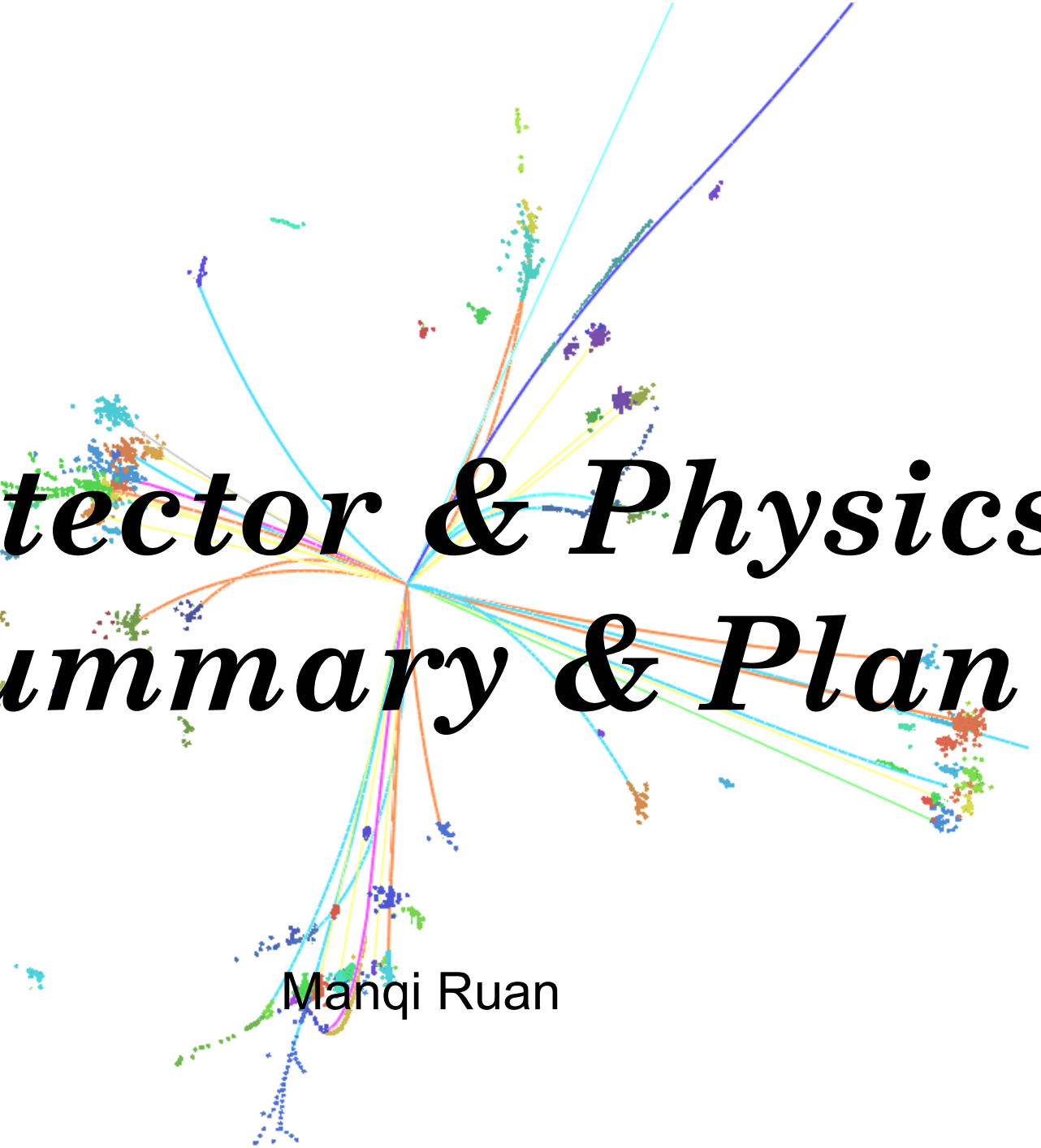
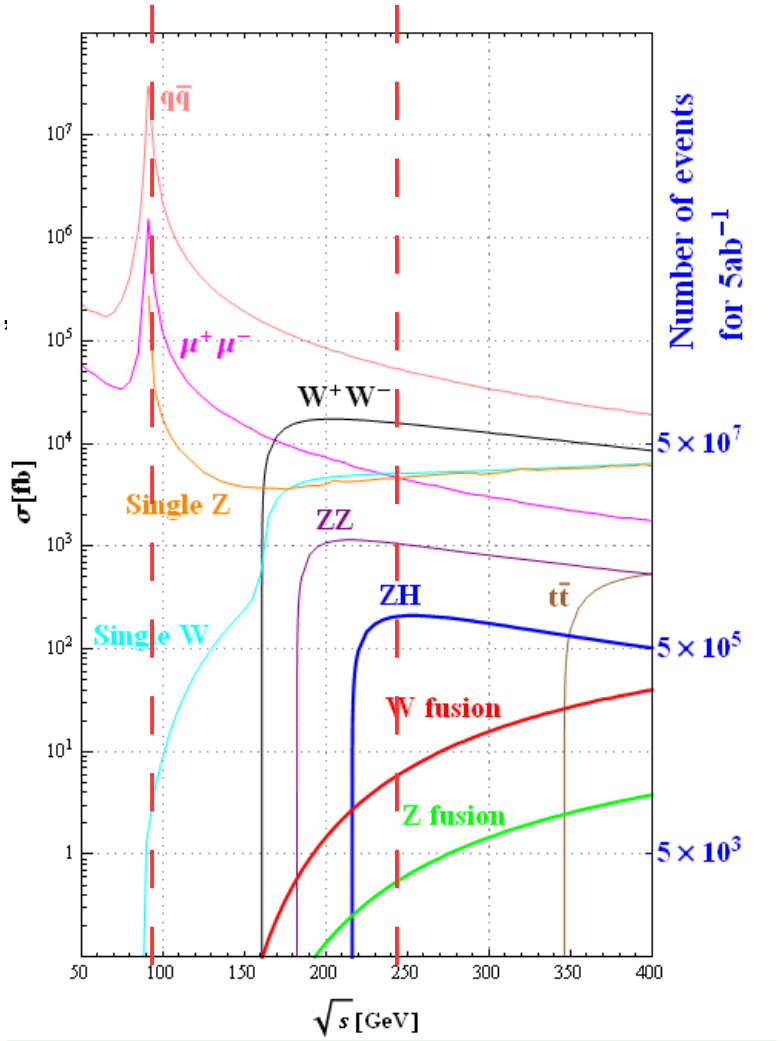


Detector & Physics Summary & Plan

Manqi Ruan

CEPC: Higgs + Z factory

- Higgs:
  - Distinguish the Higgs signal from the SM background
  - Distinguish the generation/decay mode of the Higgs
  - High efficiency/purity identification and precise measurement of **Core Physics Objects** (Lepton, Photon, Tau, JET & MET)
- Z:
  - Same requirement for Core Physics Objects
  - Particle ID, especially Kaon identification is appreciated
- **Systematic control**
  - High Stability, High homogeneity
  - Calibration
  - Alignments
  - Luminosity monitoring



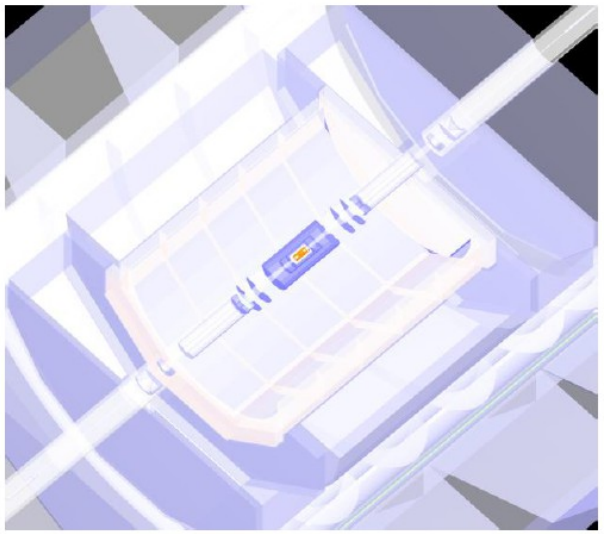
Two classes Concepts

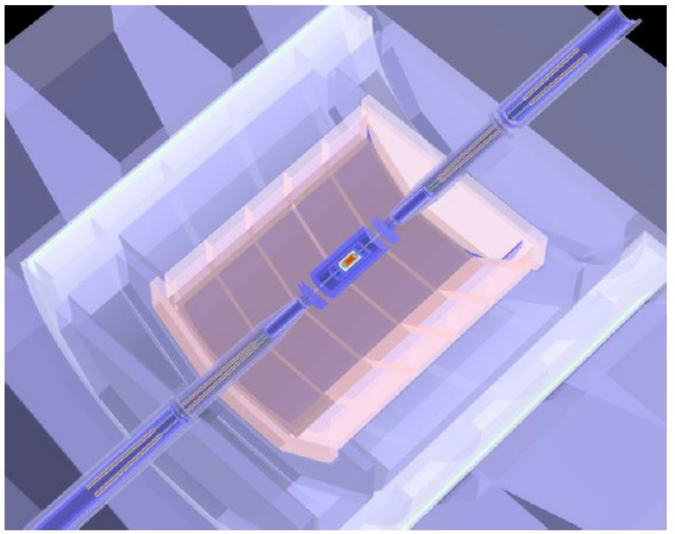
- PFA Oriented Concepts
  - TPC + High Granularity Calorimeter
  - Silicon tracking + High Granularity Calorimeter

