# Discovery through Complementarity – The EIC 2nd Detector

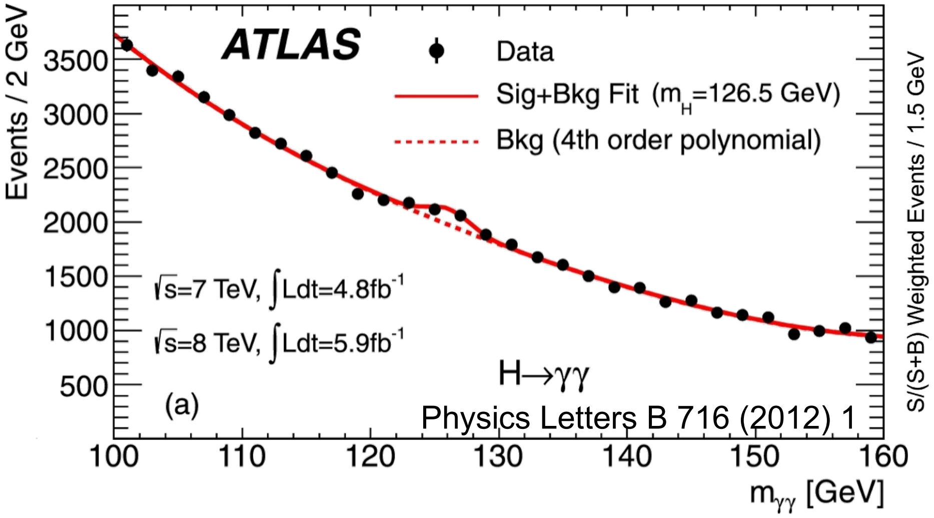
Cheuk-Ping Wong
[ cwong1@bnl.gov ]

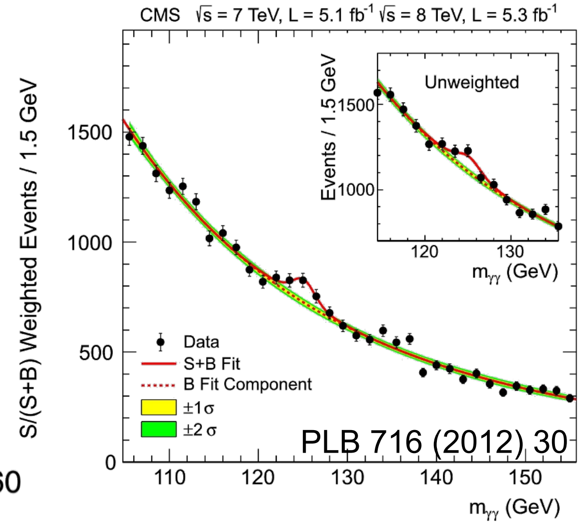
APS DNP meeting, 10-08-2024

@BrookhavenLab

# The Needs of a Second Detector

Discovery of Higgs boson from ATLAS and CMS results




- Cross-checking → validate discoveries

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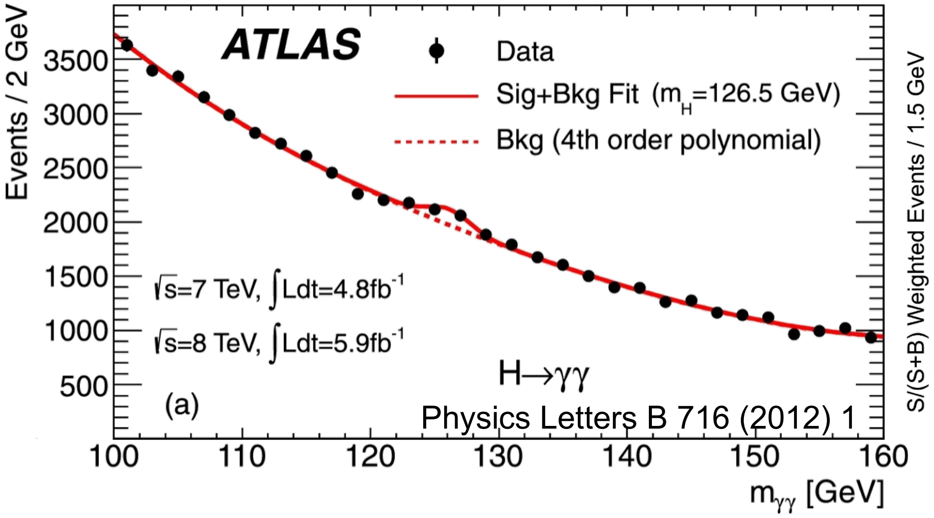


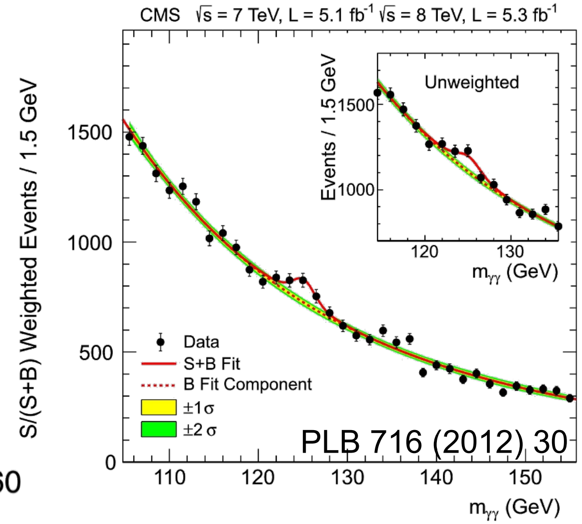


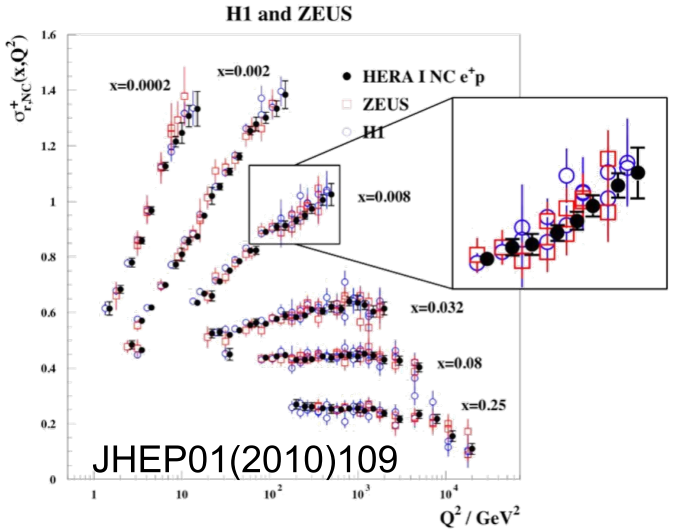


- Cross-checking → validate discoveries
- Cross Calibration → gives beyond the simple $\sqrt{2}$ statistical improvement

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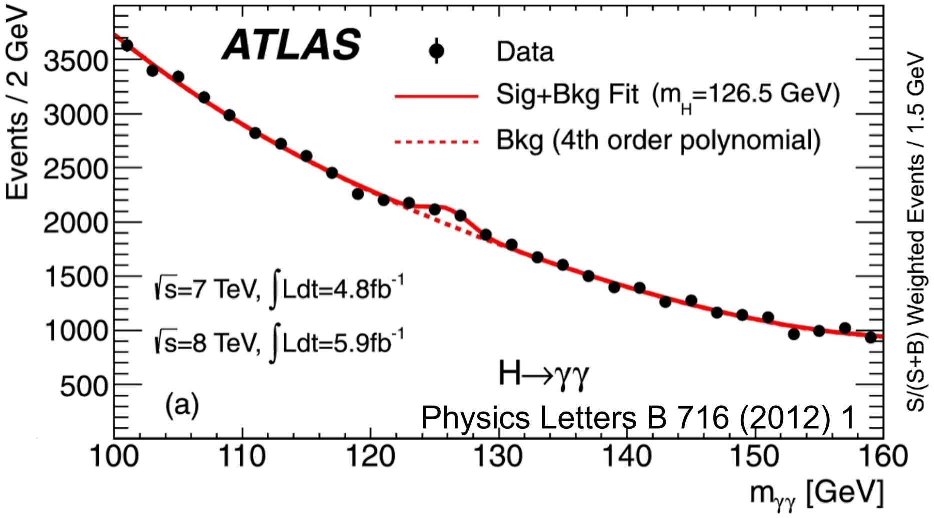
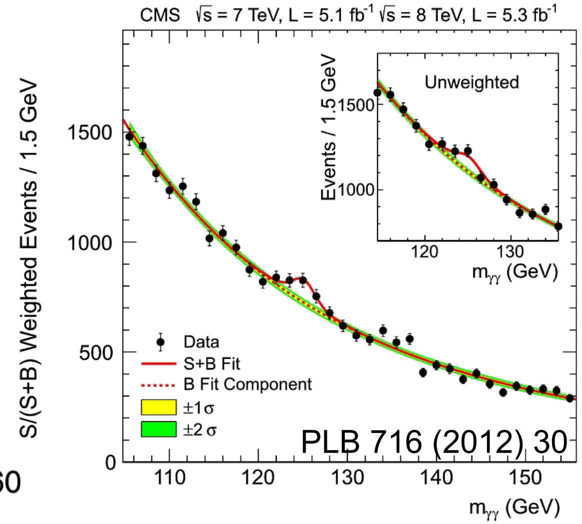
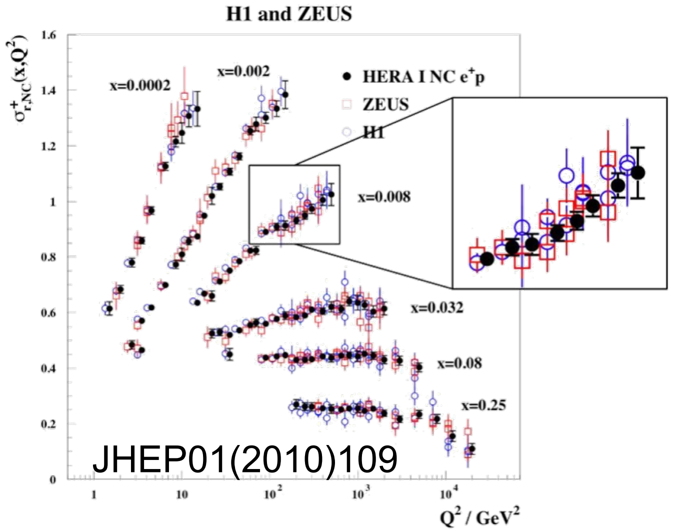


