Brookhaven National Laboratory

U.S. DEPARTMENT OF ENERGY

Discovery through Complementarity – The EIC 2nd Detector

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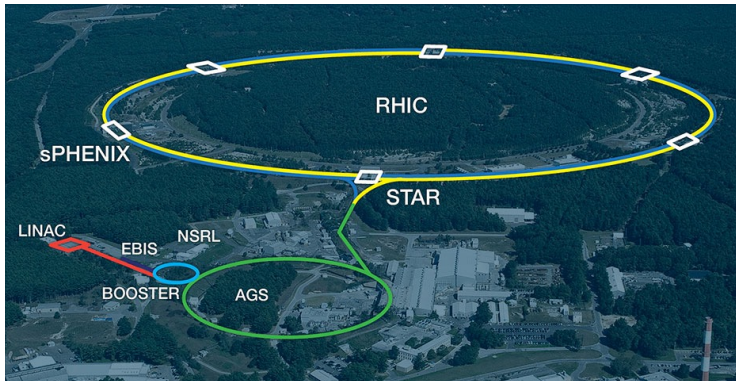
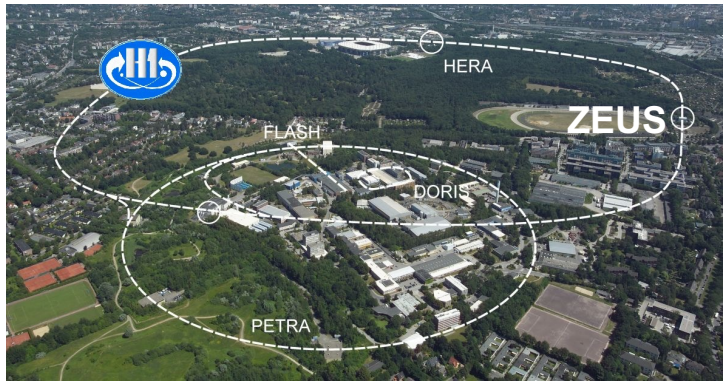
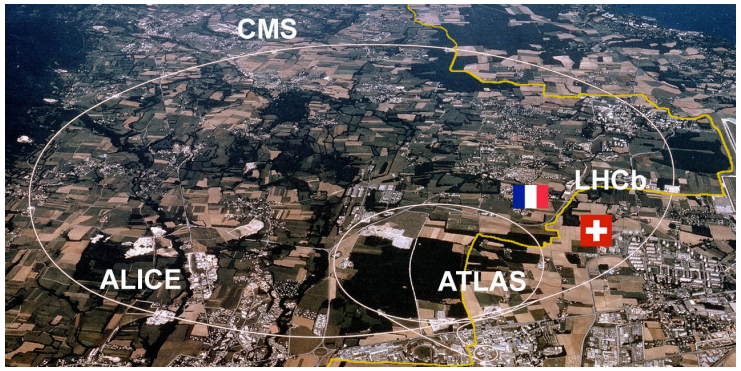
APS DNP meeting, 10-08-2024