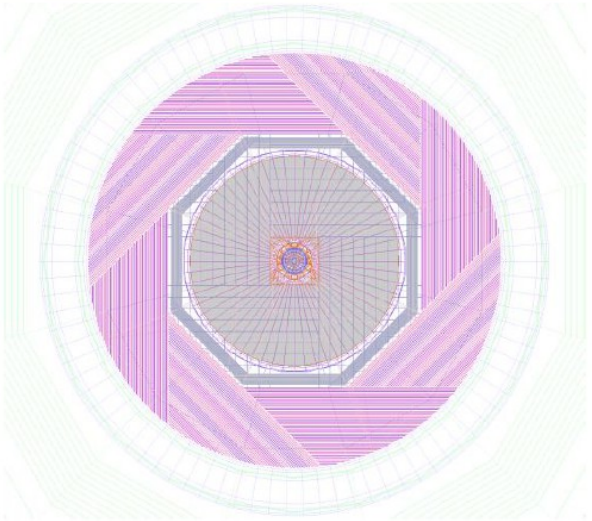
- Low Magnet Field Detector Concept
  - Wire Chamber + Dual Readout Calorimeter

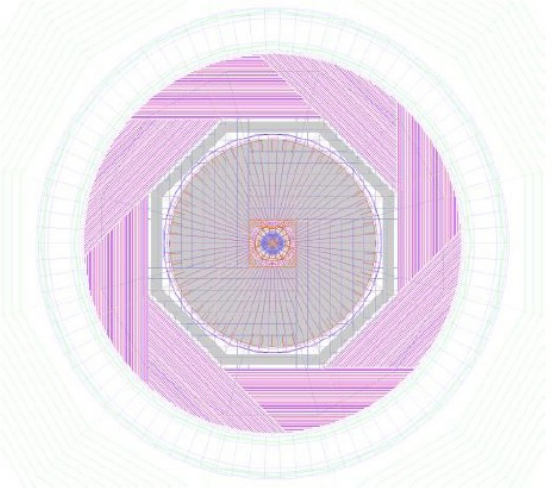
Baseline: TPC + HGC

preCDR (2015) → CDR (2017)





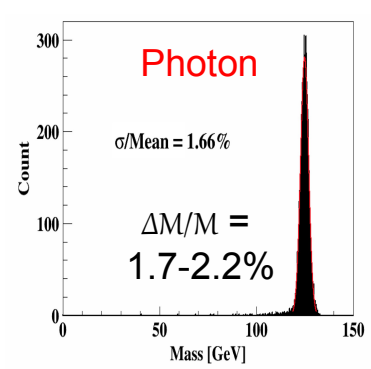


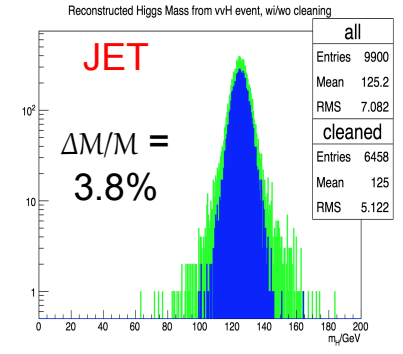


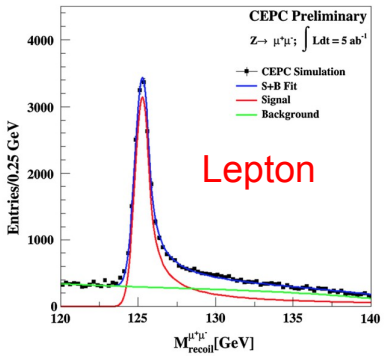
3.5 T + 48 Layers of HCAL

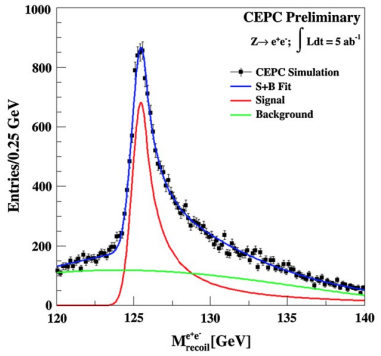
3 T + 40 Layers of HCAL

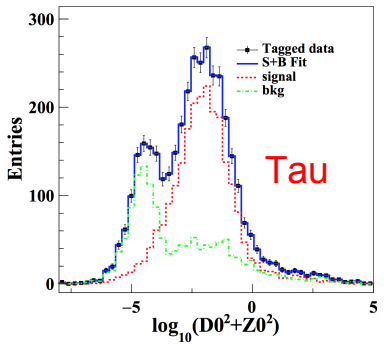
PFA Oriented Reconstruction

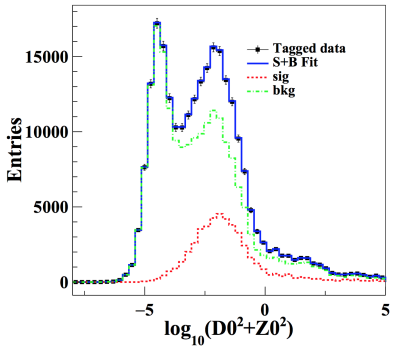












Example Working Points & Performance for Object identification (Preliminary)

	Efficiency	Purity	Mis-id Probability from Main Background
Leptons	99.5 – 99.9%	99.5 – 99.9% at Higgs Runs(c.m.s = 240 GeV), Energy dependent	$P(\pi^{\pm} \rightarrow leptons) < 1\%$
Photons*	99.3 – 99.9%	99.5 – 99.9% at Higgs Runs Energy Dependent	P(Neutron → γ) = 1- 5%
Charged Kaons**	86 – 99%	90 – 99% at Z pole Runs (c.m.s = 91.2GeV, Track Momentum 2- 20 GeV)	$P(\pi^{\pm} \rightarrow K^{\pm}) = 0.3 - 1.1\%$
b-jets	80%	90% at Z pole runs ($Z \rightarrow qq$)	P(uds → b) = 1% P(c → b) = 10%
c-jets	60%	60% at Z pole runs	P(uds → c) = 5% P(b → c) = 15%

Photon: only considering neutron background and using ToF information*
*Kaon**: Performance Highly depend on DAQ & Geometry*

Feasibility & Optimized Parameters

Feasibility analysis: TPC and Passive Cooling Calorimeter is valid for CEPC

	CEPC_v1 (~ ILD)	Optimized (Preliminary)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	84 mm is optimized on Br(H->di photon) at 250 GeV; 90mm for bhabha event at 350 GeV
ECAL Cell Size	5 mm	10 – 20 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	20 – 30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV; Margin might be reserved for 350 GeV.

High light 1: Progresses of HGC

10:30 - 12:30 Detector & Physics IV (Calorimeter): Parallel Session III

Conveners: Dr. Jianbei Liu (University of Science and Technology of China), Prof. imad laktineh (IPNL), Prof. Roberto Ferrari (INFN)

10:30 **CEPC ECAL R&D Status** *20'*

Speaker: Dr. Yunlong Zhang (University of Science and Technology of China)

Material: **Slides**

10:50 **CEPC HCAL R&D Status** *20'*

Speaker: Dr. Boxiang Yu (高能所)

Material: **Slides**

11:10 **CALICE SiW status** *20'*

Speaker: Prof. Jean-Claude Brient (LLR)

Material: **Slides**

11:30 **CALICE SDHCAL status** *20'*

Speakers: Prof. Haijun Yang (Shanghai Jiao Tong University), Prof. Haijun Yang (Shanghai Jiao Tong University), Haijun Yang (Shanghai Jiao Tong University)

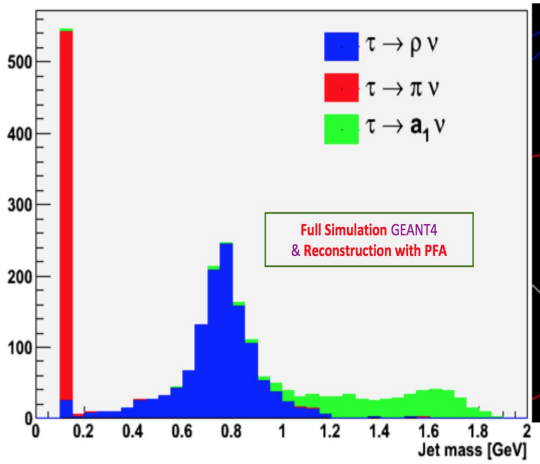
Material: **Slides**

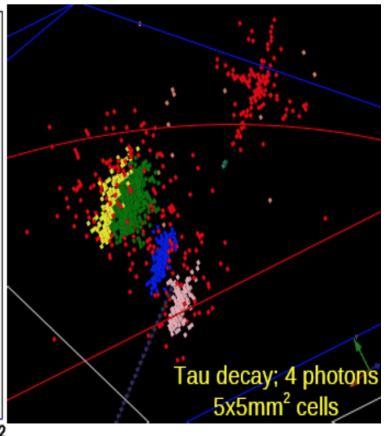
17:50 **CMS experience with HGCAL** *20'*

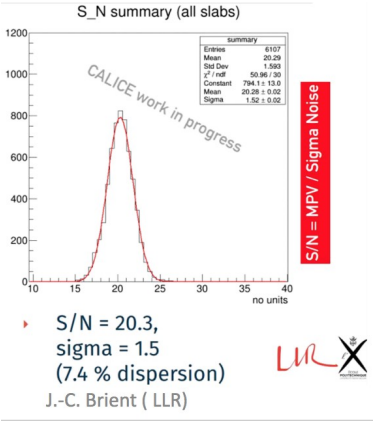
Speaker: Alberto Belloni (University of Maryland)