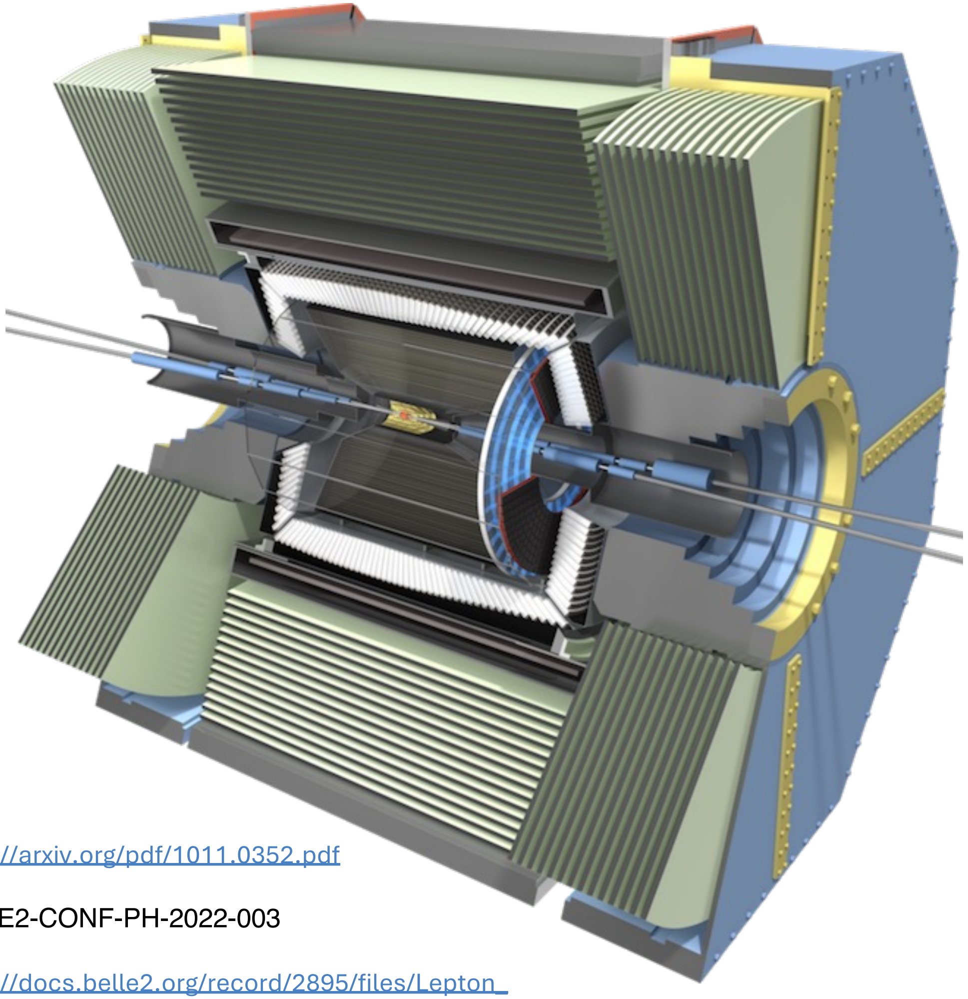




- Cross-checking → validate discoveries
- Cross Calibration → gives beyond the simple $\sqrt{2}$ statistical improvement
- Different physics focuses
- Technology Redundancy → mitigate risks

# Concepts of the 2nd Detector (Central) – Muon ID

BELLE II KLM (green)



KLM–type muon ID in the central and forward regions

https://arxiv.org/pdf/1011.0352.pdf

BELLE2-CONF-PH-2022-003

https://docs.belle2.org/record/2895/files/Lepton_identification_Moriond_2022__v2.pdf

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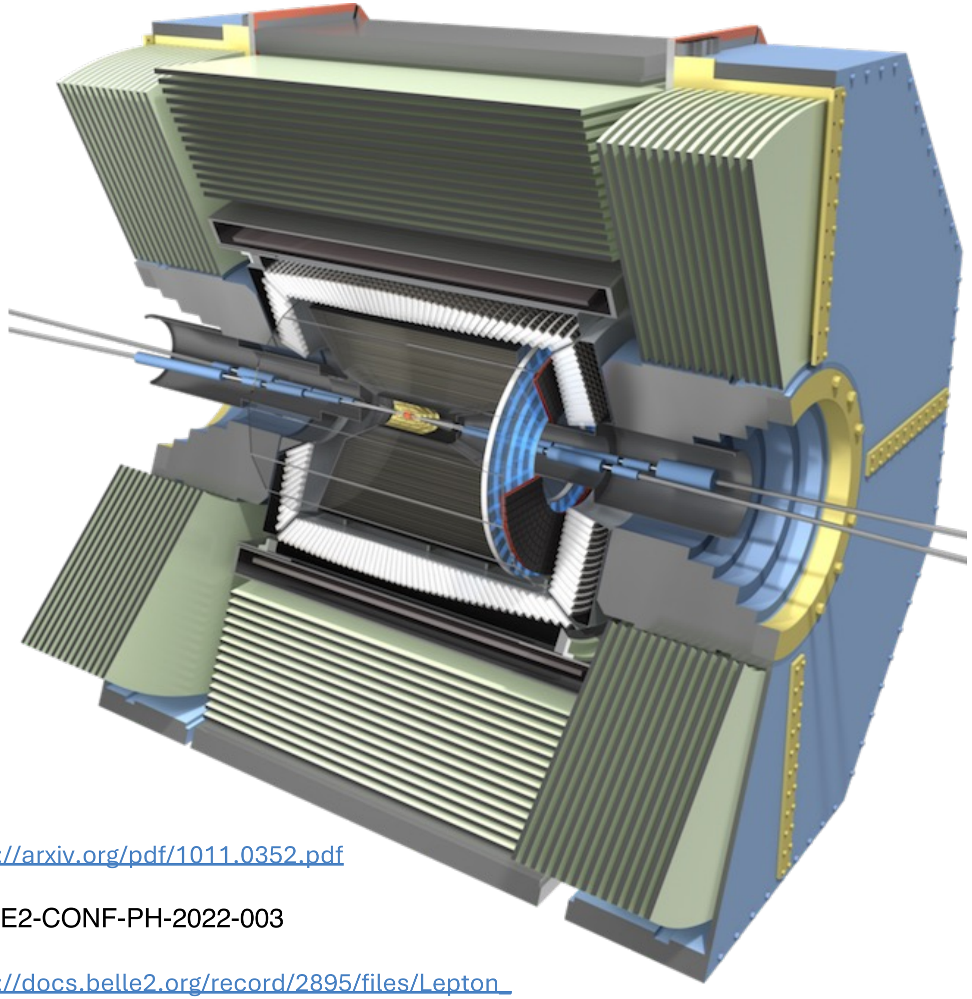

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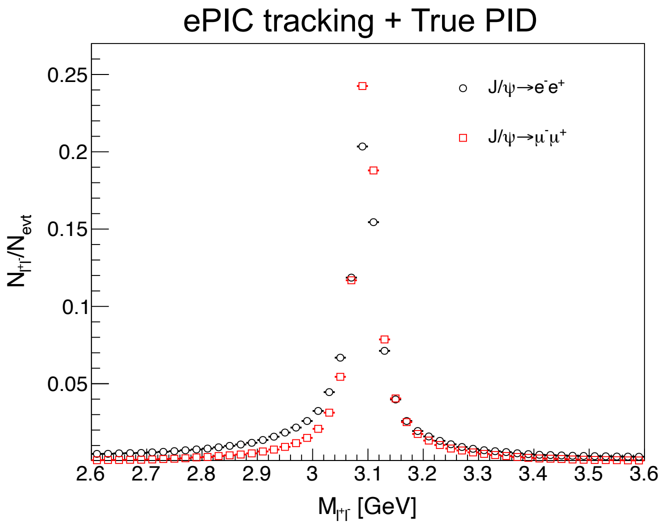