@BrookhavenLab

The Tales of Two Detectors







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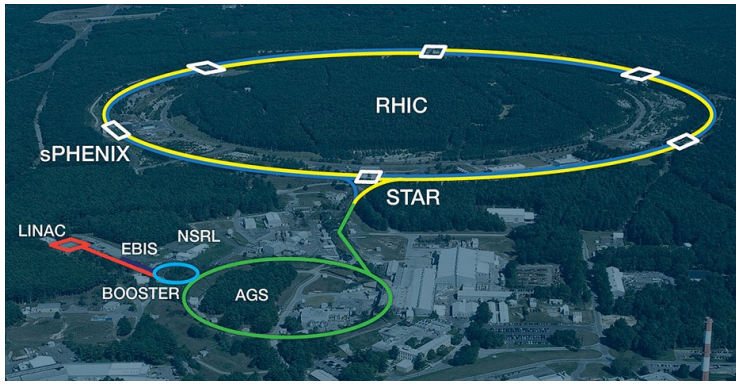
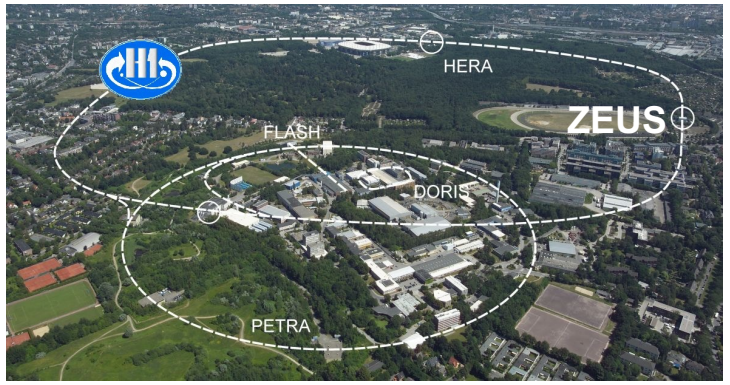
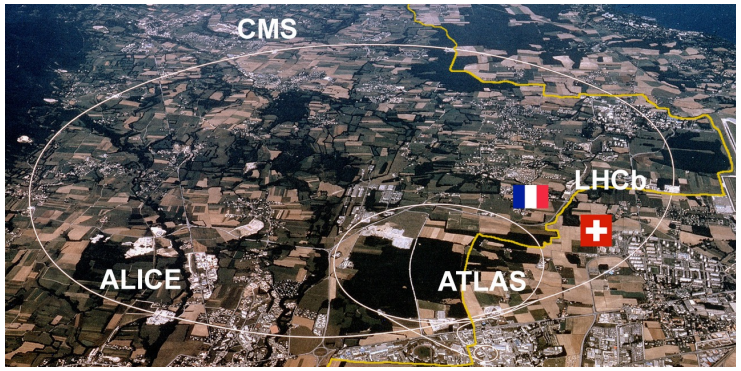
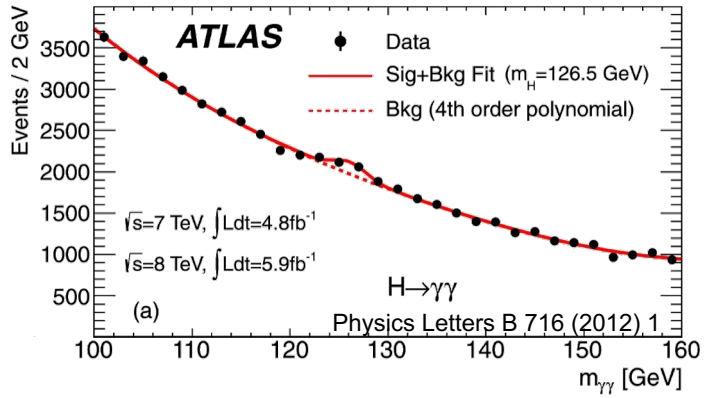


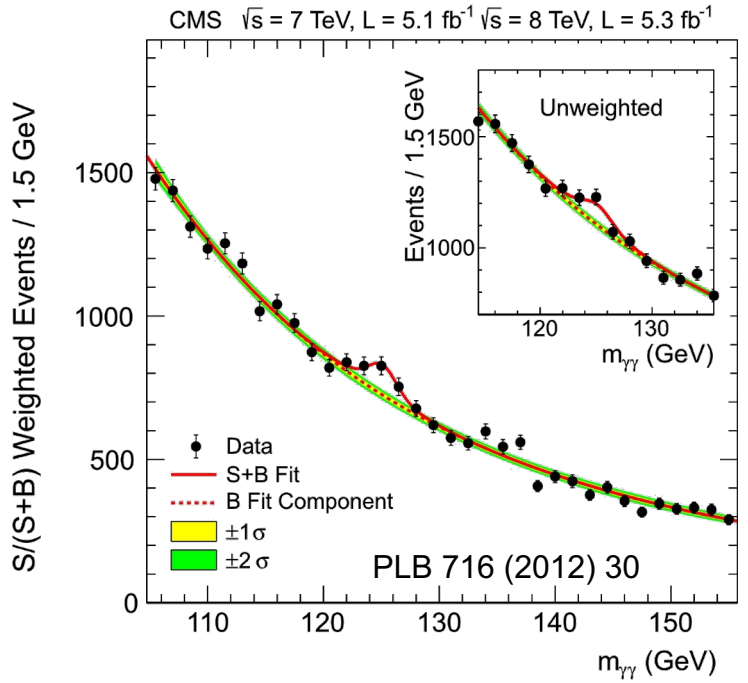




- Cross-checking → validate discoveries

Discovery of Higgs





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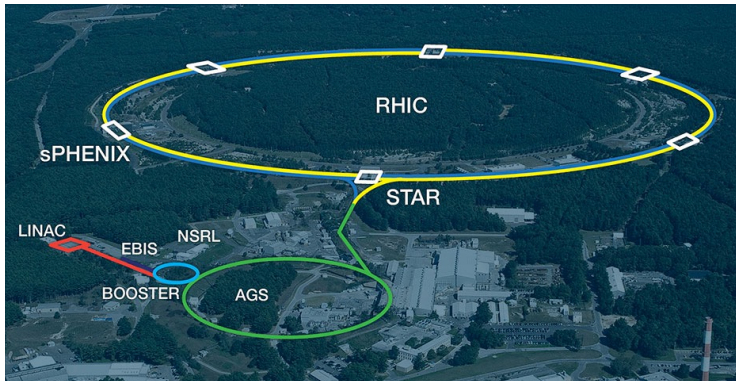

