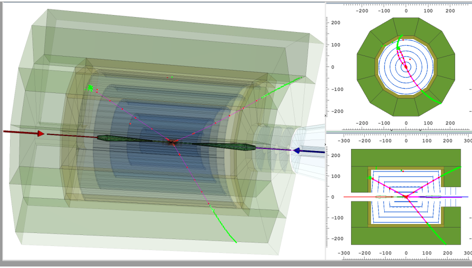
The TOPSiDE Detector Concept

Timing Optimized PID Silicon Detector



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Chao Peng, Tom Polakovic, Junqi Xie

Argonne National Laboratory

August 18, 2020

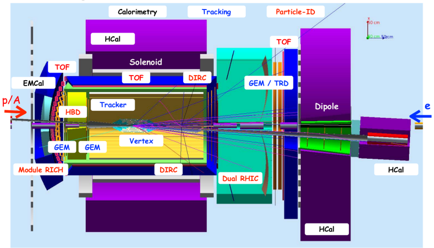
Introduction

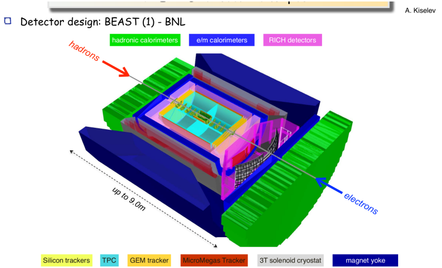
- Design motivation
- TOPSiDE concept
- Hybrid TOPSiDE (UFSD and SOI)
- Future directions with simulation

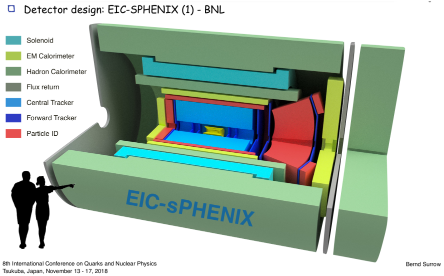
Detector design motivation

- Full acceptance 4π detector
- Full PID for all tracks
- The fewer subsystems, the better

Started a new detector from scratch.





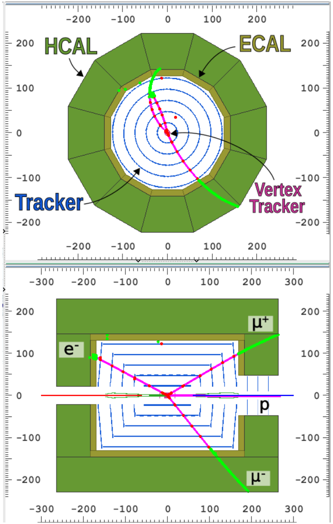


What is TOPSiDE?

TOPSiDE is a central detector concept.

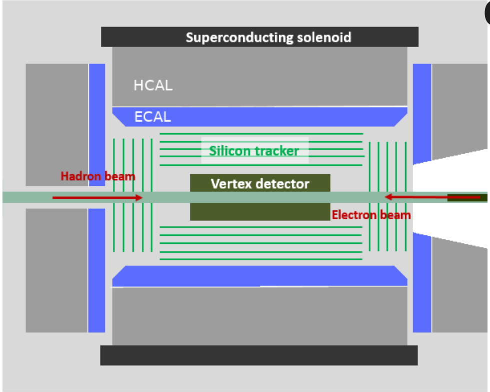
The basic ideas behind TOPSiDE:

- Simple design: **ultra-fast Si trackers** (UFSD) and granular calorimeters
- **Full PID with TOF** over entire central region $(-3 < \eta < 3)$
- Covers a **well defined central region** where extra PID detectors are not needed
- Focused efforts for dedicated PID detectors in regions where they are most needed
- Minimal material in front of calorimeters



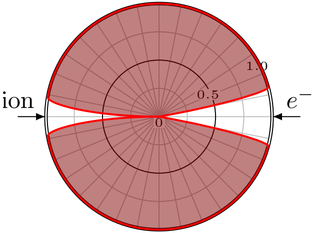
TOPSiDE

Time-of-Flight PID



Central detector region: $(-3 < \eta < 3)$

- Symmetric design with close to 4π coverage
  $\rightarrow$ **Ensure exclusivity**



TOPSiDE

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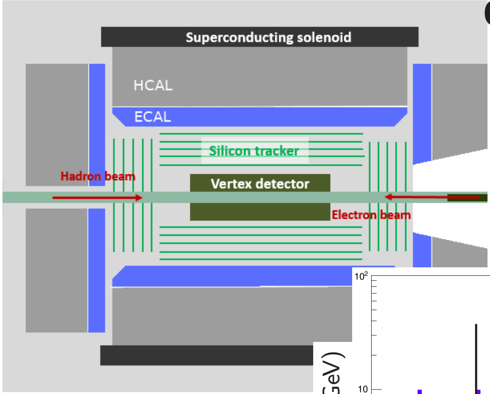