- Reduce ambiguity in quarkonium reconstruction

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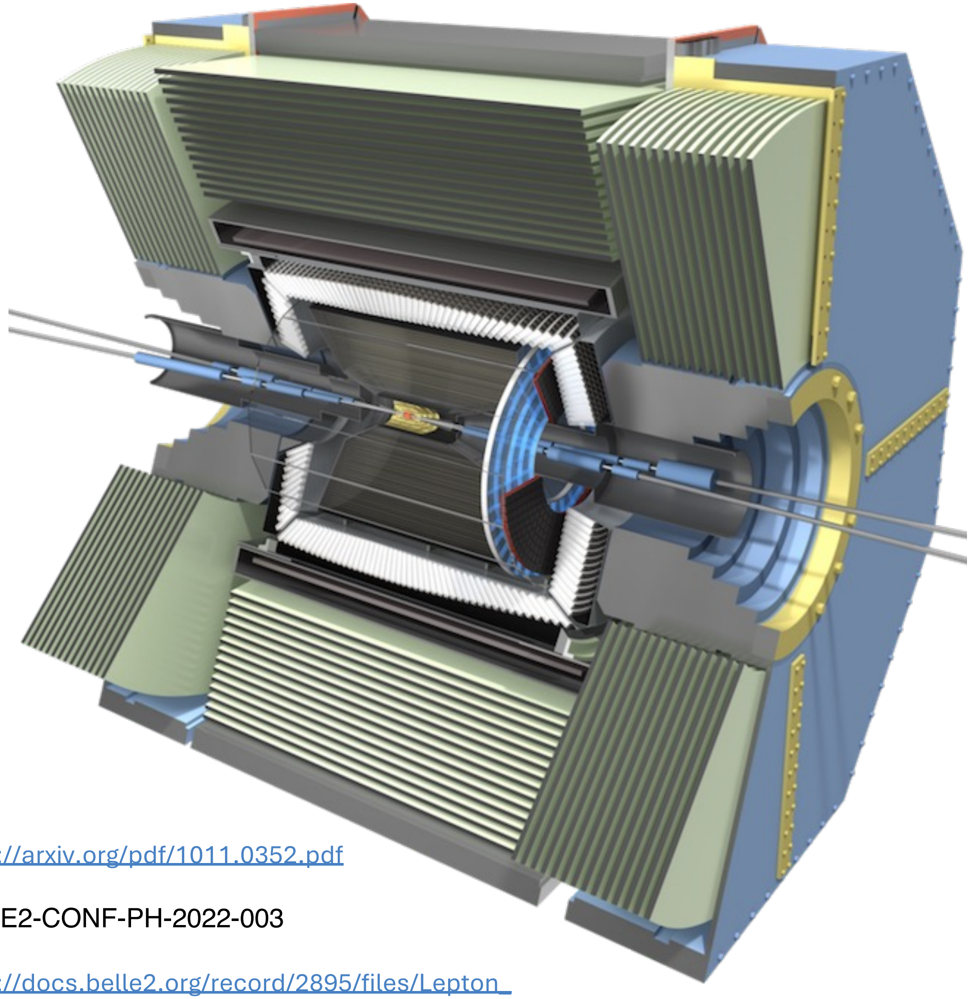

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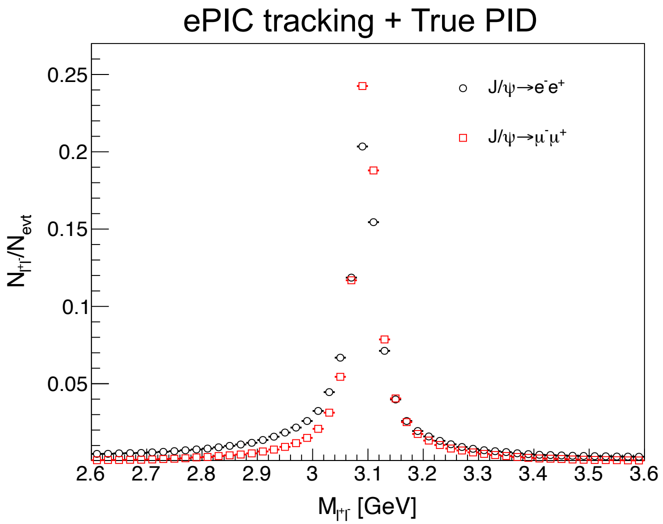


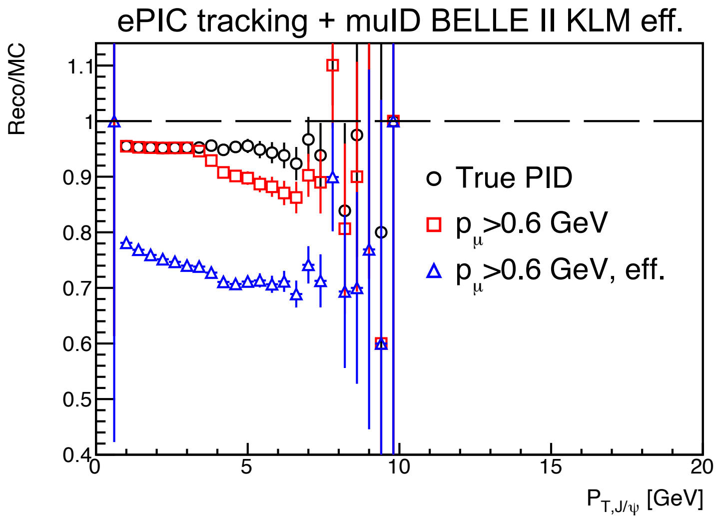


- Reduce ambiguity in quarkonium reconstruction
- Threshold muon momentum cut reduces reconstructed $J/\psi$ at p > 4 GeV
- Statistics are reduced by 15-20% after muon ID efficiency implementation
- Challenge: space limitation

https://arxiv.org/pdf/1011.0352.pdf

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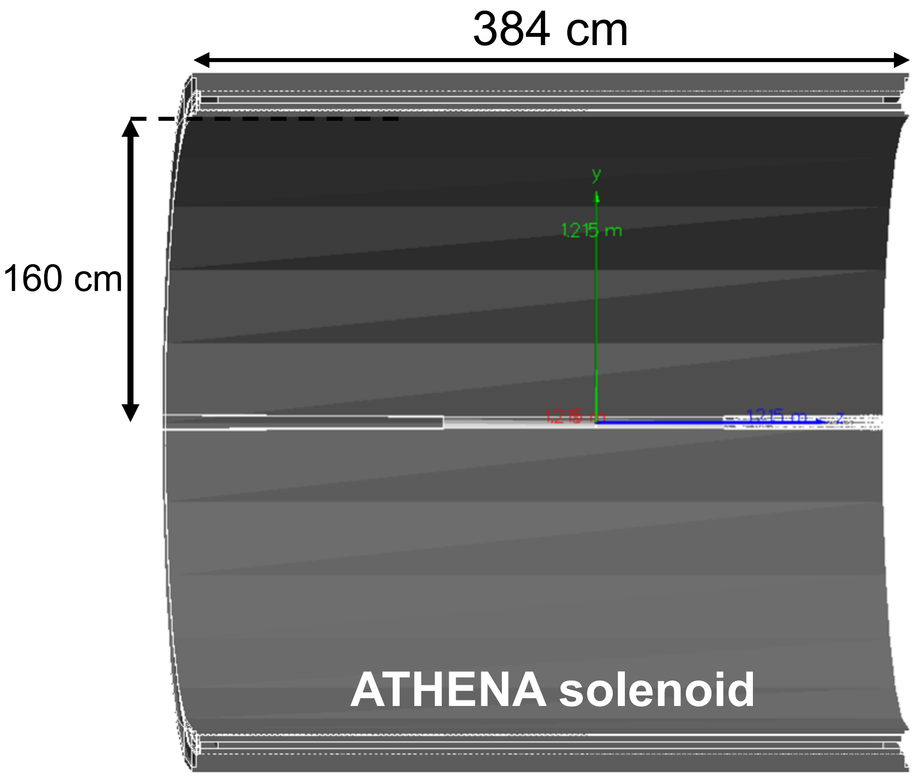
# Concepts of the 2nd Detector (Central) – Magnet

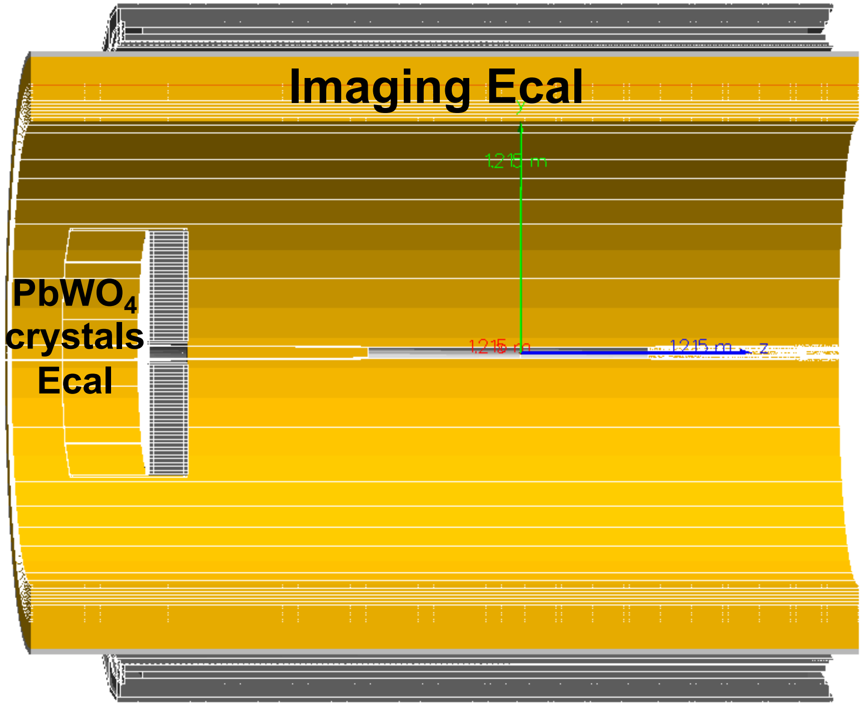
Hcal/muID not shown

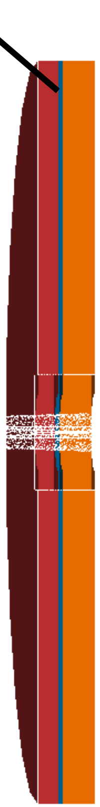



| ePIC | 2nd Detector |
| --- | --- |
| B=1.7 T | B=2T<br>improve momentum resolution |
| r=1.42 m | r=1.6 m<br>Lager inner volume |