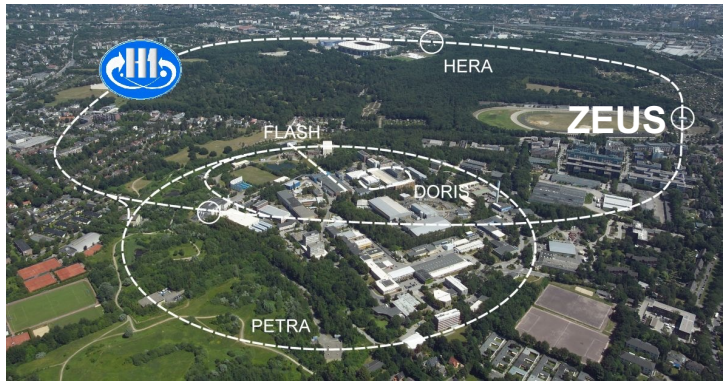

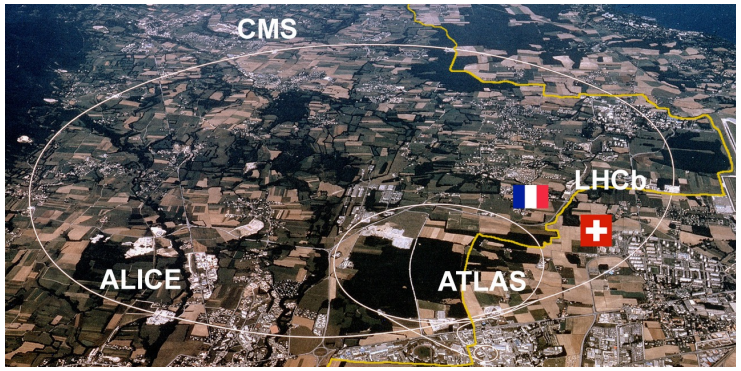

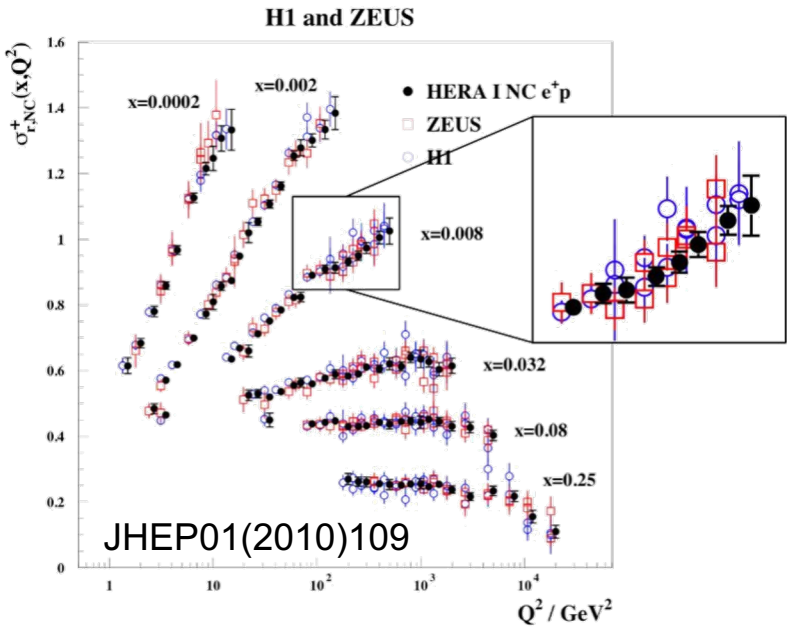

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- Cross Calibration → better control of uncertainty