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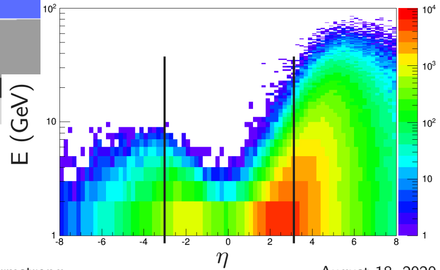
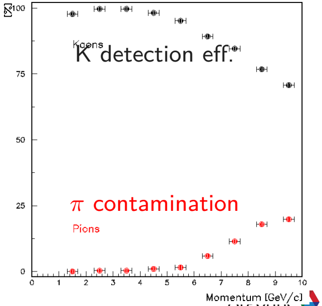
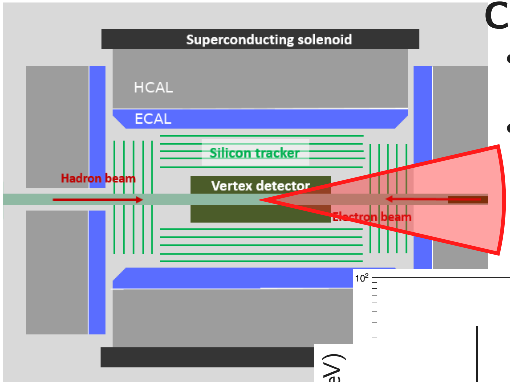
- Ultra-fast Si detectors for TOF $\pi - K - p$ separation
  $\rightarrow$ Provides PID necessary for **SIDIS**





TOPSiDE

Time-of-Flight PID



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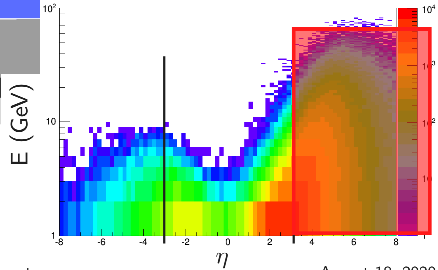
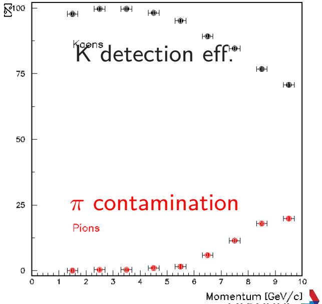
Time resolution and P_{max} define the minimum angle of central detector





TOPSiDE

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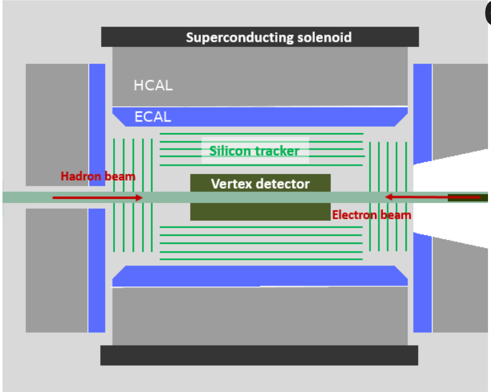
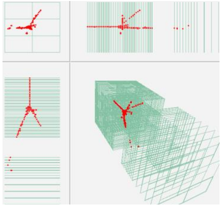


Central detector region: $(-3 < \eta < 3)$

- Symmetric design with close to 4π coverage
  $\rightarrow$ **Ensure exclusivity**
- Ultra-fast Si detectors for TOF $\pi - K - p$ separation
  $\rightarrow$ Provides PID necessary for **SIDIS**
- Imaging calorimeters and particle flow algorithms
  $\rightarrow$ PID of hadrons/neutrals and background rejection important for **DVCS and DVMP**

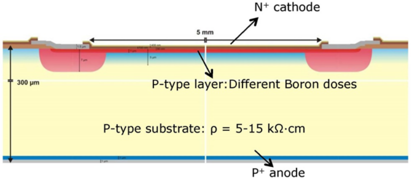


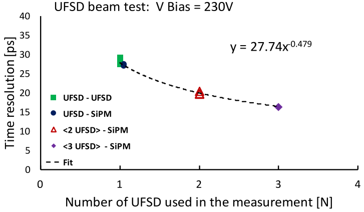
Ultra-fast Silicon Detectors

10 ps timing resolution needed for the TOPSiDE 5D Concept

- Timing for Particle ID ($\pi - K - p$ separation)