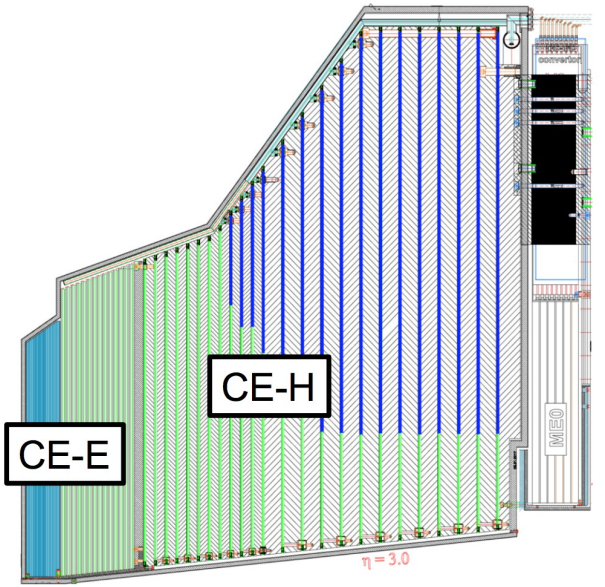
Material: **Slides**

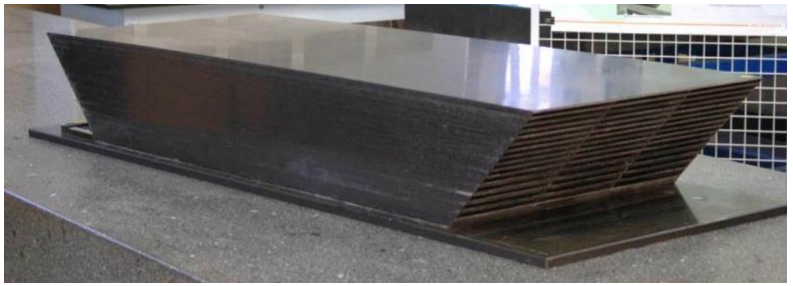
HGC – Si-W ECAL

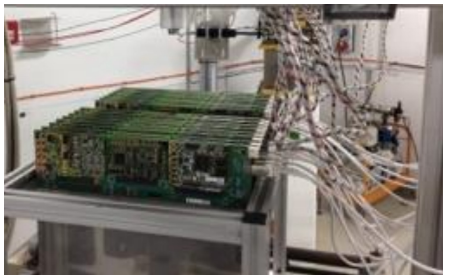


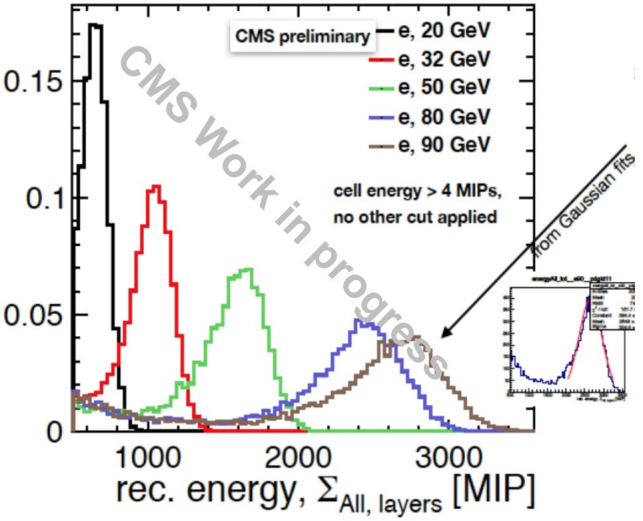






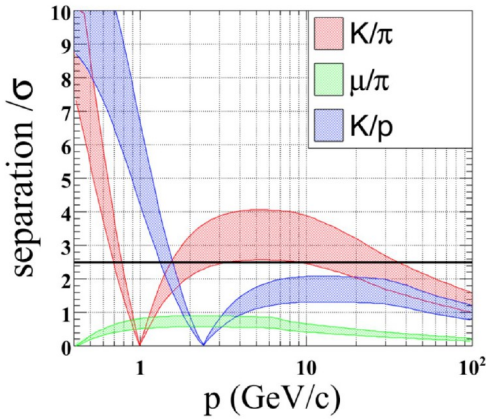


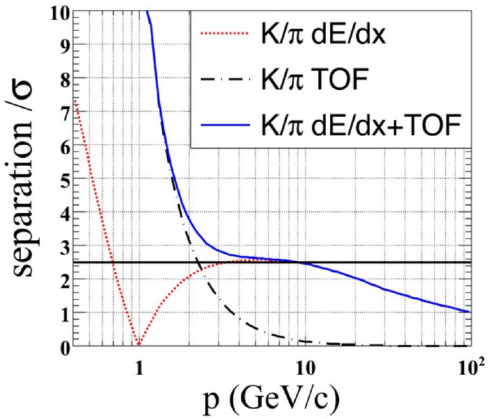




- Si-W ECAL
  - Good Separation
  - High S/N Ratio
  - Timing information
  - Cooling has been addressed
  - Usage at CMS, ATLAS Upgrade, CALICE

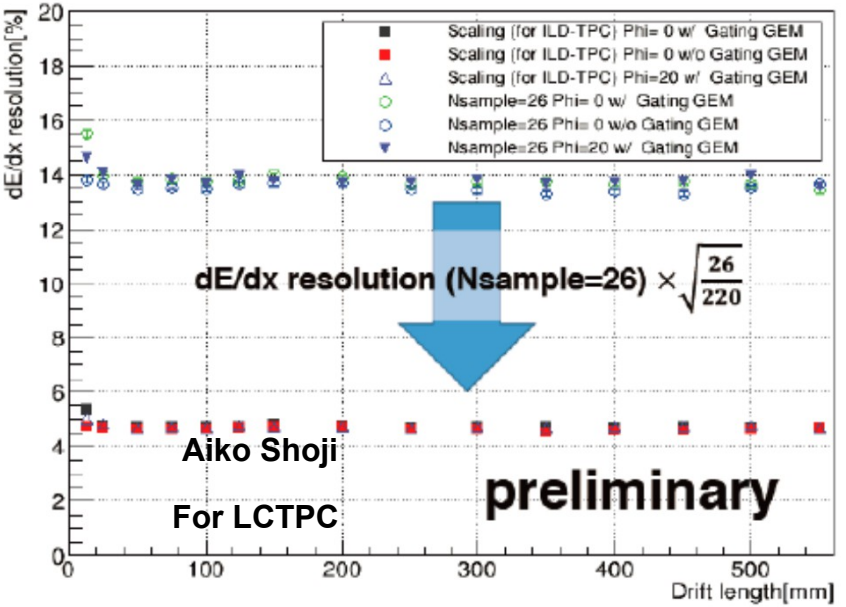
High light 2: Pid & TPC Studies





Condition		#σ(π-K / K-p)	Efficiency	Purity
MCTruth	dE/dx only	3.9 / 1.5	88%	86%
	+ TOF	4.0 / 3.2	98%	98%
20% degraded	dE/dx only	3.1 / 1.2	81%	79%
	+ TOF	3.3 / 3.0	96%	96%
50% degraded	dE/dx only	2.4 / 0.9	68%	68%
	+ TOF	2.8 / 2.9	91%	94%

- S. Prell, et.al: Simulation indicate decent Kaon id using TPC dEdx + ECAL as ToF (50 ps)