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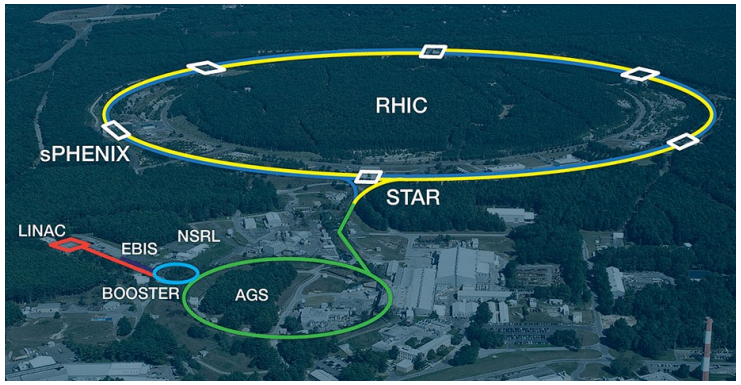
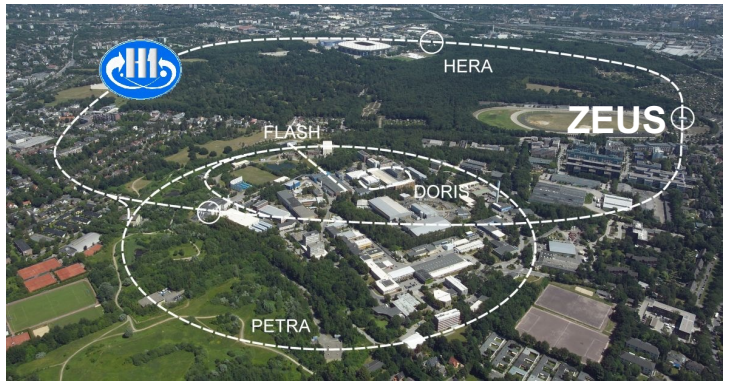
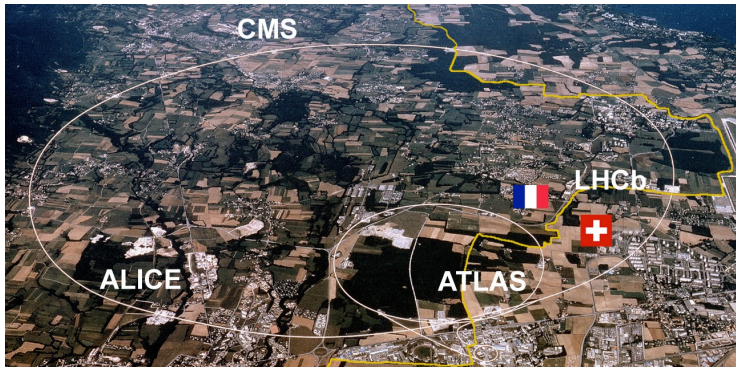
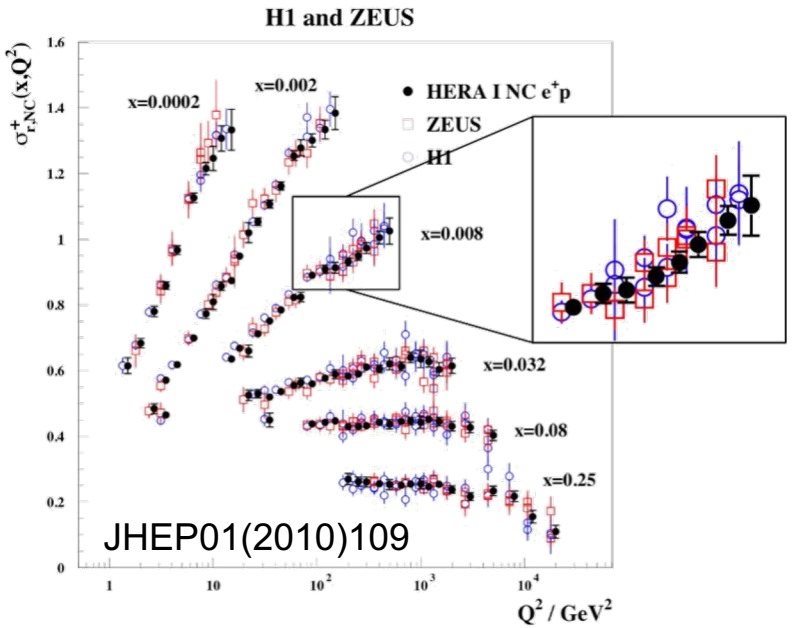