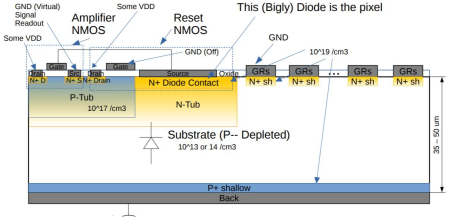
Low-Gain Avalanche Diodes (LGAD)





Cartiglia, NIM A850 (2017) 83-88

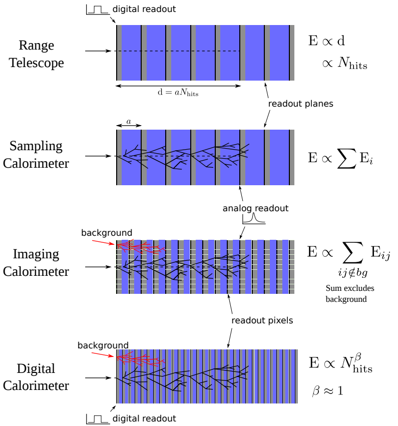
HV-CMOS



K.-W. Shin - in progress

- LGAD currently state-of-the-art (best time resolution)
- HVCMOS is promising, possibly cheaper, and monolithic design easier
- HBT SiGe technology is also promising (similar character to CMOS but faster and lower power)

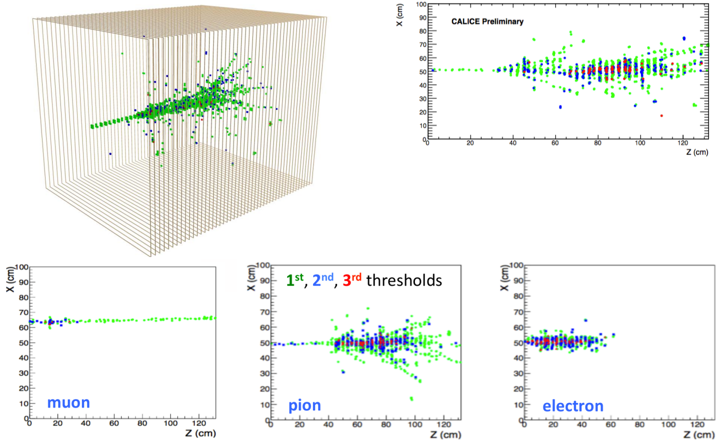
Imaging, Digital, and semi-Digital Hadronic Calorimeters



Semi-Digital (2 bits):

$E \propto \sum(\alpha N_1 + \beta N_2 + \gamma N_3)$

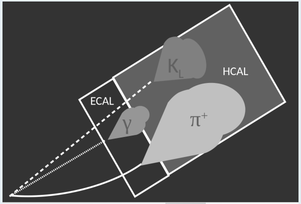
where $\alpha \sim \beta/2 \sim \gamma/3$



From D. Boumediene (LPC)-CEPC WS 2018, Roma III

Imaging Calorimetry and Particle Flow Algorithms

"Particle flow" algorithms (PFA) use **all detector information** to reconstruct event



- "Particle flow" always provides the best reconstruction.
- Higher granularity → less confusion
- Track segments connect adjacent showers associated with same primary particle
- New "Particle Flow" algorithms and methods possible with fine segmentation and excellent time resolution
- PFA output is a list of particles

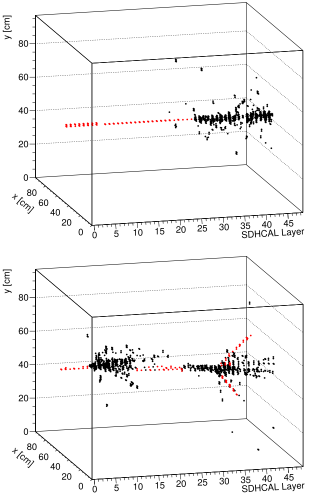
DIS 5 GeV on 60 GeV

Partic…
11 (…
321 (…
-211 (…
-211 (…
211 (…
111 (…
2112…

Proton DVCS 5 GeV on 60 GeV

Particle ID	P_x	P_y	P_z
11 (e^-)	xxxxx	xxxxx	xxxxx
2212 (p)	xxxxx	xxxxx	xxxxx
22 (γ)	xxxxx	xxxxx	xxxxx