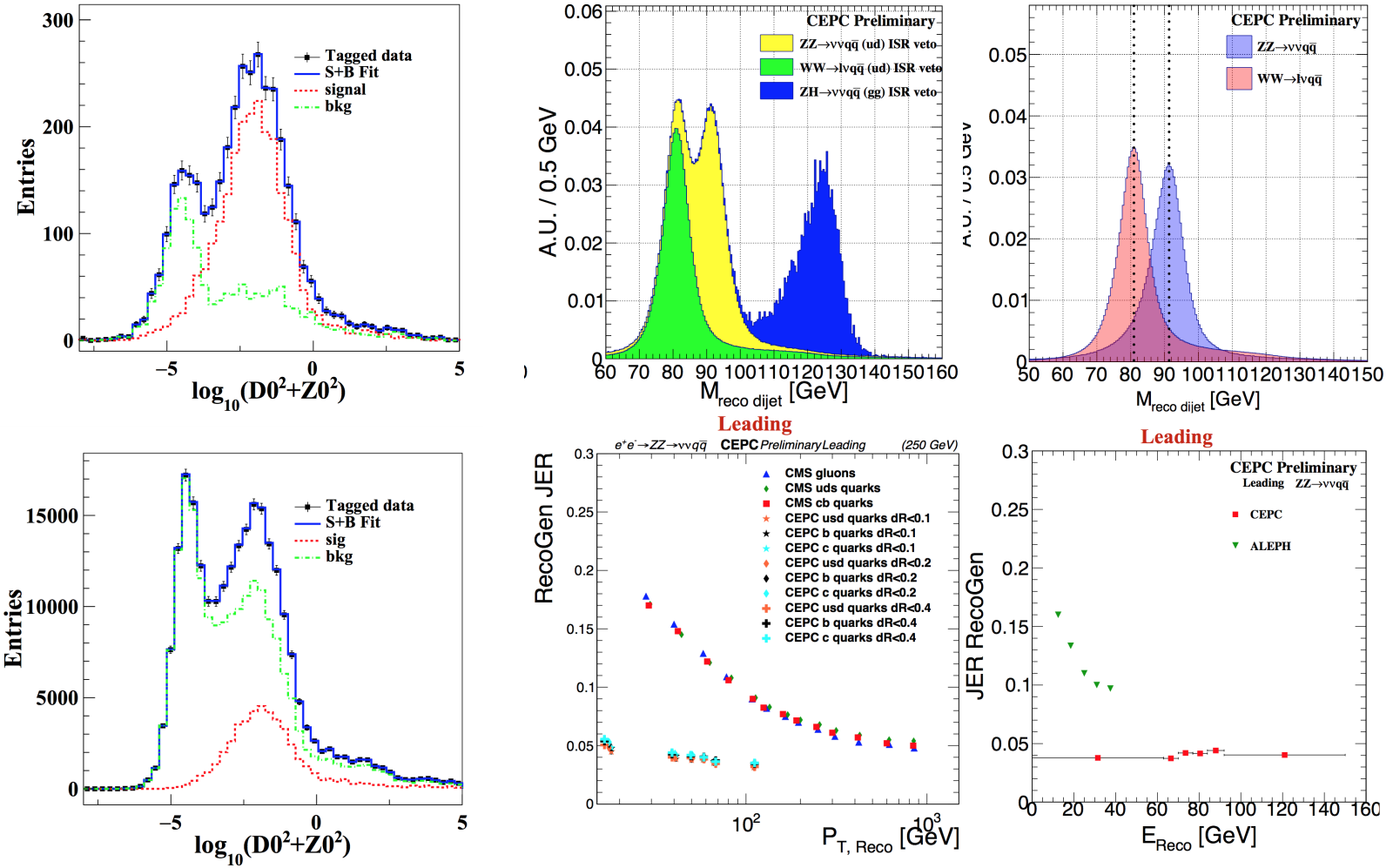


- H. Qi: Preliminary LCTPC test beam result

  dEdx ~ 4.7%, agrees with MC Simulation (3.4 – 5.1%)

- Progresses of IBF & Laser monitoring
  - *IBF controlled to 0.1%, ensure the charge distortion << Hit resolution*

High light 3: Tame of Tau & Jets



D. YU, Z.ZHANG et. al (http://indico.ihep.ac.cn/event/6618/session/22/contribution/142/material/slides/0.pdf)
Full Sim Analysis at H->tautau: high efficiency tau-finding at different environments

P. LAI et. al, (http://indico.ihep.ac.cn/event/6618/session/19/contribution/135/material/slides/0.pdf)
Events with jets: Clear separation of Bosons, Impact of Jet Clustering Evaluated, JER 3-6%

Silicon Tracking + HGC

Full Silicon Tracker in 3D

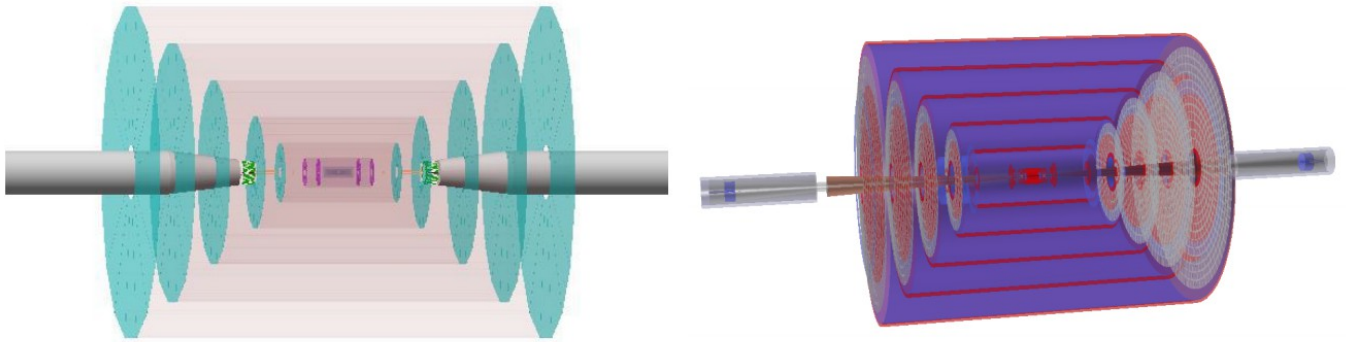
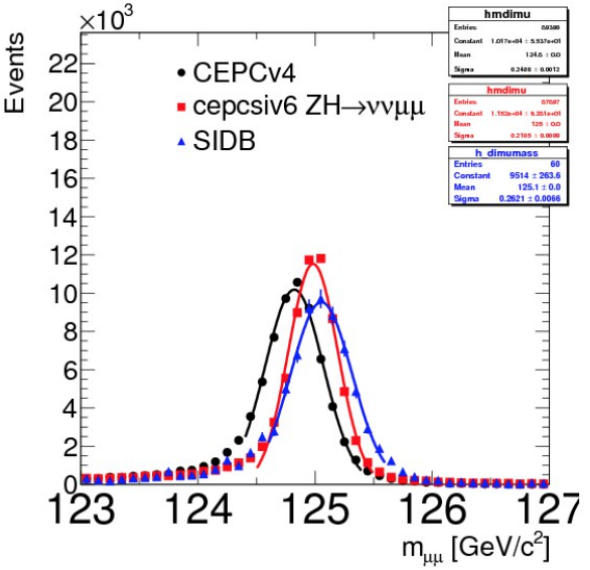
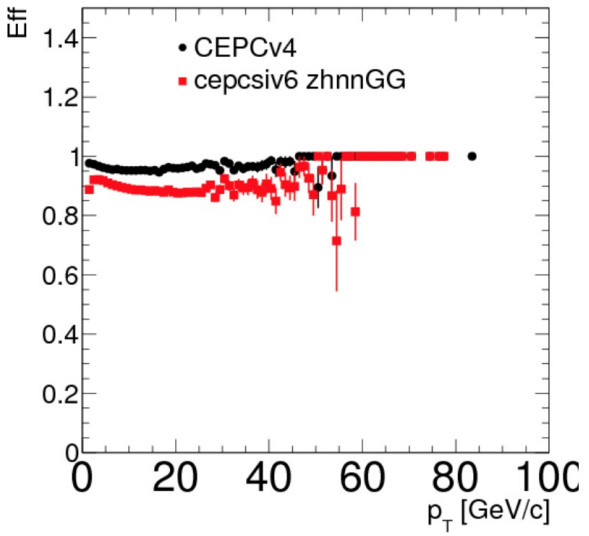


Figure: CEPCSIDV6 (left) and SIDB(right).

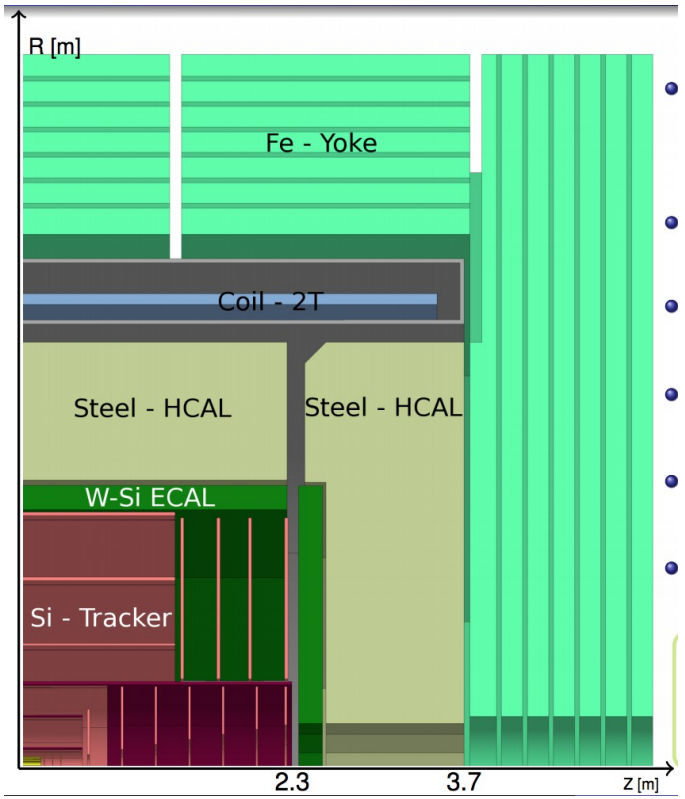


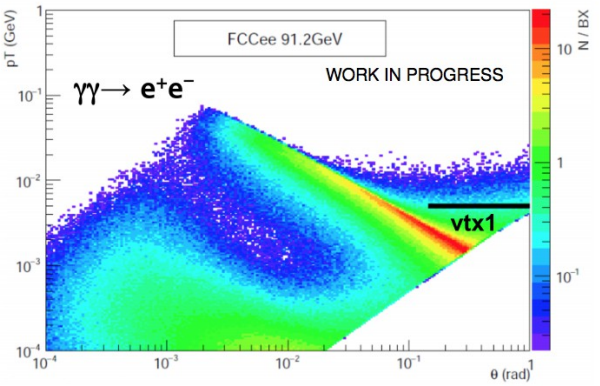


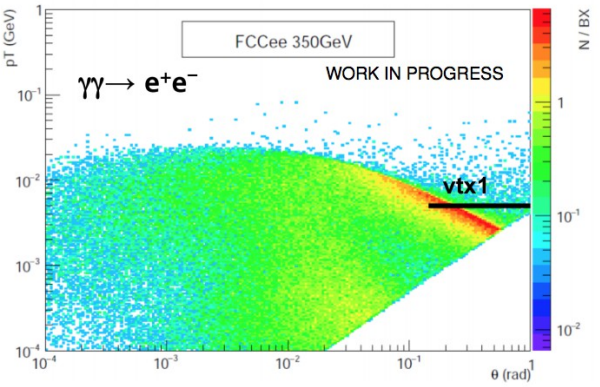
W Yao:
Partly optimized geometry Fully implemented & Validated;
Reconstruction works well for single/well isolated particles;
Track reco. Efficiency slightly degraded for tracks in Jets