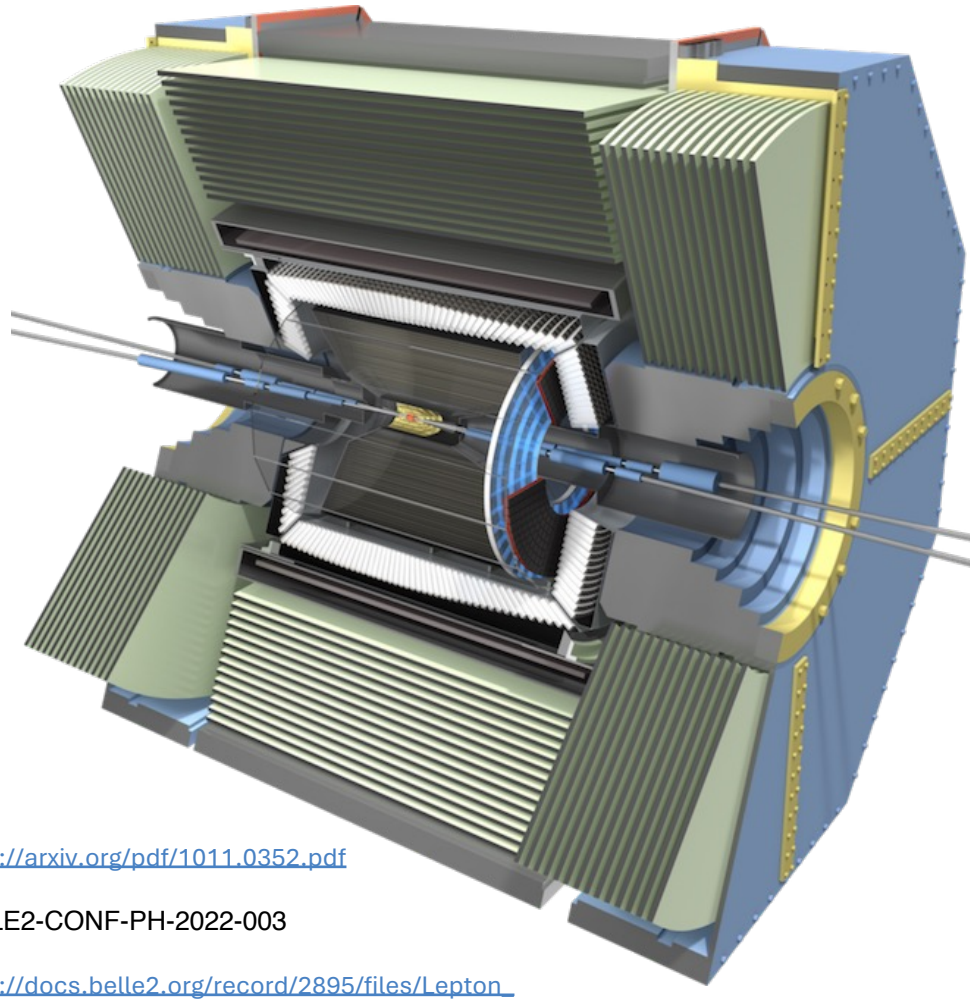




- Cross-checking → validate discoveries
- Cross Calibration → better control of uncertainty
- Different physics focuses
- Technology Redundancy

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

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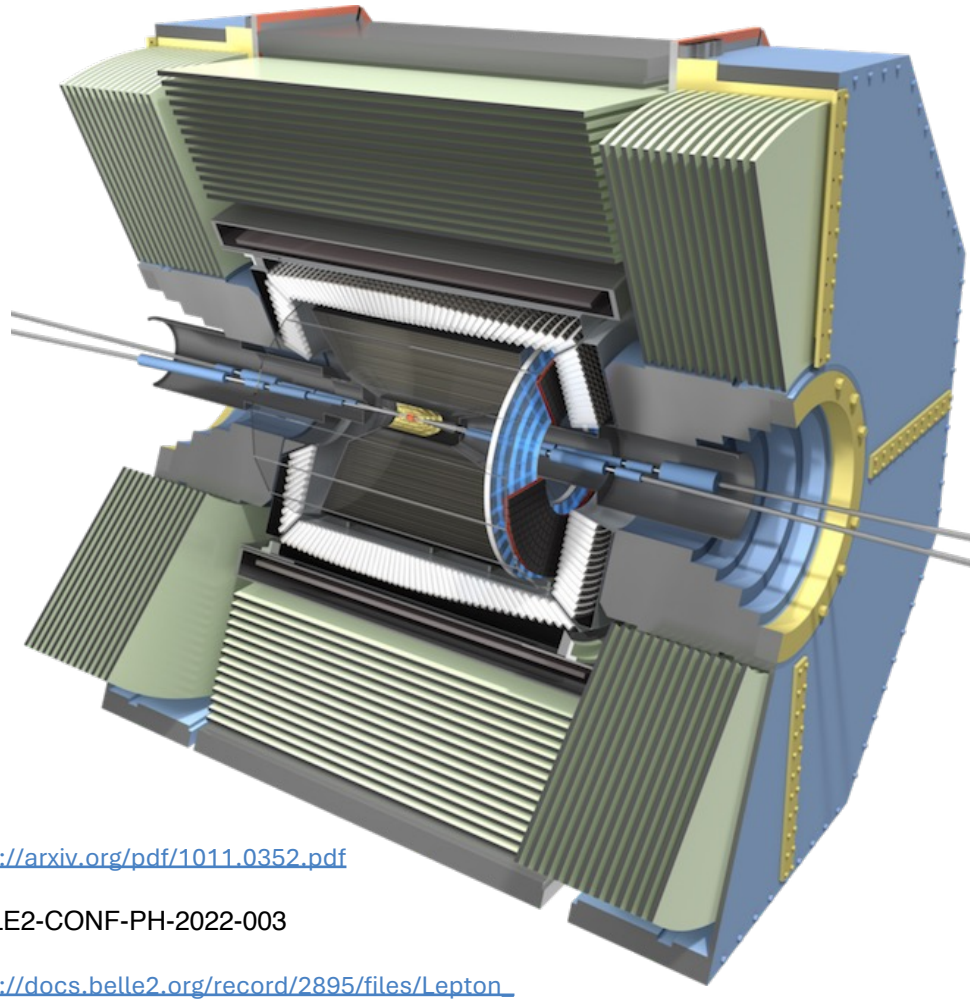