# Concepts of the 2nd Detector (Central) – Ecal

Hcal/muID not shown



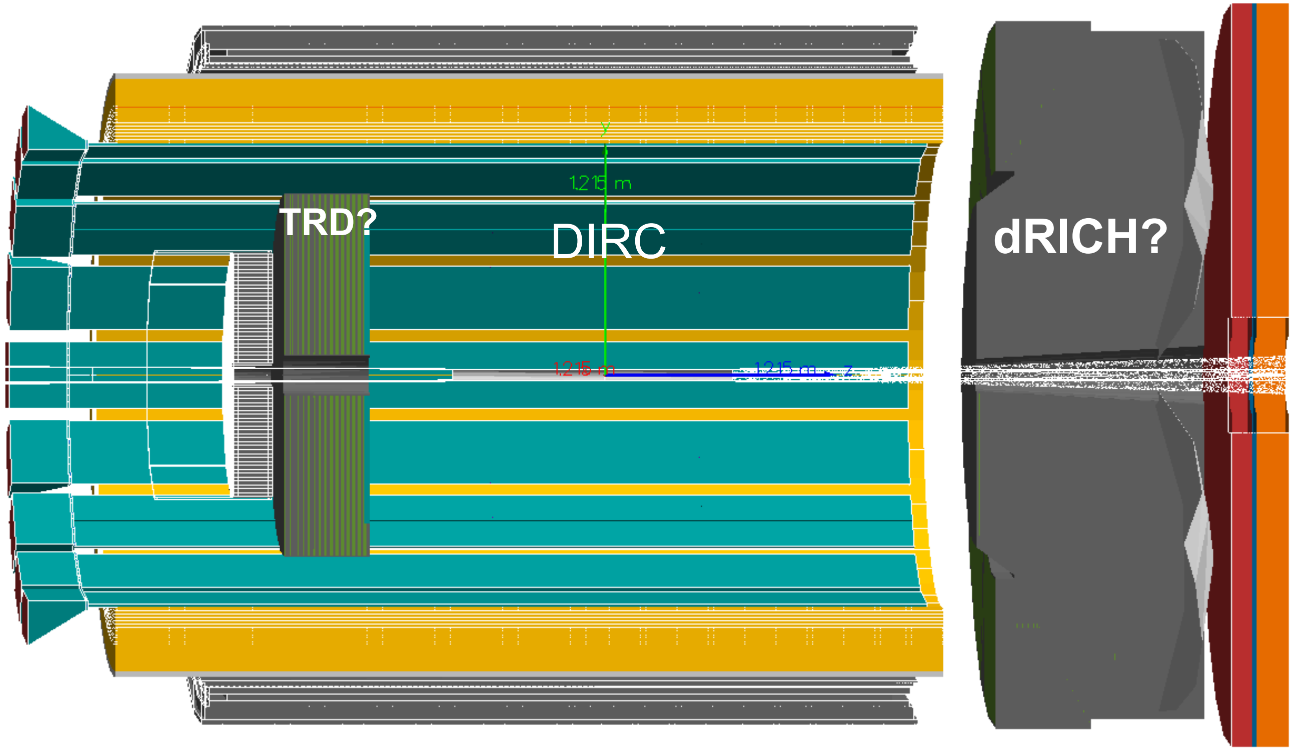




<u>Using the ePIC Ecal designs, currently</u>

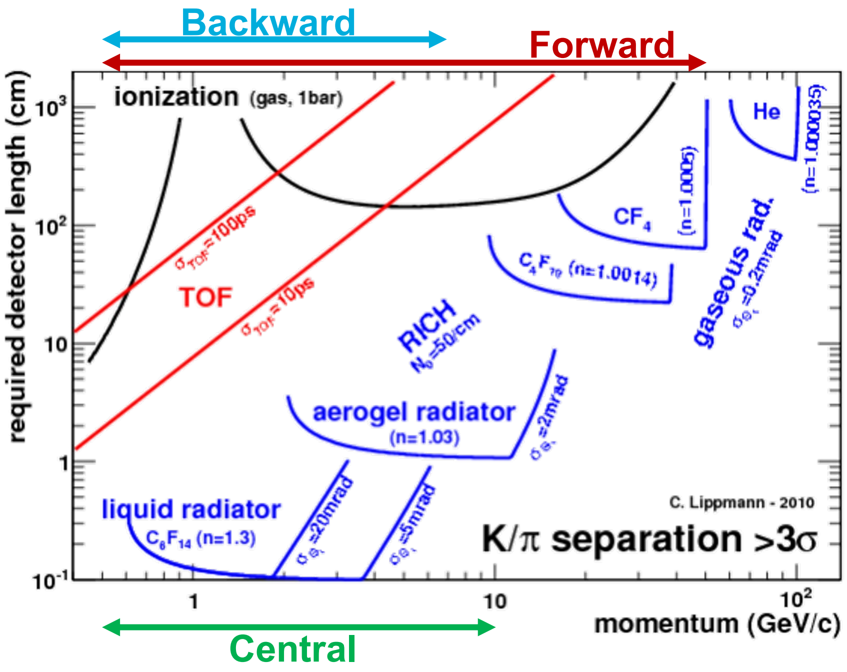
- Backward
  - Lead-tungsten crystals Ecal
  - Fine energy resolution (1-2%)
  - High pion suppression
- Central
  - 6 layers of imaging silicon sensors interleaved with 5 scintillating fiber/lead layer
  - A large section of scintillating fiber/lead layer at the outer radius
- Forward
  - Scintillating fiber/lead
  - Good pion/photon separation

# Concepts of the 2nd Detector (Central) – PID

Hcal/muID not shown

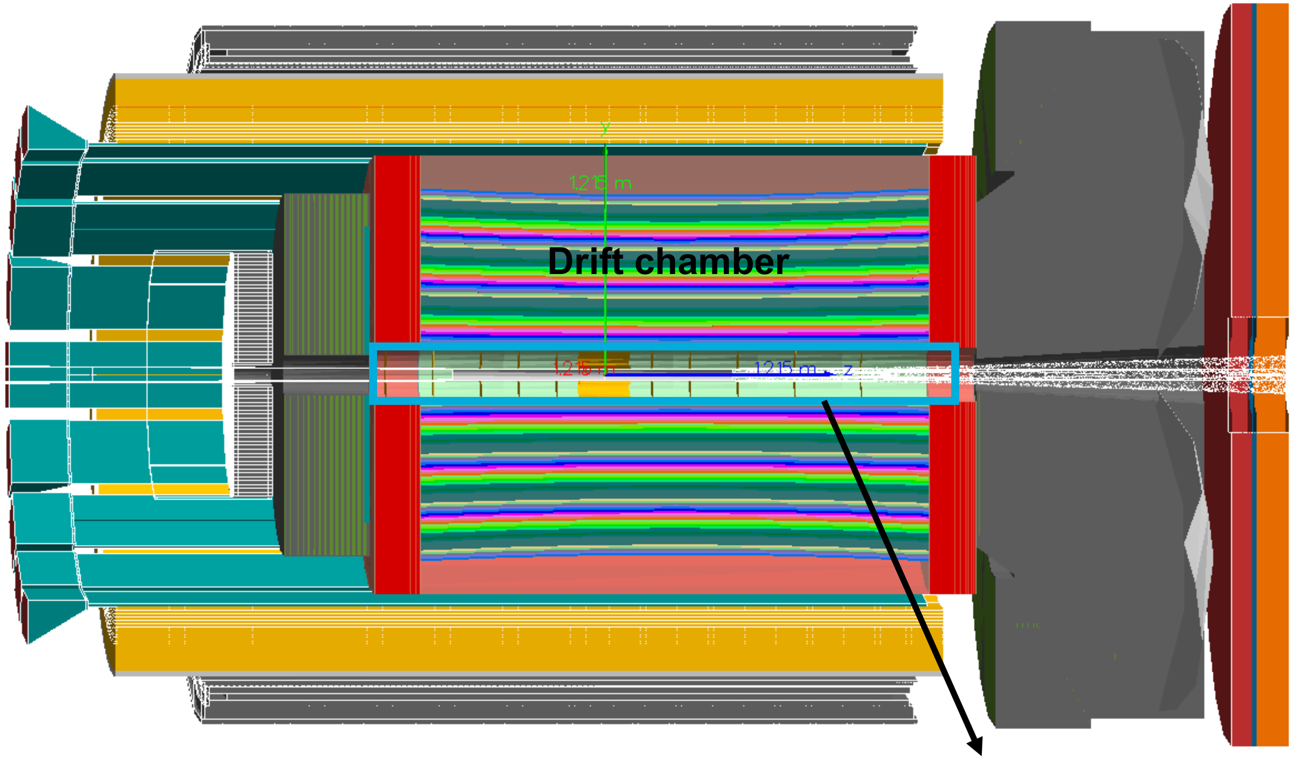



- Transition radiation detector in the backward region
  - Challenge: material budget
- Options for forward PID
  - Additional ToF for low p
  - Additional pfRICH
  - Different gas radiator
  - Challenge: space limitation