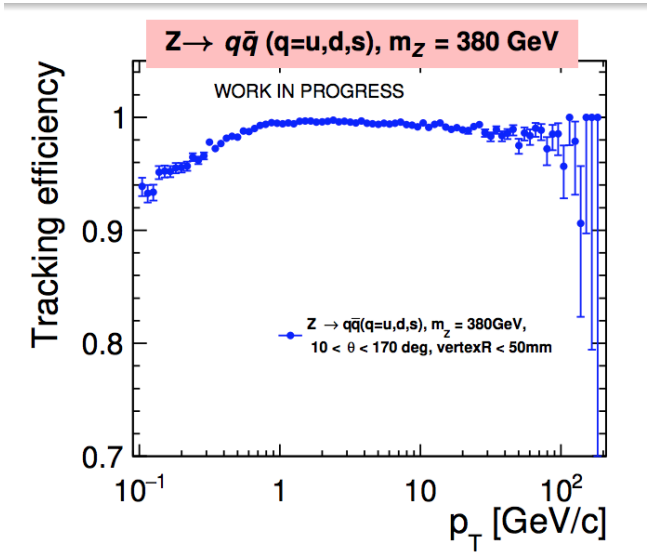
http://indico.ihep.ac.cn/event/6618/session/4/contribution/42/material/slides/0.pdf

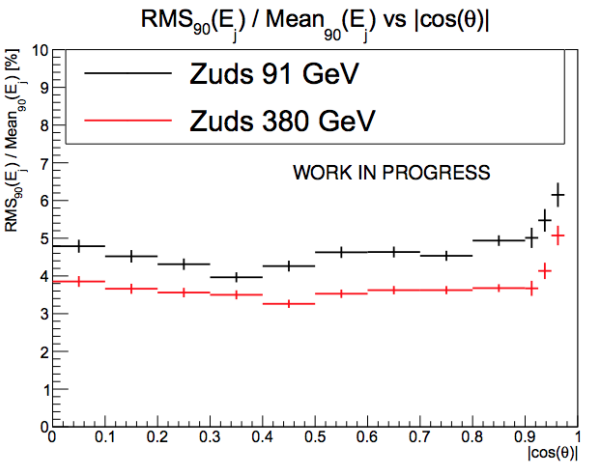
CLIC Inspired FCC-ee detector









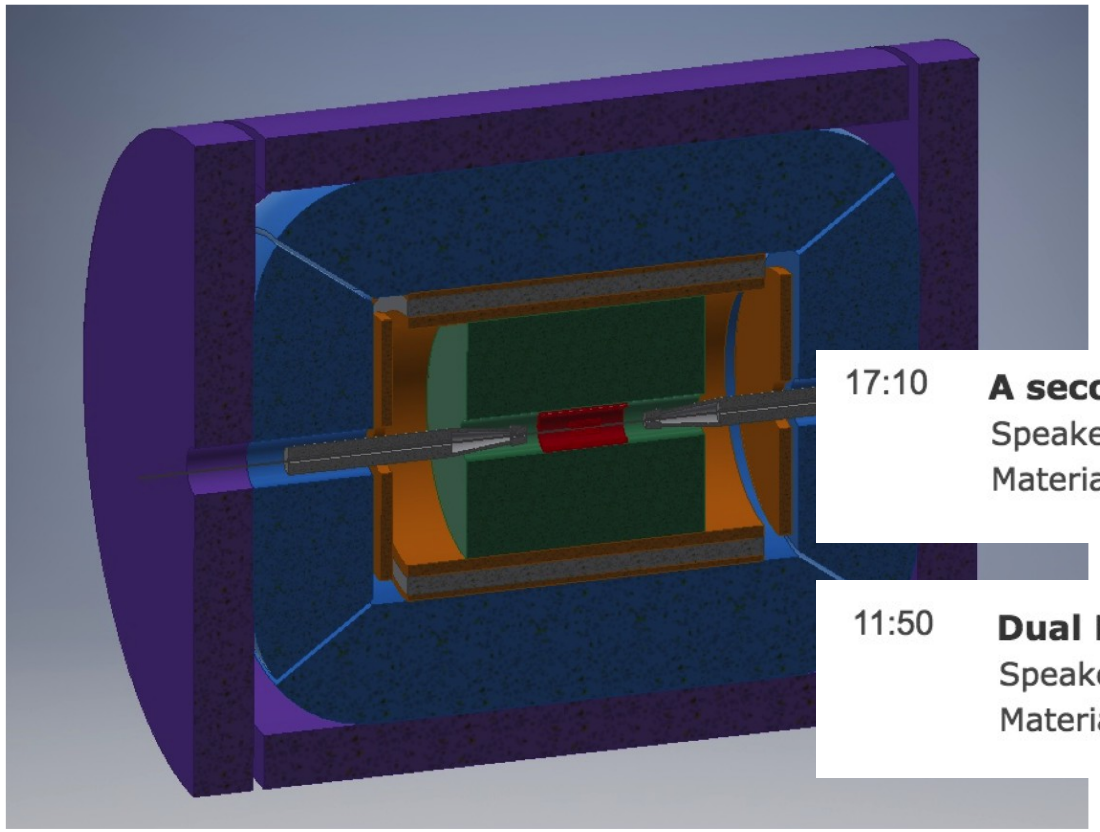


Si+HGC	B-Field/Tesla	Rout/m	ECAL	HCAL Layers
FCC-ee	2	2.2	40 layers, 22 X_0	44 layers, 5.5 λI
CEPC	3	1.8	30-20 layers, 24 X_0	40 layers, 4 λI

Same concept, different parameters; MDI; Properly functional Reconstruction

O. Viazlo:
http://indico.ihep.ac.cn/event/6618/session/4/contribution/47/material/slides/0.pdf

Low magnet field detector concept



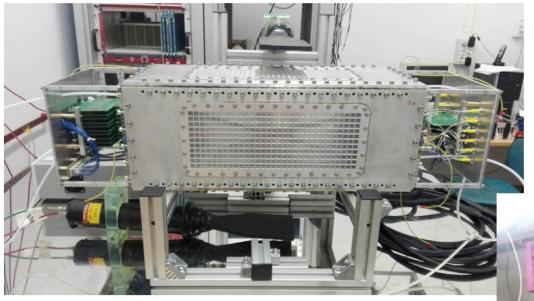
17:10 **A second detector proposal for CEPC** *20'*
Speakers: Franco Bedeschi (INFN), Franco Bedeschi (INFN)
Material: **Slides**

11:50 **Dual Readout Calorimeter at the CEPC** *20'*
Speaker: Roberto Ferrari (INFN)
Material: **Slides**

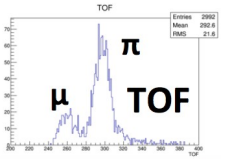
09:00 **An ultra-light drift chamber with particle identification capabilities** *30'*
Speaker: Prof. Franco Grancagnolo
Material: **Slides**

Hardware prototyping & test beam

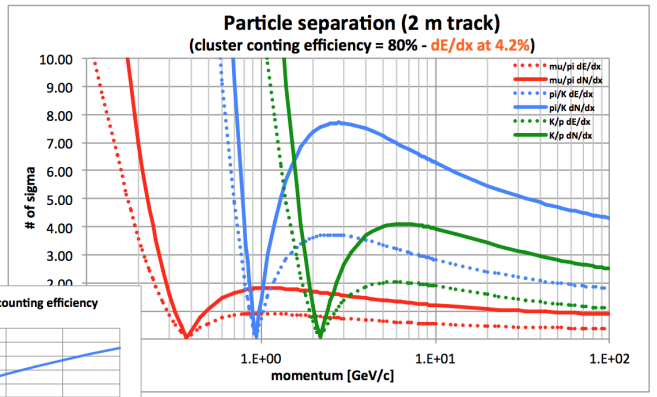
60 cm, 144 cells prototype

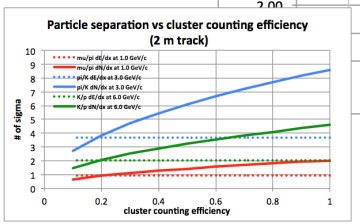


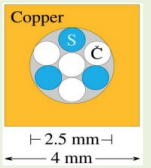
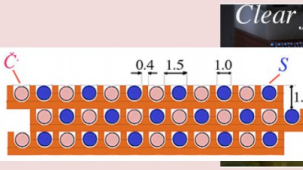
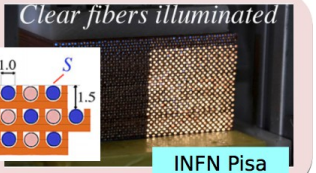
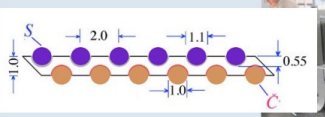
Cosmic rays test stand