Semi-Digital HCAL

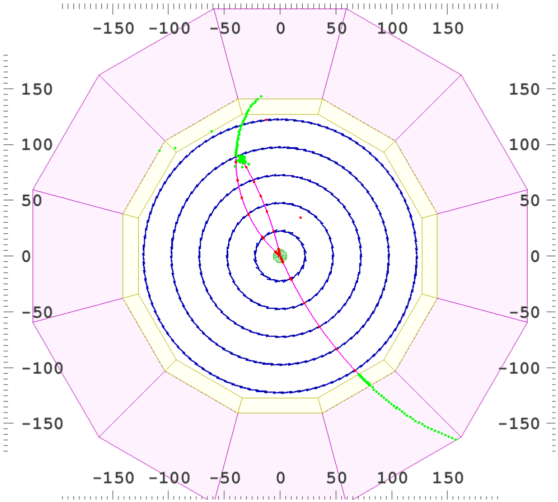


SDHCAL - CALICE, JINST 11 (2016) no.04, P04001

Hybrid TOPSiDE Silicon Detectors

Use both UFSD and SOI detectors

- Goal of 10 ps time resolution is at **track level**
- UFSD not required for entire detector
- SOIPIXD → precision tracking
- UFSD → precision timing
- SOIPIXD vertex tracking with outer UFSD tracker



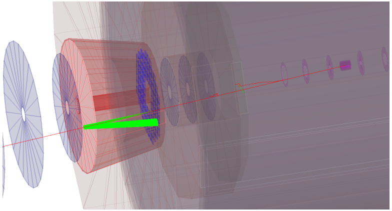
Calorimetry ideas to explore

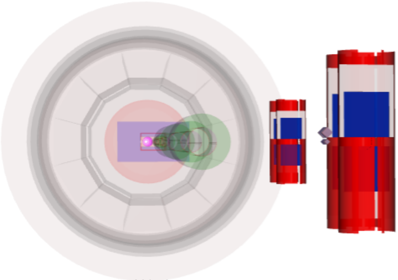
- Imaging calorimetry vs non-imaging
- Impact on reconstruction of low energy electrons
- Extra timing measurement at large radius?

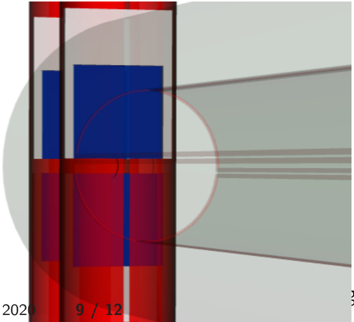
TOPSiDE Simulation Tools

Argonne Software Effort

- Detailed silicon detector descriptions
- Generic tracking reconstruction framework almost complete.
- New detectors quickly and easily implemented
- Staves, frames, cables and other support easily added
- Modern reconstruction framework for algorithm development



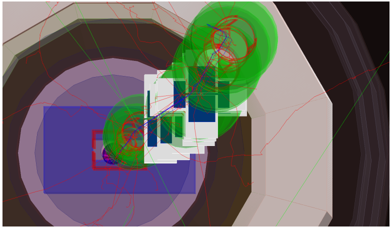


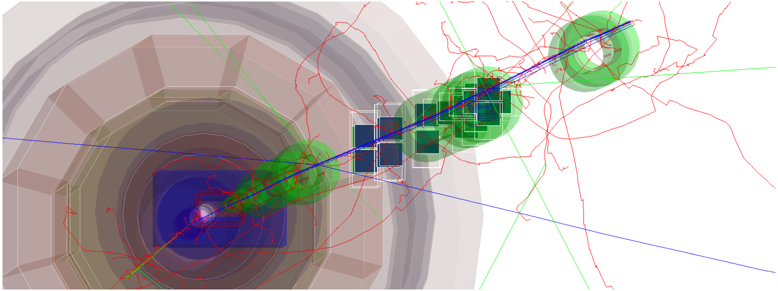


TOPSiDE Simulation Tools

Goals

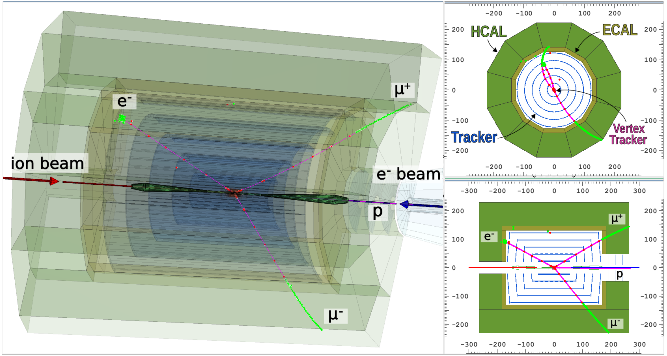
- Develop/assemble full end-to-end simulation and reconstruction framework
- Targeting long term use for the EIC project





Conclusion

- TOPSiDE concept gaining popularity
- UFSD and SOI technology highly complementary
- Different calorimetry options need to be fully explored



Thank You!