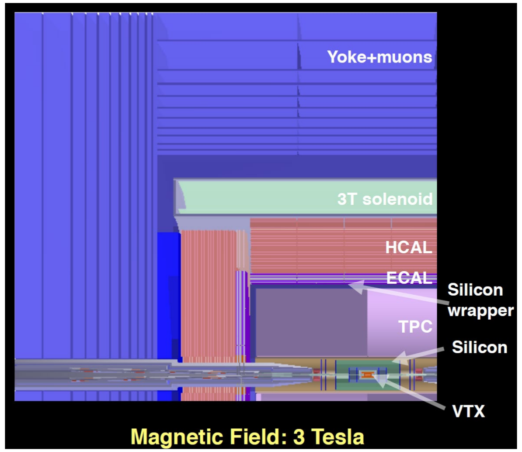


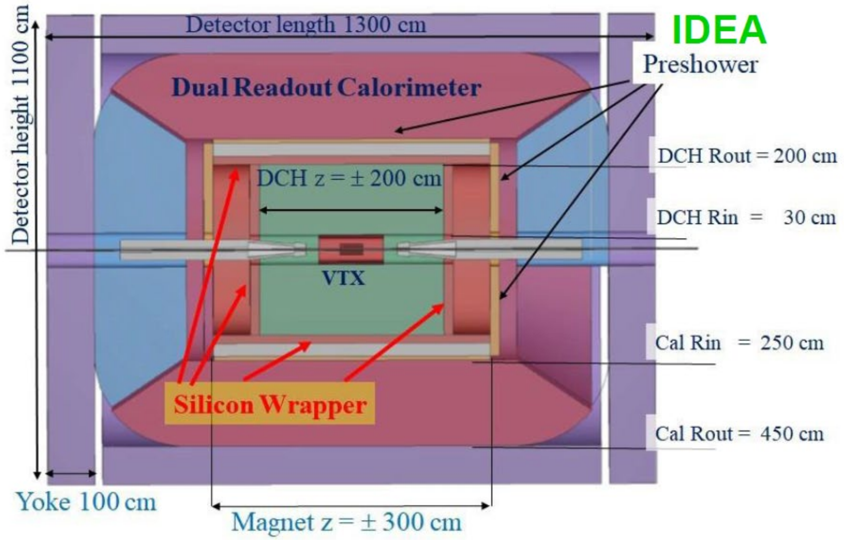
Thanks to the hard work of the CALICE and RD52 collaboration, proven options exist that can satisfy stringent jet requirements. A PFA calorimeter is current being built for HGCAL.