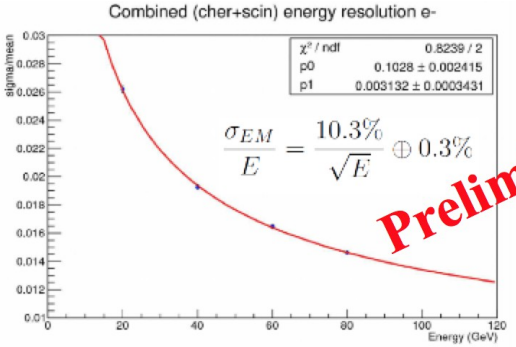


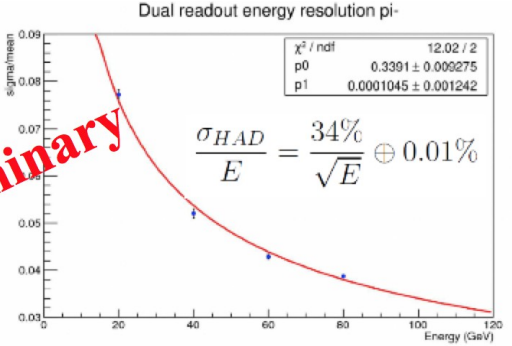
Beam test at PSI last September



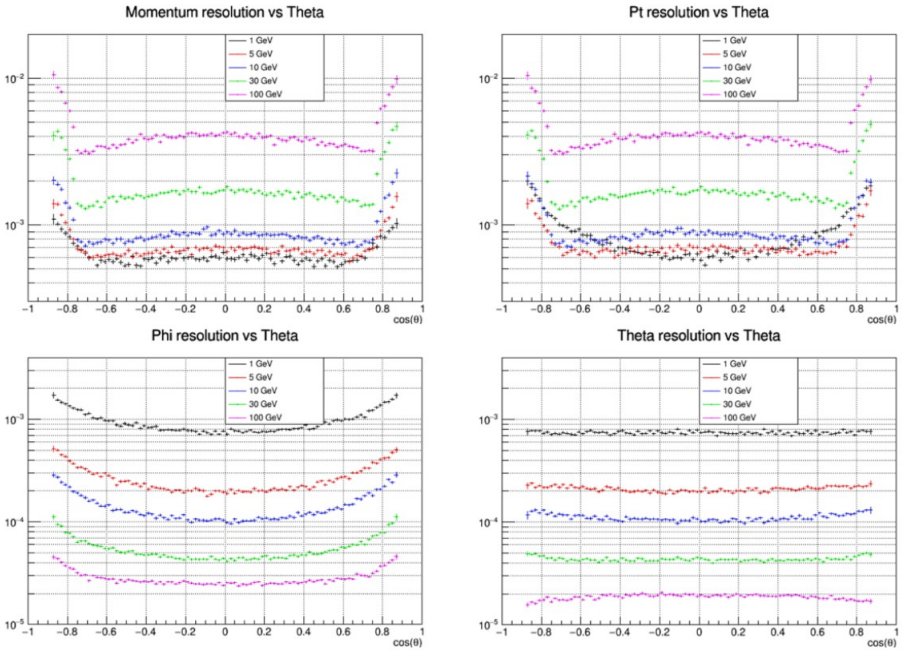


2003 DREAM	Cu: 19 towers, 2 PMT each 2m long, 16.2 cm wide Sampling fraction: 2%	 
2012 RD52	Cu, 2 modules Each module: 9.2 × 9.2 × 250 cm³ Fibers: 1024 S + 1024 C, 8 PMT Sampling fraction: ~4.6% Depth: ~10 λ_{int}	  INFN Pisa
2012 RD52	Pb, 9 modules Each module: 9.2 × 9.2 × 250 cm³ Fibers: 1024 S + 1024 C, 8 PMT Sampling fraction: ~5.3% Depth: ~10 λ_{int}	  INFN Pavia

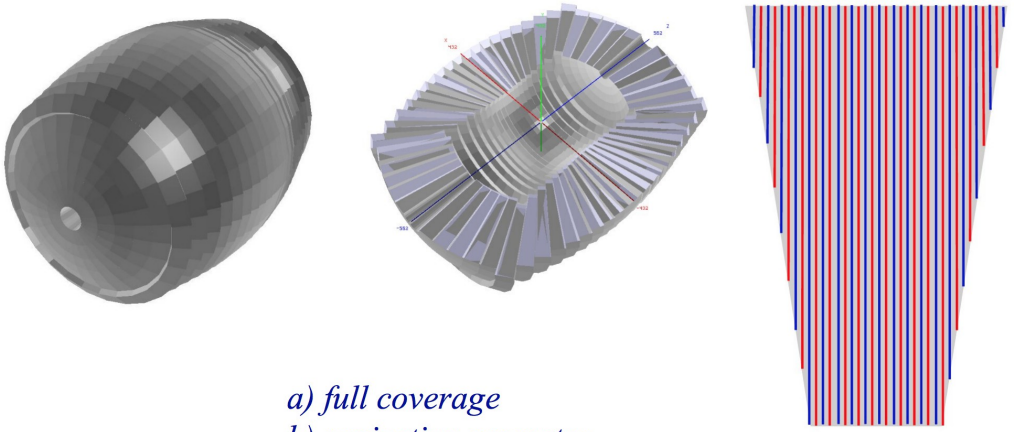




Implemented into Simulation



Dual-readout calorimeter description for CepC/FCCee simulation sw:



a) full coverage
b) projective geometry

Both Wire Chamber & Dual readout Calorimeter have been implemented;

Need Validation, Digitization & Dedicated Analysis to Study the performance at jet and Physics event level

Common topics

- Beam energy monitoring
  - 1 MeV accuracy is conditionally accessible (Very demanding) – Needs more careful study
- Deep learning in Flavor Tagging
  - Significant Impact observed
    - At Z pole: B-tagging purity improved from 89%->93% (eff = 80%)
    - At Higgs Sample: C-tagging purity improved by ~50% (eff = 60%)
  - Much to be explore
- Computing:
  - Appreciation to Dirac, IHEPCC, BES, QMUL, IPAS...
  - Short in Computing Power: Only covers 1/10 of SM Background in 1 geometry set
- DAQ
  - By giving some of the present examples, I am trying to give a hint on how the future DAQ system would move, but it is hard to predict new technology more than 10 year ahead
  - We need our own thoughts like xTCA
  - We need development from Industry
    - New FPGA, high IO
    - Powerful CPUs,PPUs
  - We should not wait, but keep working/improving

G. TANG

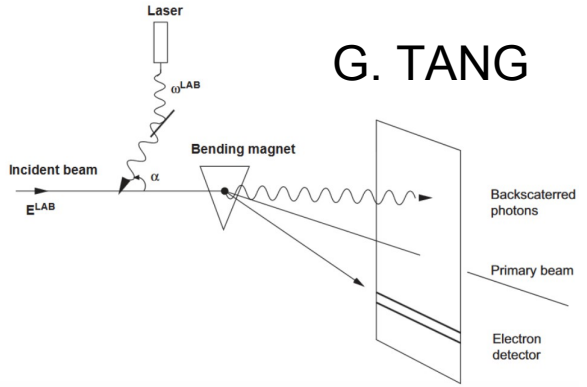
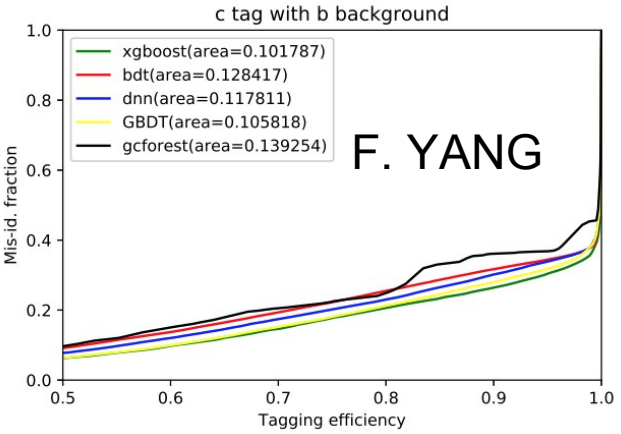


Fig. 8. Scheme of the proposed energy spectrometer based on Compton backscattering.