# Concepts of the 2nd Detector (Central) – Tracking

Hcal/muID not shown



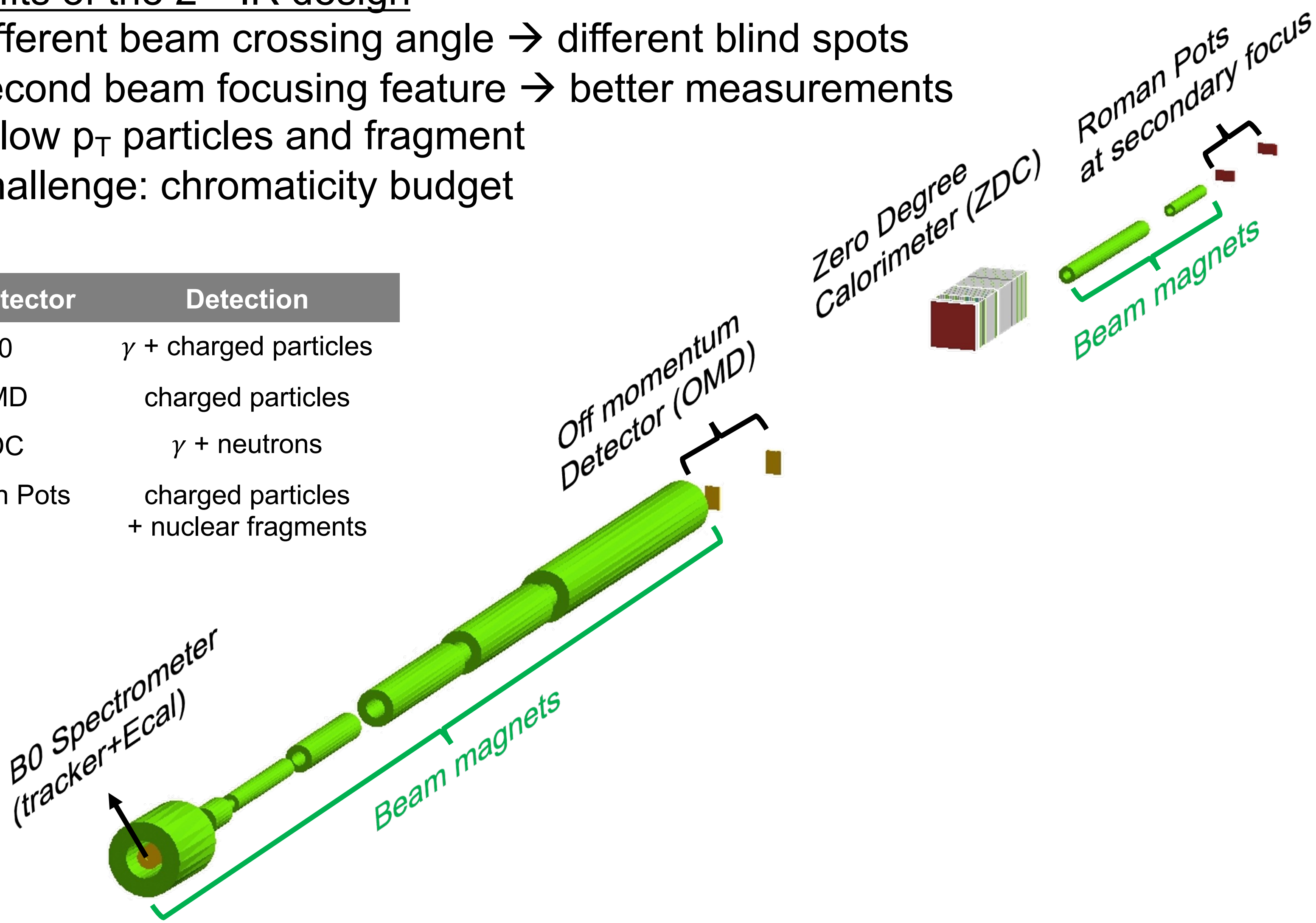

- Mixed-tracking technologies
  - Inner silicon tracker for vertexing
  - Large volume of non-silicon detector for tracking
- More hits for better pattern recognition, redundancy, and resistance against backgrounds
- Could provide PID at low momentum using dE/dx
- Examples:
  1. Gas detector (TPC or drift chamber)
  2. Scintillating fiber

# Concepts of the 2nd Detector (Far-Forward)

Benefits of the 2nd IR design

- Different beam crossing angle → different blind spots
- Second beam focusing feature → better measurements of low $p_T$ particles and fragment
- Challenge: chromaticity budget

| Subdetector | Detection |
| --- | --- |
| B0 | $\gamma$ + charged particles |
| OMD | charged particles |
| ZDC | $\gamma$ + neutrons |
| Roman Pots | charged particles + nuclear fragments |



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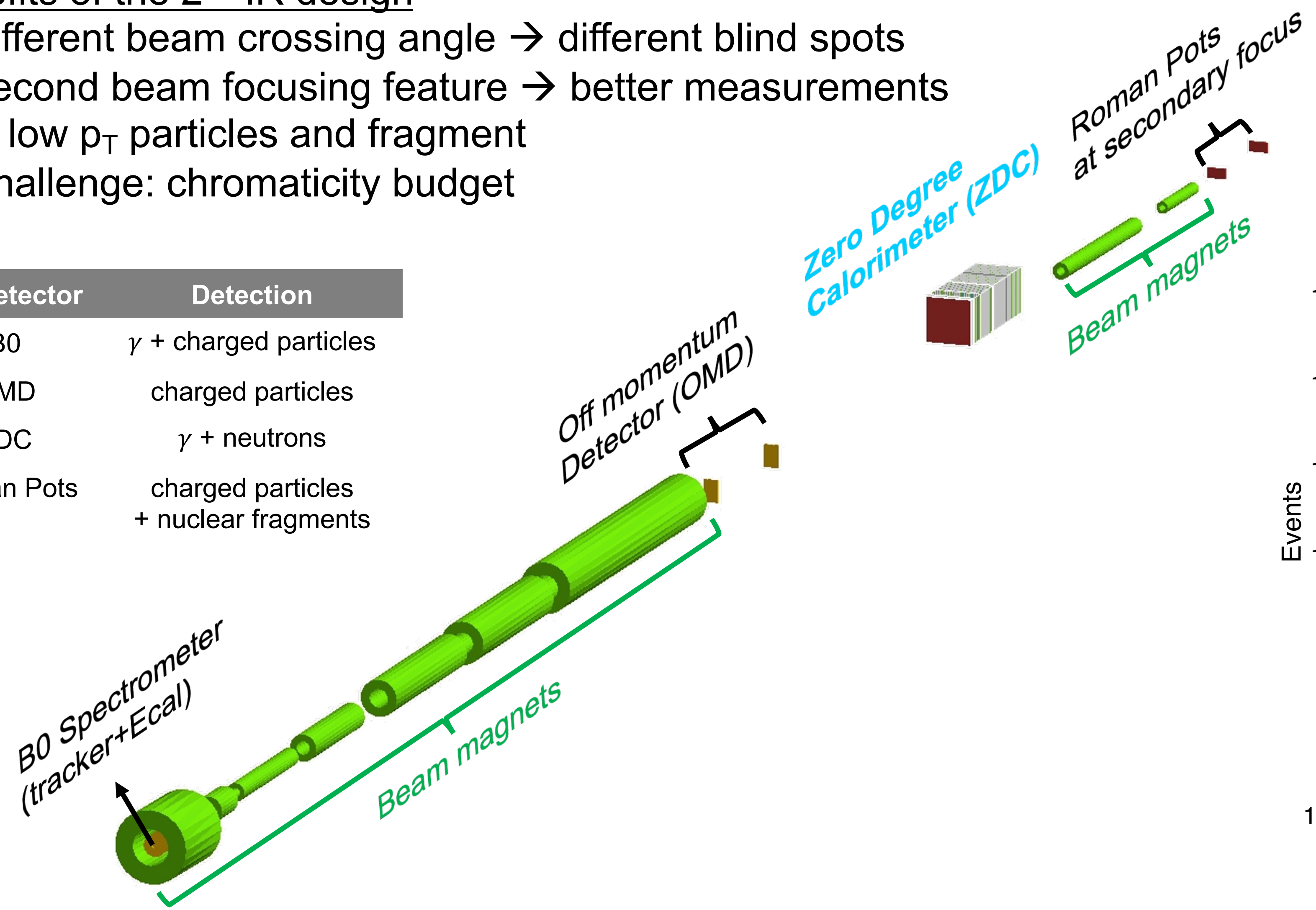