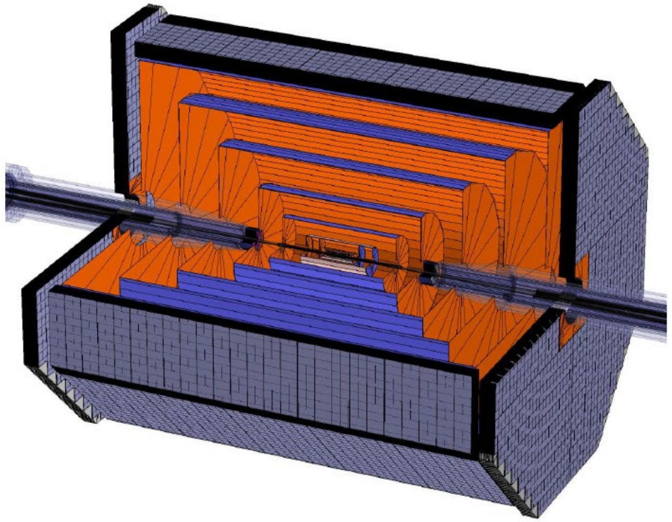


Tracking

Baseline and two well developed alternatives

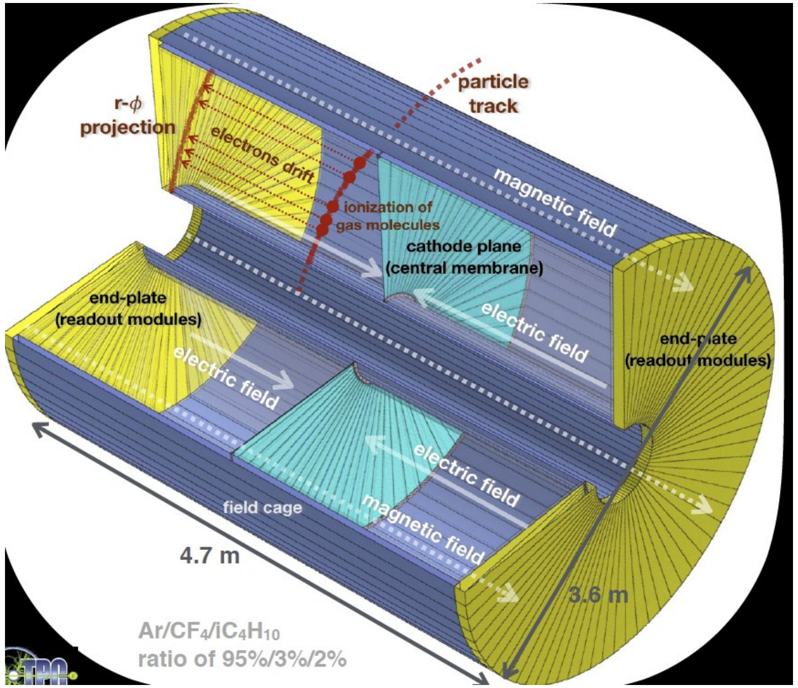


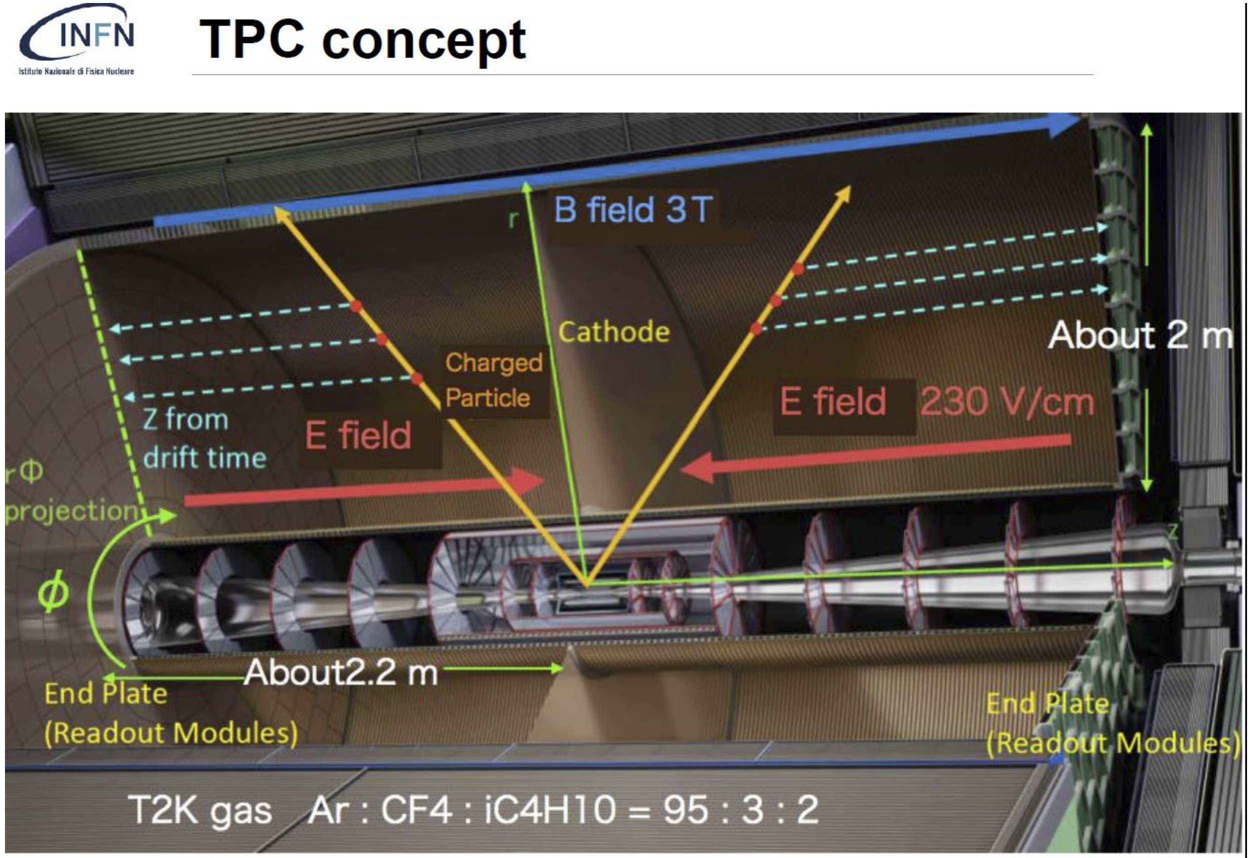




Three alternative concepts

- Baseline
  - Vertex detector (VXD)
  - Main tracker: Time Projection Chamber (TPC) + inner and outer silicon tracker
- Full Silicon Tracker
  - Same vertex detector
  - Full silicon tracker
- Drift chamber
  - Similar vertex detector
  - Drift Chamber Tracker + silicon wrapper

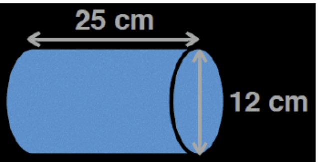

particle
track
r-ϕ
projection
electrons drift
ionization of
gas molecules
magnetic field
cathode plane
(central membrane)
end-plate
(readout modules)
electric field
electric field
end-plate
(readout modules)
electric field
field cage
magnetic field
4.7 m
3.6 m
Ar/CF4/iC4H10
ratio of 95%/3%/2%

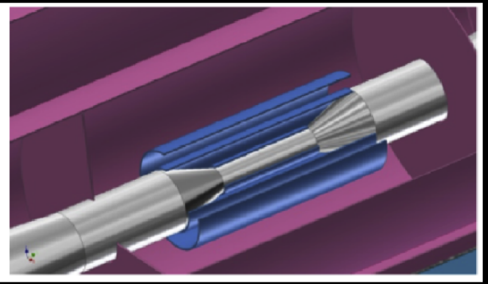

INFN
Istituto Nazionale di Fisica Nucleare
TPC concept
B field 3T