F. YANG



14:40 **Beam Energy monitoring via Compton Scattering** *20'*
Speaker: Mr. Guangyi Tang (高能所)
Material: Slides

15:00 **Computing at CEPC** *20'*
Speaker: Mr. Xianghu ZHAO (IHEP)
Material: Slides

15:20 **Machine Learning at CEPC** *20'*
Speaker: Prof. Fan Yang (XMU)
Material: Slides

18:10 **Advanced DAQ systems for current and future colliders** *20'*
Speaker: Prof. Zhen An LIU (IHEP)
Material: Slides

VTX & Silicon Sensors

08:00 - 10:00 Detector& Physics II(Silicon vertex detector & tracker): Parallel Session II

Conveners: Prof. Meng Wang (Shandong University), Prof. Daniela Bortolleto

08:00 **Status report from Vertex Detector group** *20'*
Speaker: Prof. Qun OUYANG (IHEP)
Material: Slides

08:20 **Pixel sensor technologies for the CEPC** *20'*
Speaker: Prof. Sebastian Grinstein (Barcelona)
Material: Slides

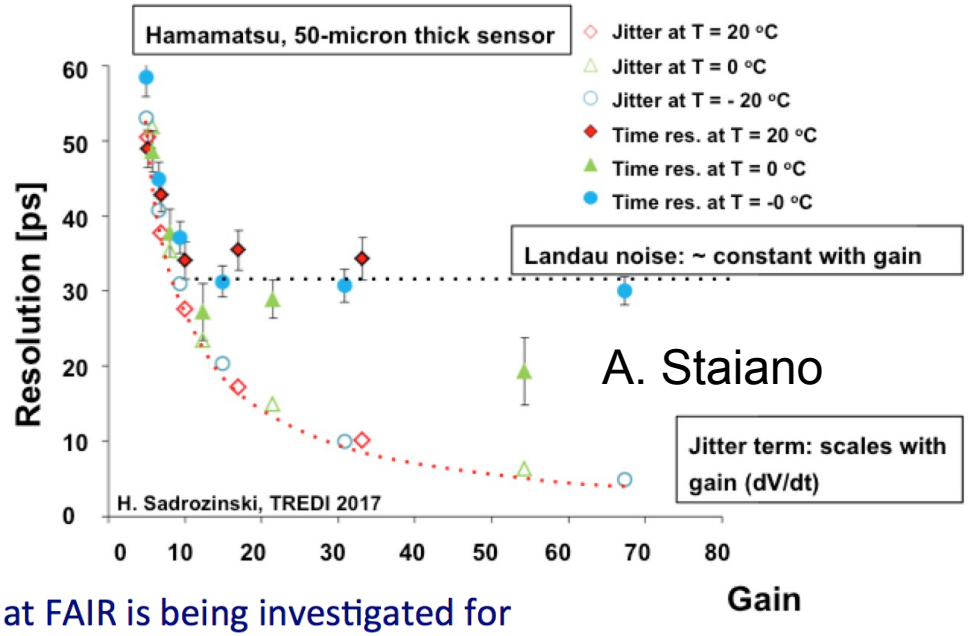
08:40 **CMOS Pixel Sensors for ILC Related Vertexing & Tracking Device** *20'*
Speakers: Christine HU-GUO (I), Dr. Christine Hu-Guo (IPHC-IN2P3/CNRS, UDS)
Material: Slides

09:00 **Alpide and other developments** *20'*
Speaker: Prof. Walter Snoeys
Material: Slides

09:20 **Overview of SOI development** *20'*
Speaker: Dr. Yunpeng LU (Institute of High Energy Physics, CAS)
Material: Slides

09:40 **Tracking in four dimensions** *20'*
Speaker: Amedeo Staiano (I)
Material: Slides

Ultra high speed silicon sensor
30 ps resolution -
4 dimensional tracker
Performance improved



A. Staiano

- The potential of the CPS developed for the CBM experiment at FAIR is being investigated for vertexing and tracking at the ILC
- Expected performances for the ILD-VXD:
  - σ_{sp} <~ 4 µm & Δt ~ 2-4 µs (layer dependent)

C. HU-GUO

PSIRA

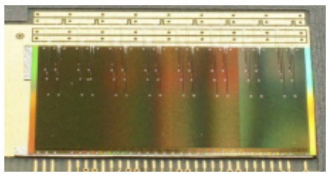
ALPIDE CMOS Pixel Sensor Chip for the ALICE ITS upgrade now in production

Used also for the new Muon Forward Tracker (MFT) detector in ALICE

Detection Efficiency > 99%

Fake hit rate << 10^{-5} /event/pixel

Position resolution < 5 µm



W. SNOEYS

To Machine

16:30 - 18:15 MDI (joint detector and accelerator) I: Parallel Session V

Conveners: Dr. Suen Hou (SINICA), Prof. Michael Sullivan (SLAC National Accelerator

Location: C305

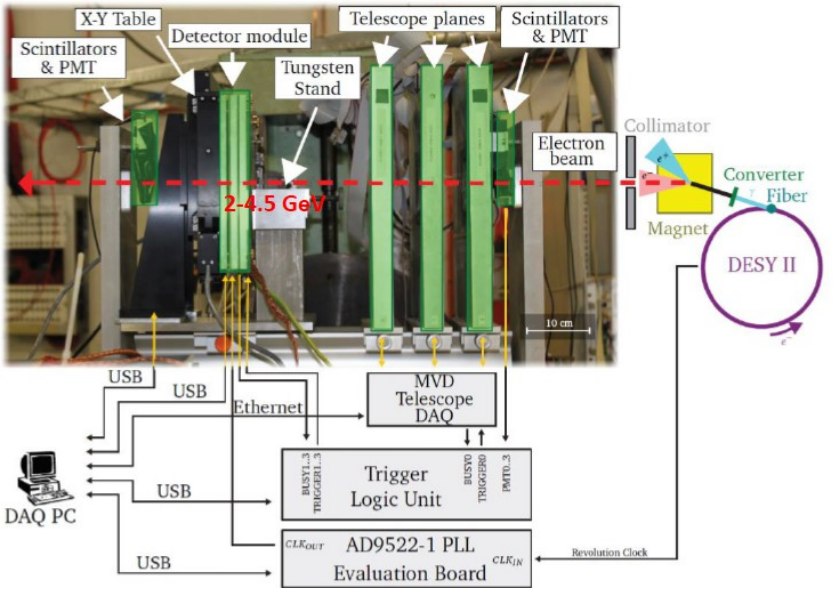
16:30 **Introduction (interaction region, magnets, etc.)** *25'*
Speaker: Mr. Chenghui Yu (Institute of High Energy Physics)
Material: **Slides**

16:55 **Radiation backgrounds at CEPC** *20'*
Speaker: Dr. Hongbo ZHU (IHEP)
Material: **Slides**

17:15 **MDI at SuperKEKB** *20'*
Speaker: Mr. Peter Lewis (Hawaii U.)
Material: **Slides**

17:35 **Overview of LC FCAL** *20'*
Speaker: Prof. Ivanka Bozovic (VINCA)
Material: **Slides**

17:55 **LumiCal at CEPC** *20'*
Speaker: Dr. Suen Hou (SINICA)
Material: **Slides**



1. Luminosity of Bhabha counting is demanded to $\delta L/L$ ***~ 0.1%*** wtih Si Strip to reach r_{inner} to resolution ***<10 μm***

   A "floating LumiCal" has unknown systematics on r_{inner}

   By adding electron tracking to calibrate "mean of r_{inner}" to ***1 μm → to reach*** $\delta L/L$ ***~ 0.01%***

MDI: Challenges everywhere!

To theory

16:30 - 18:15 Detector & Physics (joint with theory) VI: Parallel Session V

Conveners: Patrizia Azzi (INFN-PD), Prof. Yaquan FANG (高能所)

Location: B326

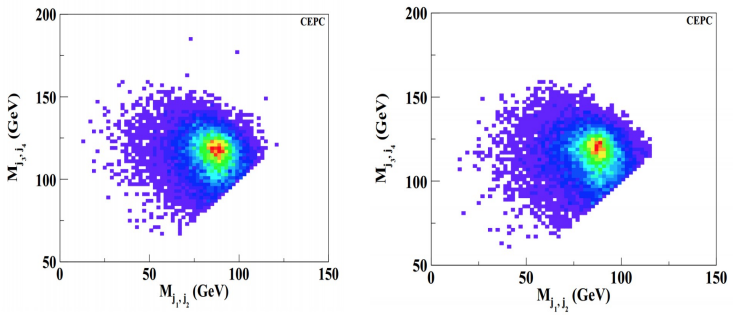
16:30 **HI-LHC & challenge for CEPC - Higgs** *20'*
Speaker: Nicola De Filippis (Politecnico and INFN Bari)
Material: Slides

16:50 **HL-LHC & challenge for CEPC - EWK** *20'*
Speaker: Prof. Paolo Azzurri (INFN Pisa)
Material: Slides

17:10 **Study of the CEPC Higgs decaying into two photons** *20'*
Speaker: Ms. Zhenyu Zhang (WHU)
Material: Slides

17:30 **Combination of CEPC Higgs precision measurement** *20'*
Speaker: Mr. Kaili Zhang (IHEP)
Material: Slides

17:50 **Long lived particles** *20'*
Speaker: Prof. James Beacham (OSU)
Material: Slides



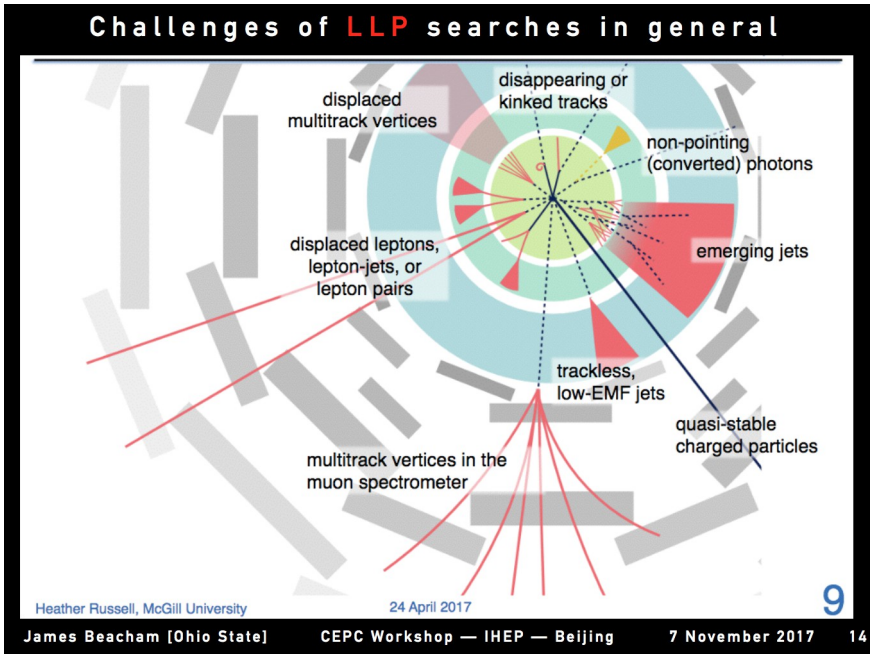
14:00 - 16:00 Detector & Physics V (Simulation): Parallel Session IV