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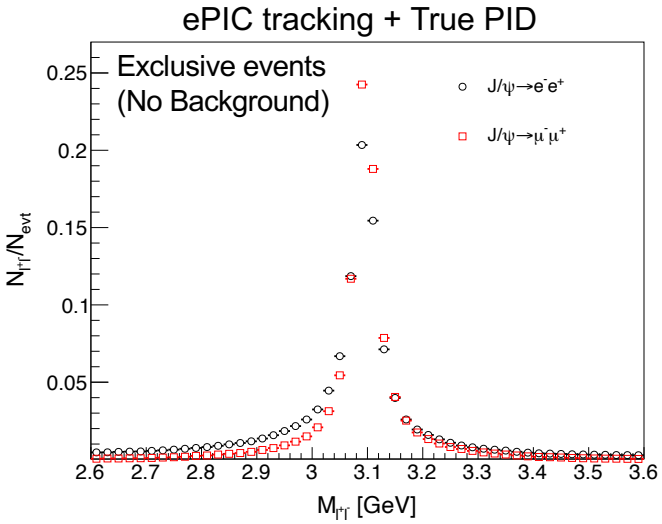

- Reduce ambiguity in quarkonium reconstruction

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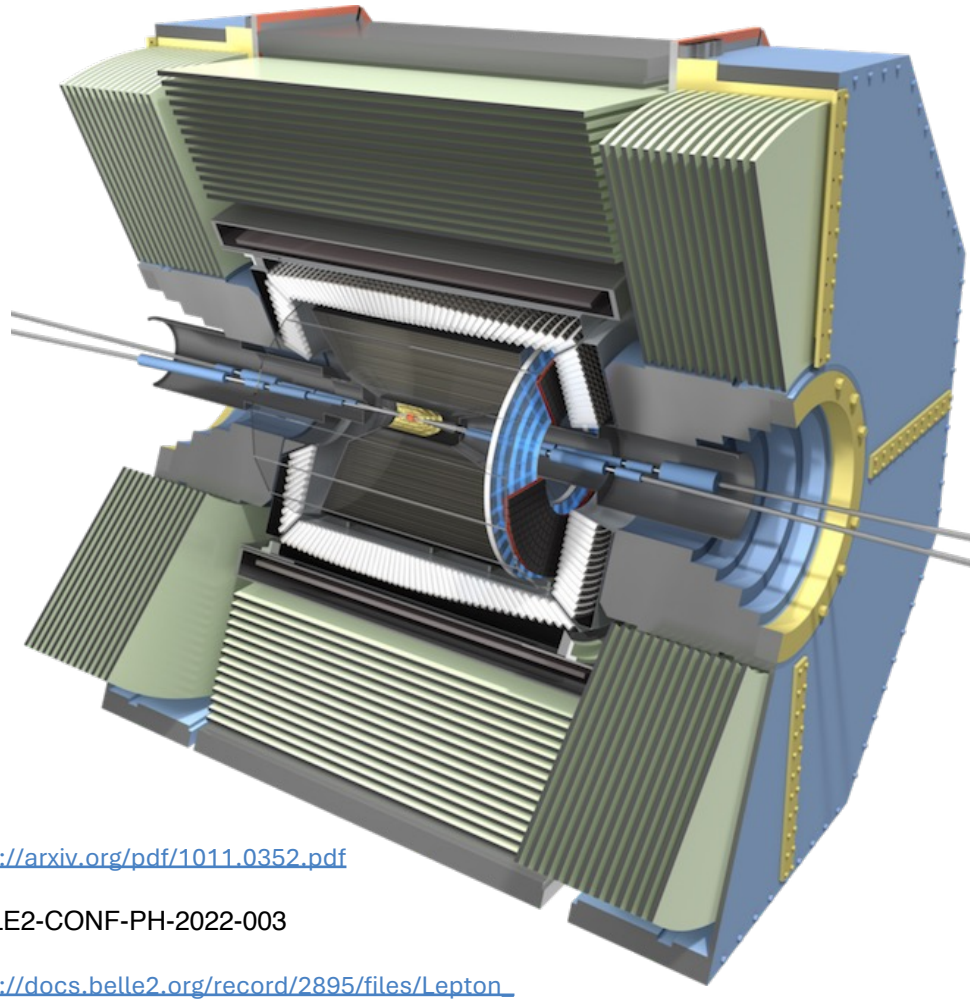