r
Cathode
Charged
Particle
About 2 m
E field 230 V/cm
Z from
drift time
E field
rΦ
projection
ϕ
About2.2 m
End Plate
(Readout Modules)
End Plate
(Readout Modules)
T2K gas Ar : CF4 : iC4H10 = 95 : 3 : 2

Vertex detectors: baseline

Baseline Pixel Detector Layout

3-layers of double-sided pixel sensors



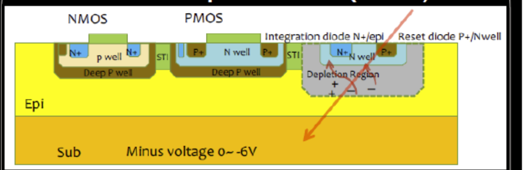


- ILD-like layout
- Innermost layer: σ_{SP} = 2.8 µm
- Polar angle θ ~ 15 degrees

Implemented in GEANT4 simulation framework (MOKKA)

		$R(mm)$	$\|z\|(mm)$	$\|cos\theta\|$	$\sigma(\mu m)$	$Readout\ time(us)$
Ladder 1	Layer 1	16	62.5	0.97	2.8	20
	Layer 2	18	62.5	0.96	6	1-10
Ladder 2	Layer 3	37	125.0	0.96	4	20
	Layer 4	39	125.0	0.95	4	20
Ladder 3	Layer 5	58	125.0	0.91	4	20
	Layer 6	60	125.0	0.90	4	20

CMOS pixel sensor (MAPS)



Integrated sensor and readout electronics on the same silicon bulk with "standard" CMOS process:
- low material budget,
- low power consumption,
- low cost ...