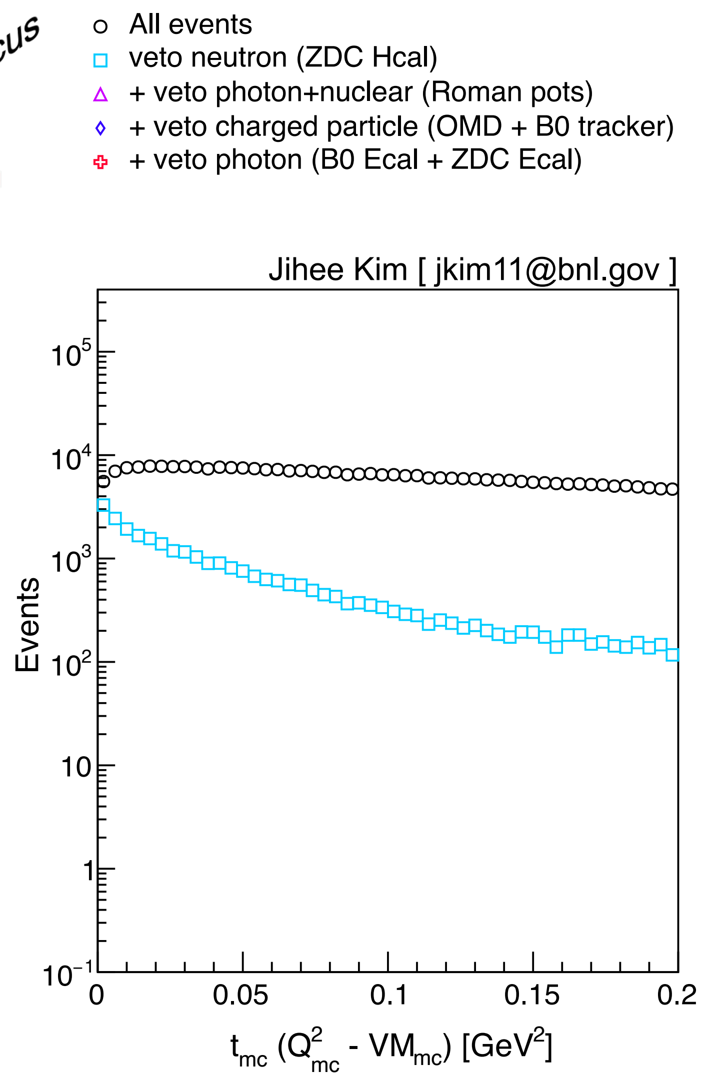

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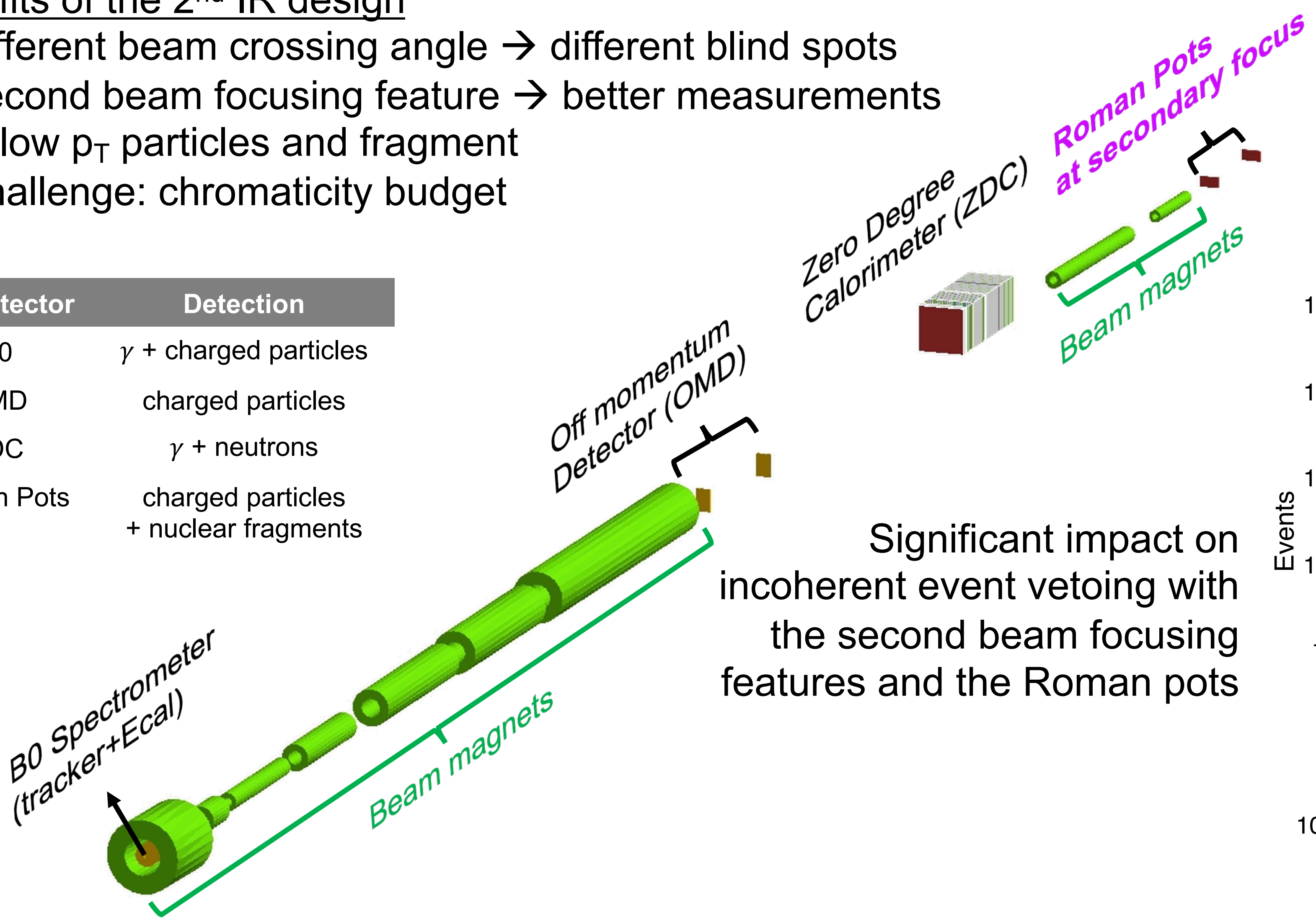
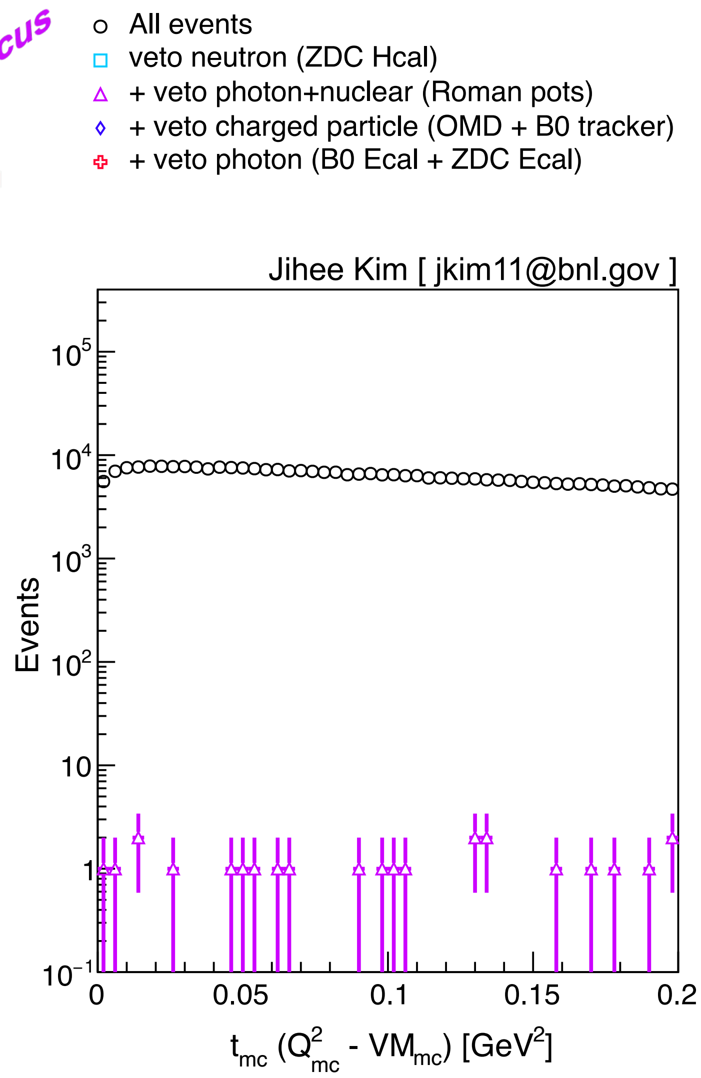



Significant impact on incoherent event vetoing with the second beam focusing features and the Roman pots



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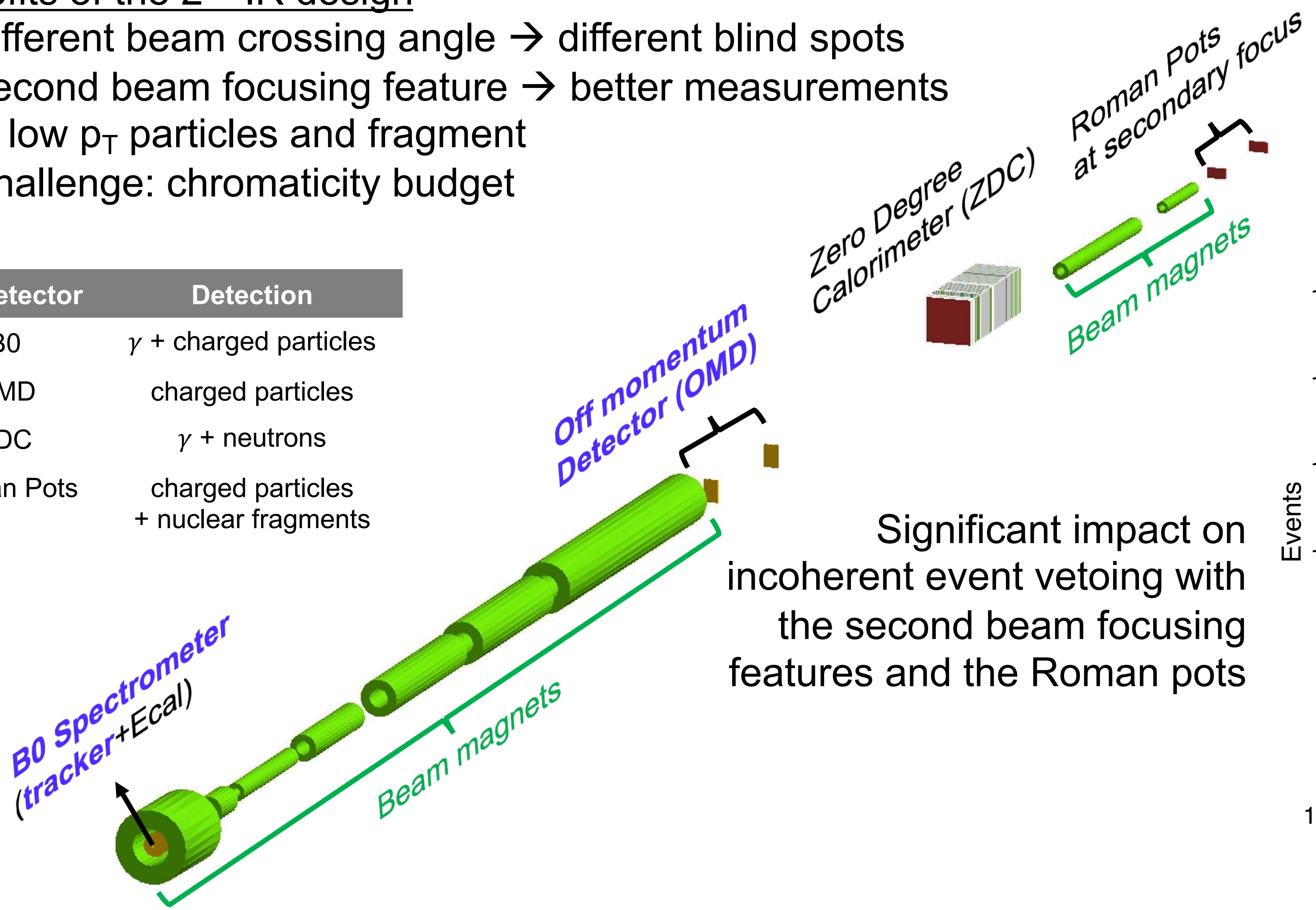