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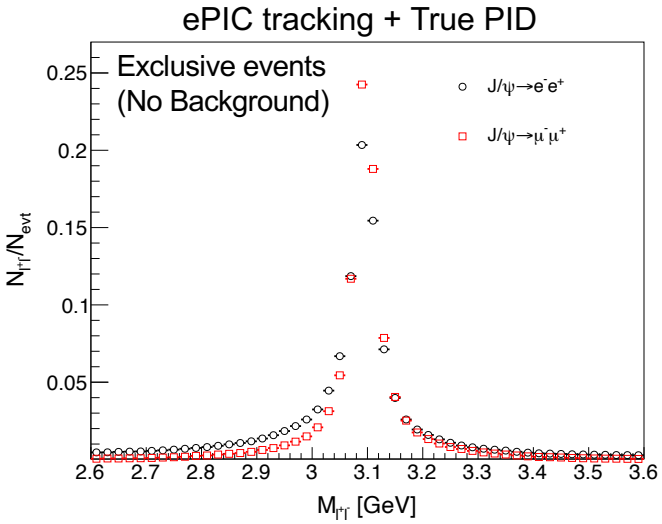
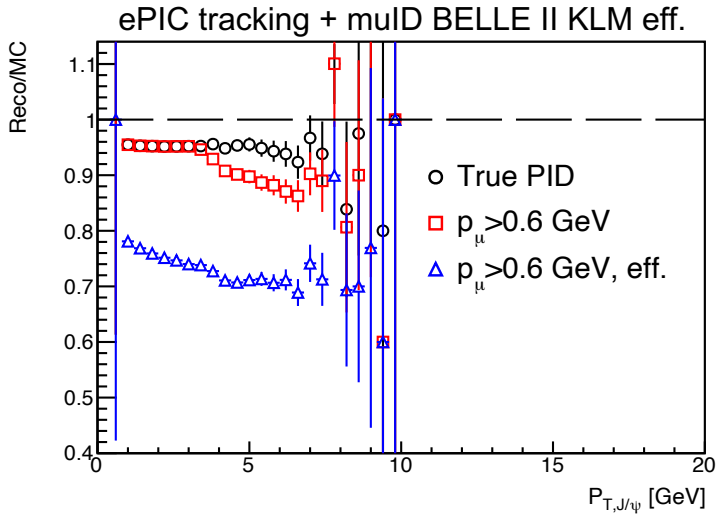
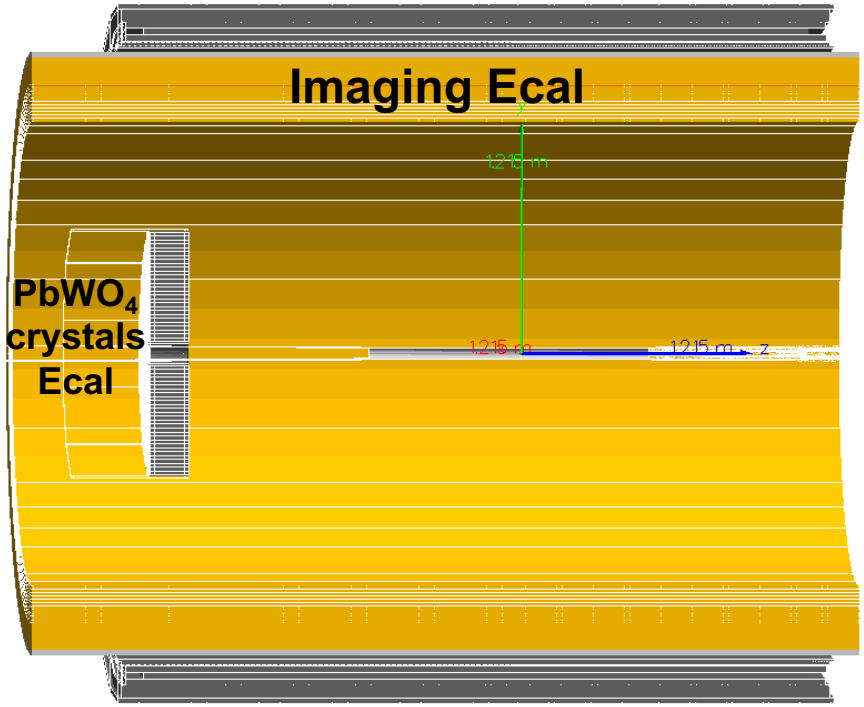




- Reduce ambiguity in quarkonium reconstruction
- Threshold muon momentum cut reduces reconstructed J/ψ at p > 4 GeV
- Efficiency reduced by 15-20% after muon ID smearing
- Challenge: space limitation

Concepts of the 2nd Detector (Central) – Ecal

Hcal/muID not shown



Scintillating Fiber Ecal

Using the ePIC Ecal designs, currently

- Backward
  - Lead-tungsten crystals Ecal
  - Fine energy resolution (1-2%)
  - High pion suppression (1 in 10^4 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
  - Fine spatial resolution for pion/photon separation (SiPM pixel size of 6x6 mm^2)