Wei Wei

17/09/2019 CEPC Tracking R&D - Paolo Giacomelli 6

Drift Chamber Option – IDEA Concept

Lead by Italian Colleagues

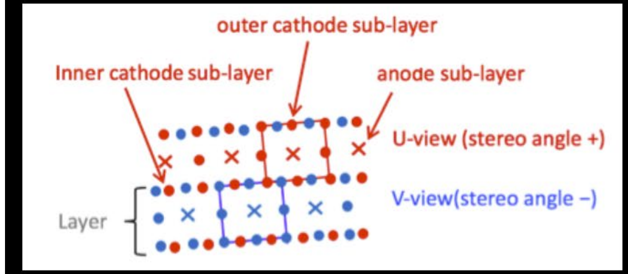
Low-mass cylindrical drift chamber

Follows design of the KLOE and MEG2 experiments

- Length: 4 m
- Radius: 0.3- 2m
- Gas: 90%He – 10%iC_4H_{10}
- Material: 1.6% X_0 (barrel)

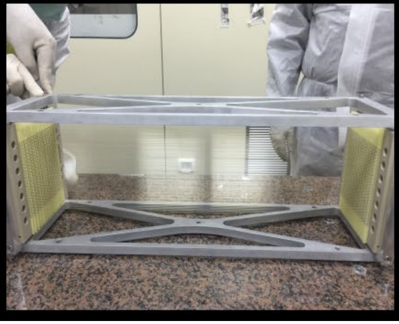
- Spatial resolution: < 100 μm
- dE/dx resolution: 2%
- Max drift time: <400 nsec
- Cells: 56,448

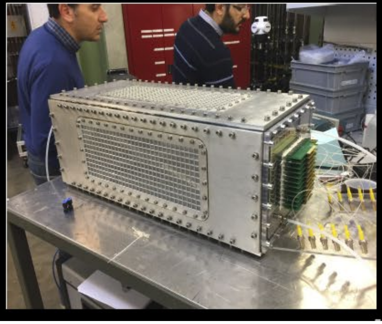
Layers: 14 SL × 8 layers = 112
Cell size: 12 - 14 mm



Stereo angle: 50-250 mrad

MEG2 prototype being tested





EM resolution: need new benchmarks

From Michael Peskin:

- Monophoton + dark matter search: This has actually be studied by Jenny List at DESY. She claims that the analysis has only a weak dependence on photon energy resolution. Much more important is angular coverage down to small angles.
- Study of tau+tau- in Z and Higgs decays: Here photon performance is needed to discriminate tau -> pi, rho , a1. However, Jean-Claude Brientl claimed that the crucial need is for good pattern recognition and photon ID down to small energies, while the actual photon energy resolution is less important
- Efficiency for h-> gamma gamma: This is a real need; the photon-photon efficiency here is somewhat pathetic, even worse than CMS. However, the statistics is not high in any event, and HL-LHC will give us an excellent value of BR(h->gamma gamma)/BR(h->ZZ*).
- Graham Wilson suggested that improved EM resolution might be important in W studies. A method for measuring the W mass is to use the endpoint in W-> e nu. This wins strongly with better EM resolution.
- Similarly, finding the exotic mode h -> tau e under the background of h-> tau tau depends on good performance at the endpoint.

More work needed here on this theme
Are these still interesting after HL-LHC?
Are there rare physics topics involving EM particles that need to be added?