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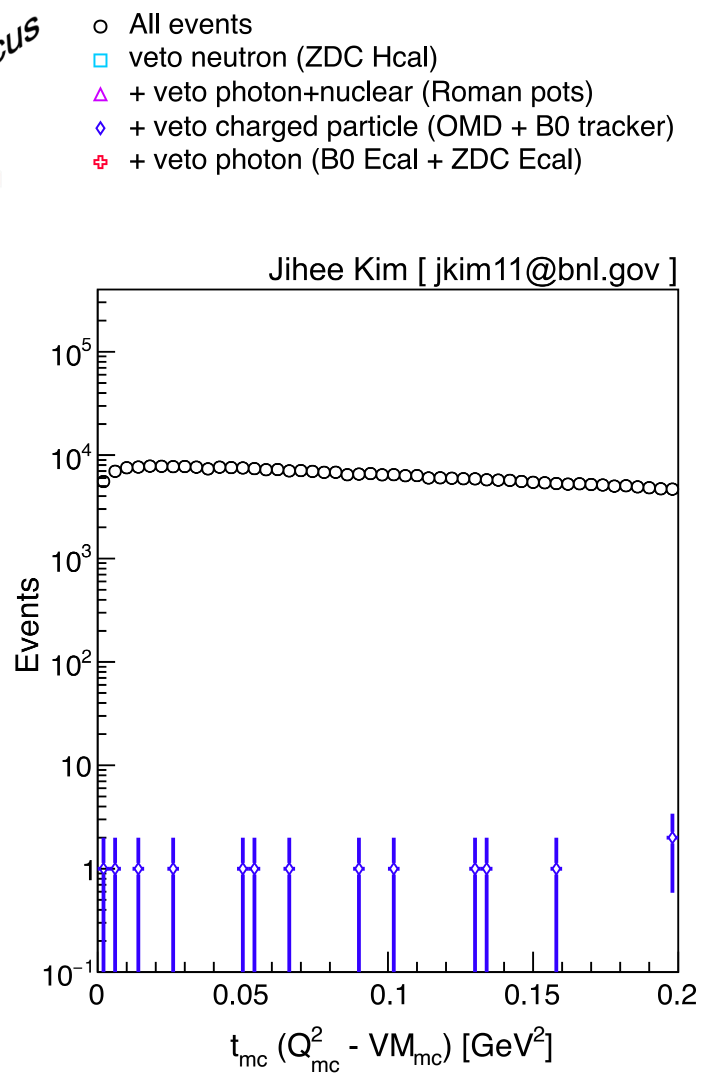

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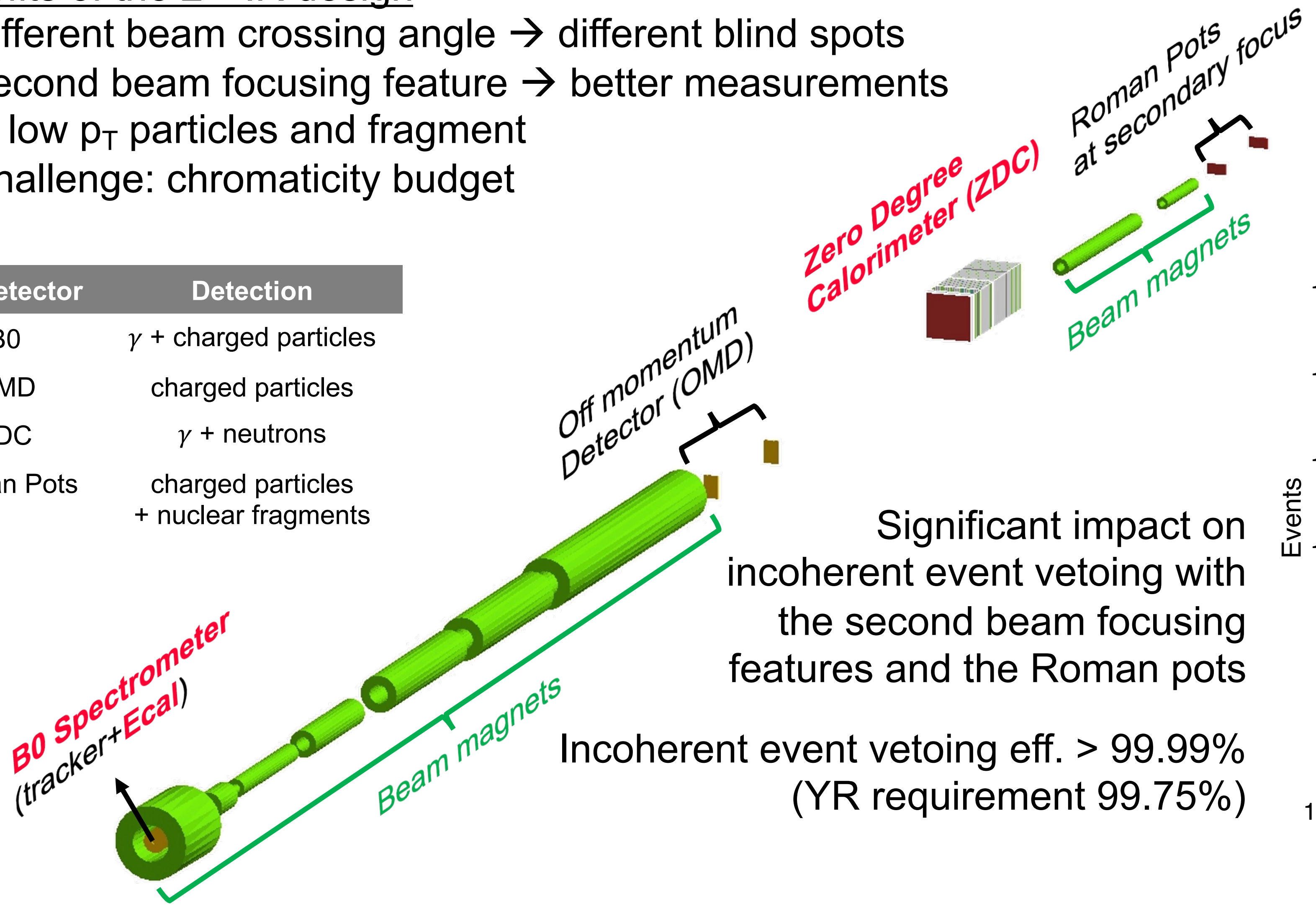
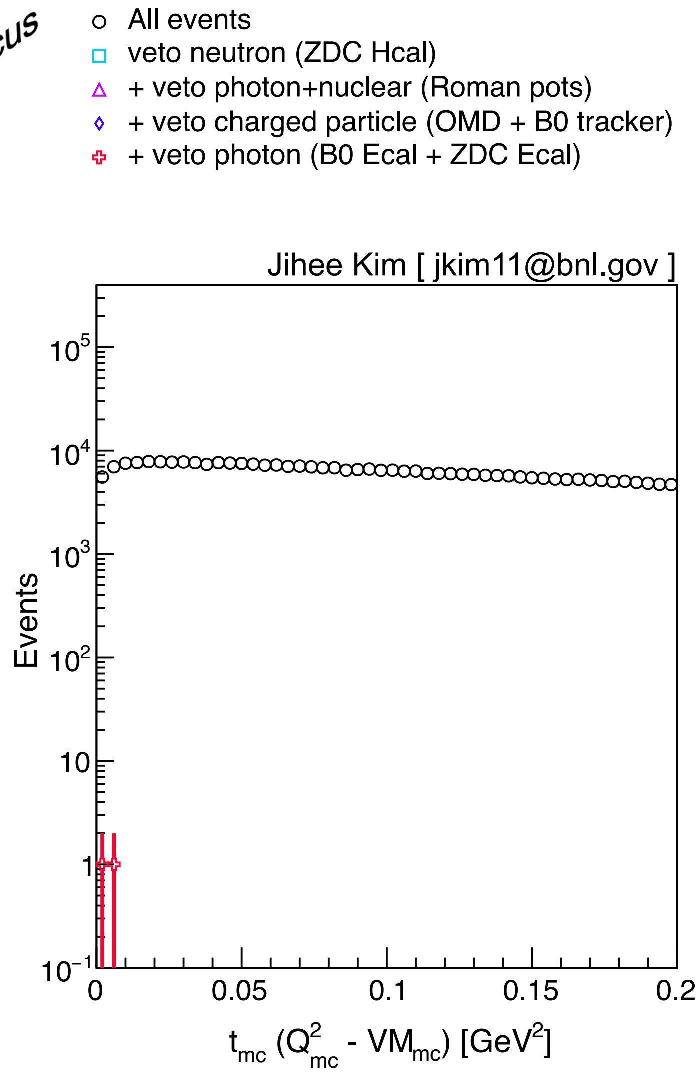



Significant impact on incoherent event vetoing with the second beam focusing features and the Roman pots

Incoherent event vetoing eff. > 99.99%
(YR requirement 99.75%)



# Summary

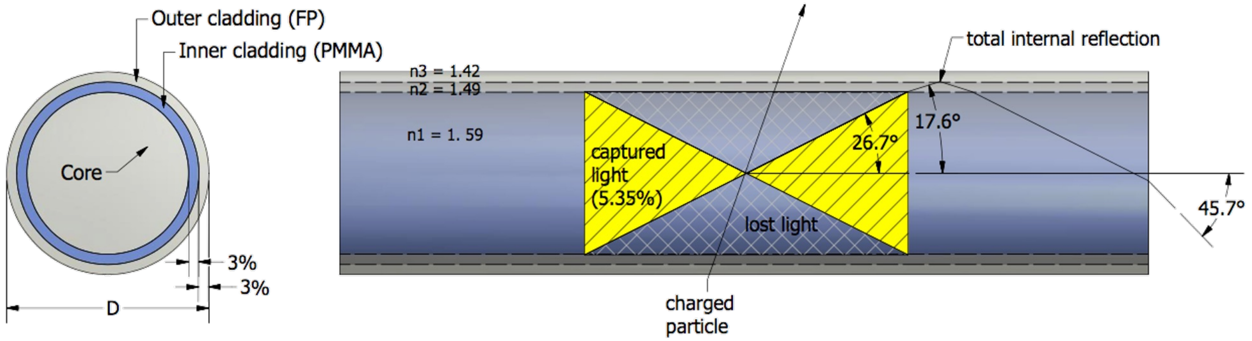
- A second detector is **essential** for the EIC experiments
  - Cross checking
  - Cross Calibration
- A second detector should provide **complementarity** to ePIC
  - Stronger magnet
  - Muon ID
  - Mixed-technology tracking system
  - Different IR design
  - Options of Ecal and PID?