Conveners: Dr. Sasha Glazov (DESY), Mr. Manqi Ruan (IHEP)

Location: B326

14:00 **Fast Simulation for CEPC** *20'*
Speaker: Dr. Gang LI (EPD, IHEP, CAS)
Material: Slides

- CEPC would deliver game changing precision for EW parameters
  - possible x 10-100 improvement factors to LEP1 & 2 precision
  - W mass and width to ~1 MeV (make a visit to the threshold if possible)
  - Z pole physics also very worth to be exploited



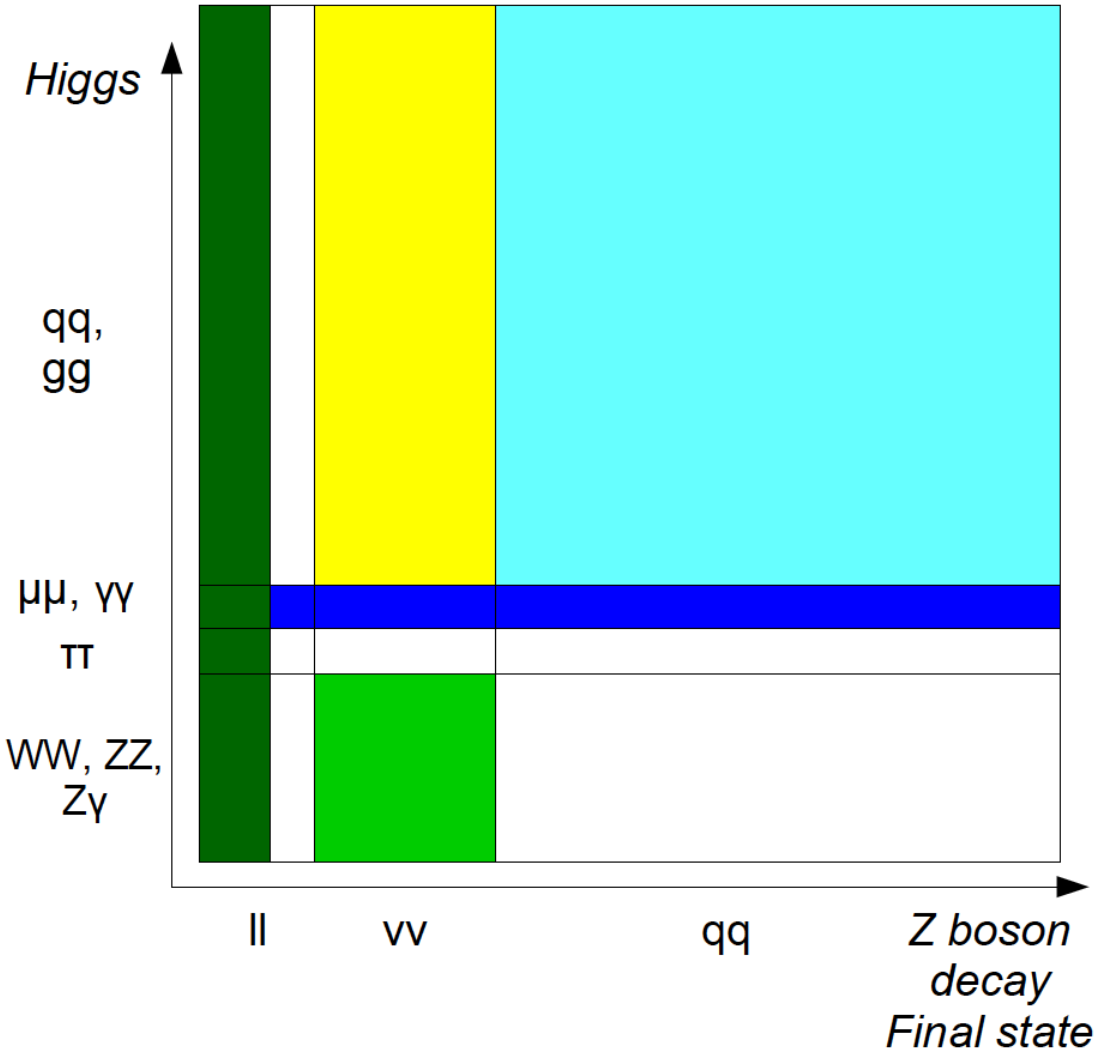
Summary

- Lots of interesting talks
  - Results + Ideas...
- To do:
  - Making solid conceptual design: a coherent picture that links machine, theory & detector;
  - Requirement, Performance & Hardware design
- To make an efficient collaboration
  - Dedicated manpower & long term programs (PostDoc + Visiting Scholars + Position)
  - Common efforts to the future:
    - Physics potential studies
    - Detector hardware & technologies
    - Common DAQ
    - Common software/algorithm, Artificial intelligence
- Apology for these missing points/items & my personal bias...


Thank you!

Back up

Optimization Benchmarks



Lepton & Momentum resolution: Br = 6.7%

Flavor Tagging & JER: Br = 14%

Composition of Jet/MET, lepton: Br = 4%

Jet Clustering: Br = 50%

Photon/ECAL: Br = 0.2%

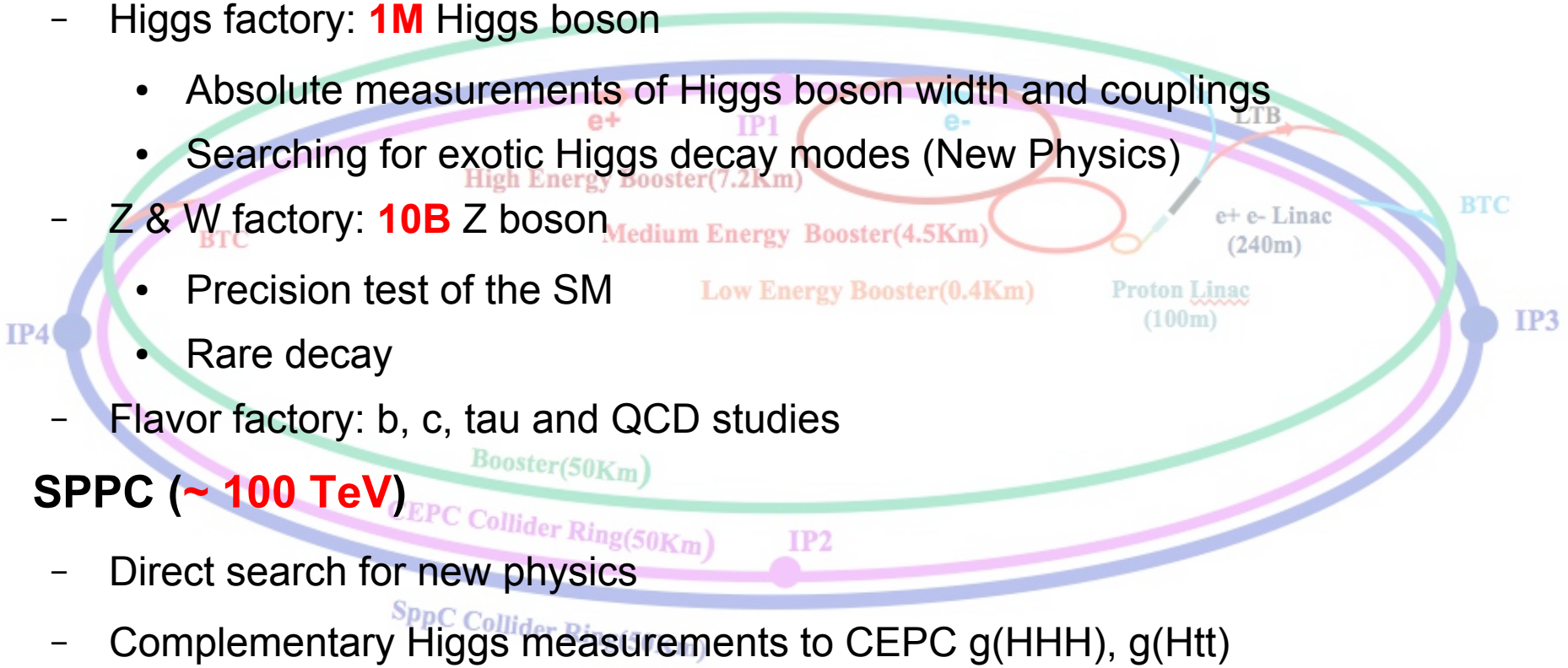
Tracking: H→μμ, Br = 0.02%

qqH, H->inv. MET & NP: SM Br = 0.1%

EW, Br(tau->X) @ Z pole: Separation

Science at CEPC-SPPC

- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **10B** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**



Complementary