# Back Up

LHCb: arXiv:2305.10515
CERN-DRDC-2024-001

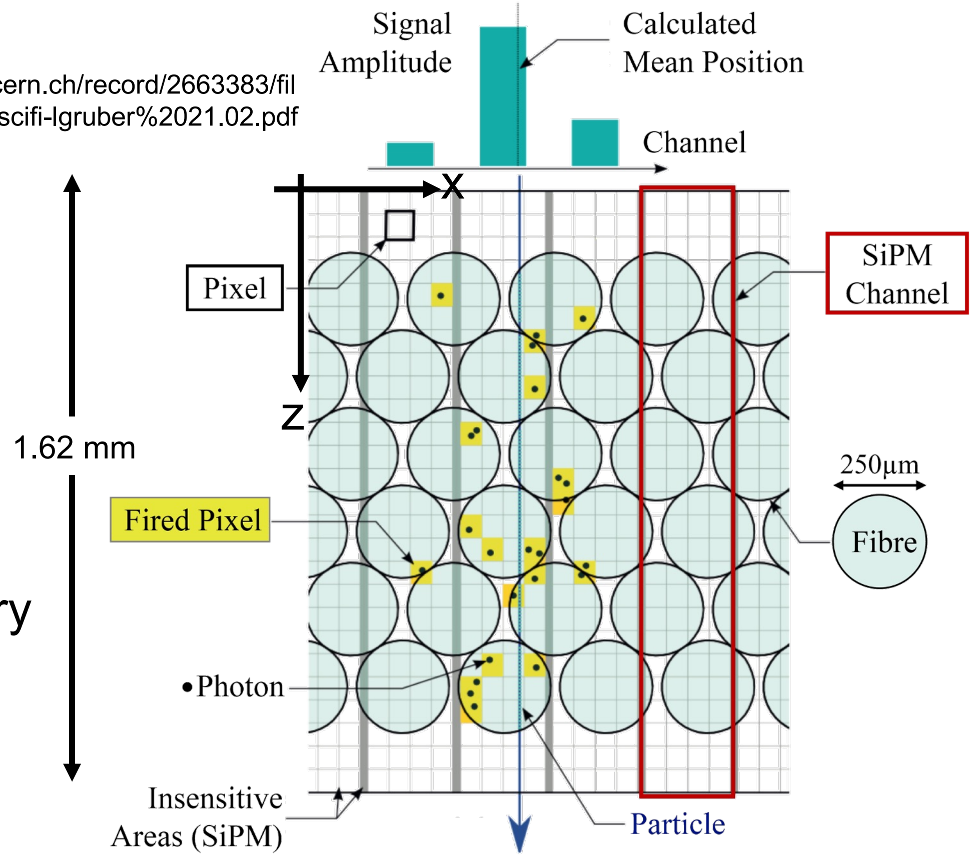
# Scintillating Fiber (LHCb)

Double-clad polystyrene fiber
- D=250 um → hit pos. res. < 70 um
- 8k photons per MeV of ionization energy
- Excited electron decay times=2.4 ns
- Attenuation length~3.5 m




Hamamatsu SiPM (MPPC S13552 – H2017)
- Pixel size ~ 60 um
- <10% noise cluster rate with front-end clustering and -50 ℃ cooling using Novec

https://cds.cern.ch/record/2663383/files/vci2019-scifi-lgruber%2021.02.pdf

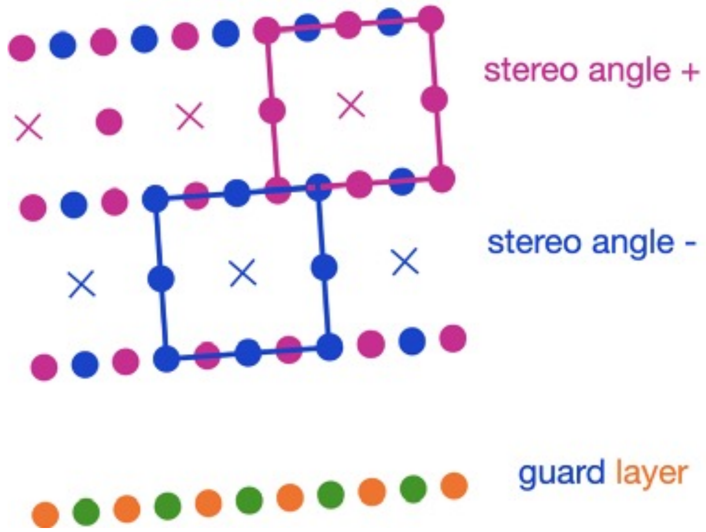



Material budget=1.1% x 12 layers

Technology advancement
- Scintillating fiber with improved radiation hardness
- Modify claddings to boost light yield
- Cryogenic cooled SiPMs with microlenses for light recovery

IDEA: EPJ Plus (2022) 137:231
MEG II: NIMA 936 (2019) 501

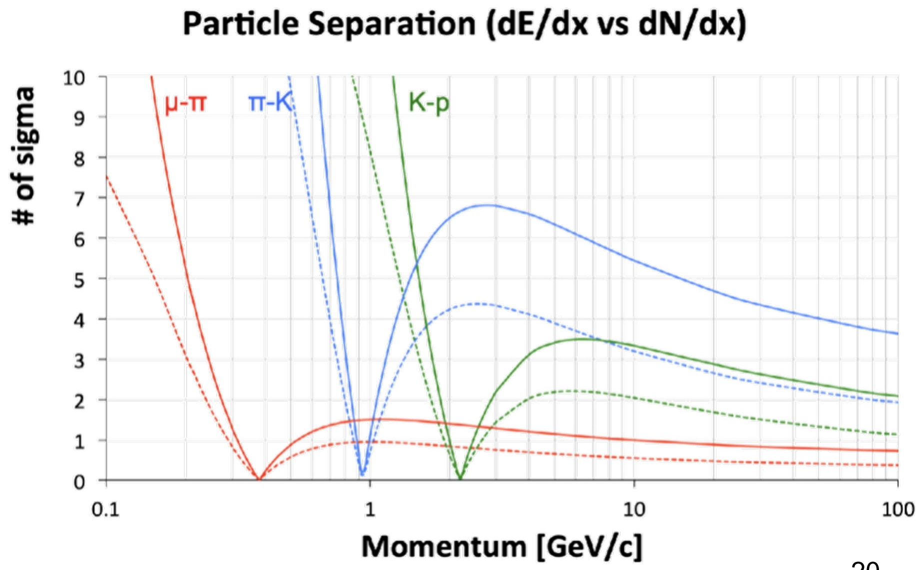
# Drift Chamber (IDEA/MEG II)




<u>Reduction of material</u>
by storing helium gas in the wire support endplates
IDEA: $0.016X_0$ ($0.05X_0$) in the barrel (forward and backward) region

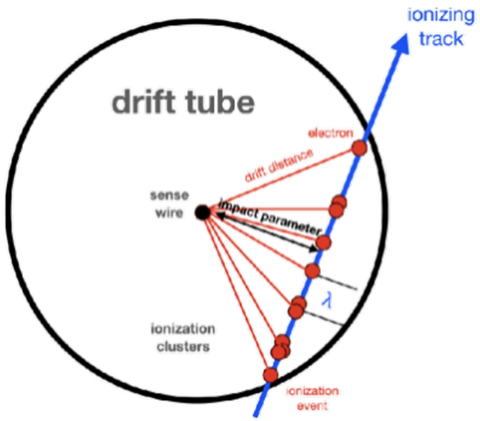
<u>More uniform equipotential surface</u>
A high ratio of the field to sense wires and a high wire density by enmeshes the positive and negative stereo angle orientations
IDEA: 4 m long, r = 35-200 cm, 400k wires, res ~ 100 um

<u>PID capability</u> with the cluster counting method
Adding timing information to the wires to count individual ionizing events of the traversing track and dE/dx information




Technology advancements

- Carbon-fiber wire vs tungsten wire reduce $X/X_0$ by a factor of 5
- Low - mass service/cooling structures
- See Andy's slides from last week




Brookhaven National Laboratory

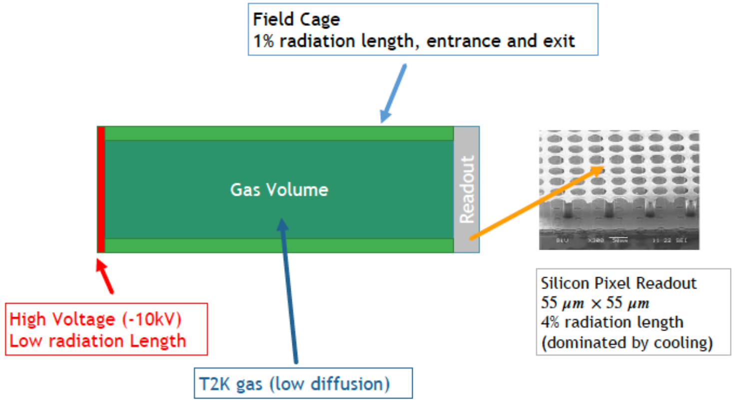
Cheuk-Ping Wong

# TPC/mini TPC

## GridPIX aka miniTPC

https://indico.bnl.gov/event/18414/contributions/76157/attachments/47563/80668/EIC_Technology_Inventory_Temple.pdf

- Basic idea: Small $\Delta R$ TPC with Si Pixel readout on one endcap
  - PID ($\pi - K - p$) from 100 MeV/c to 800 MeV/c
  - Tracking with large number of hits (pattern recognition)
  - Works only in barrel (field!)
- GridPIX
  - Avalanche grid in front of 55 x 55 $\mu m^2$ pixels.
  - >90% efficiency for single electrons.
  - Small area is not particularly expensive: 1800 chips (order/produce/test 3600) = $716k
  - Careful: 1.2-5.4 kW of power
  - Services bulky: Gas, power, cooling
  - Realistic $X/X_0$?




Reality check:
- Very compelling for D2
- Provided tracking an dE/dx (compare with ToF/AC-LGAD)
- Excellent Pattern recognition
- Less sensitive to backgrounds
- Generic R&D ongoing
- Need to see concrete prototype