Concepts of the 2nd Detector (Central) – PID

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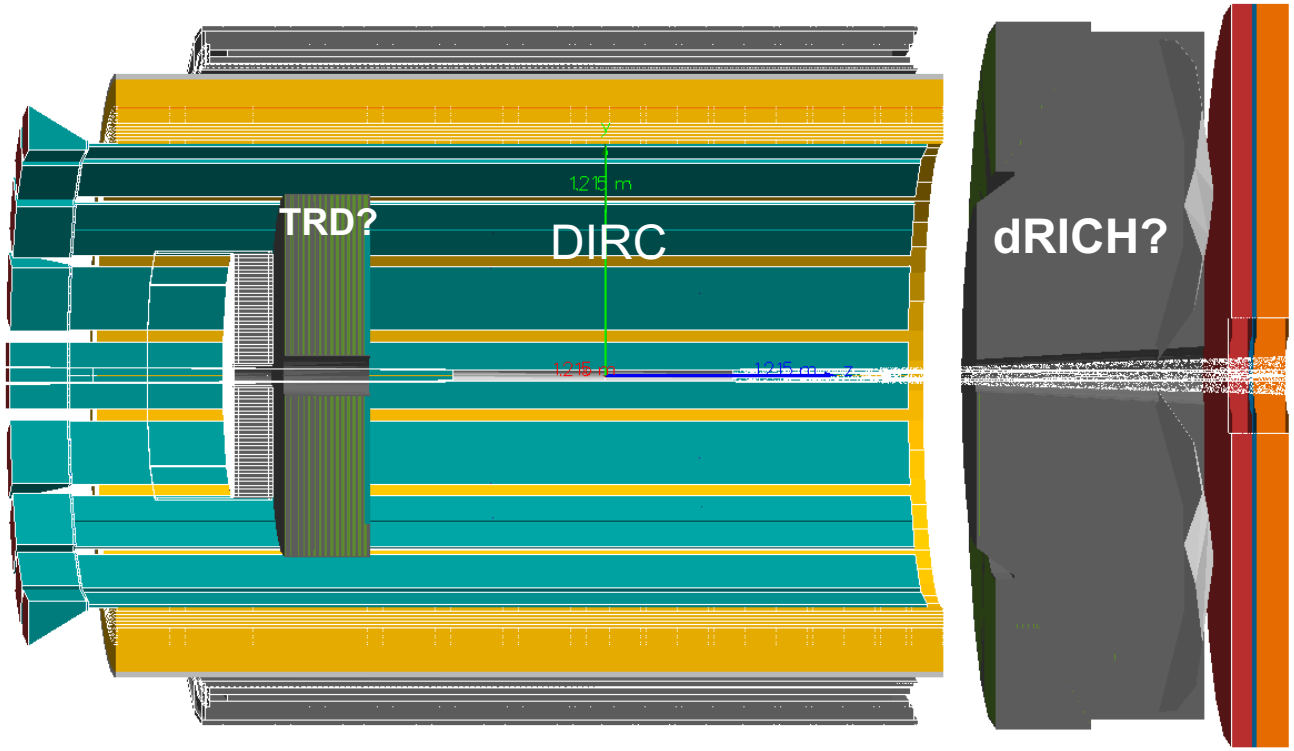
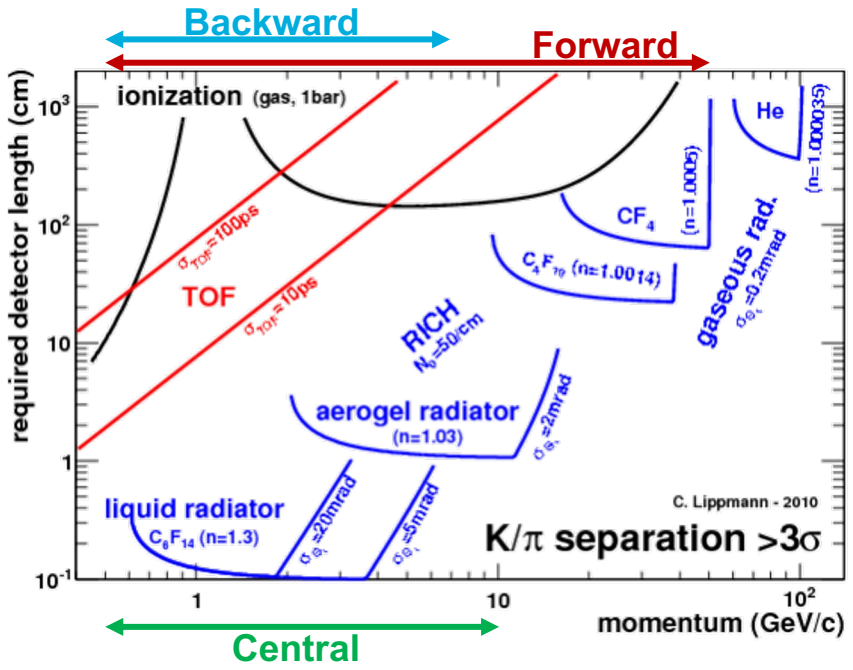
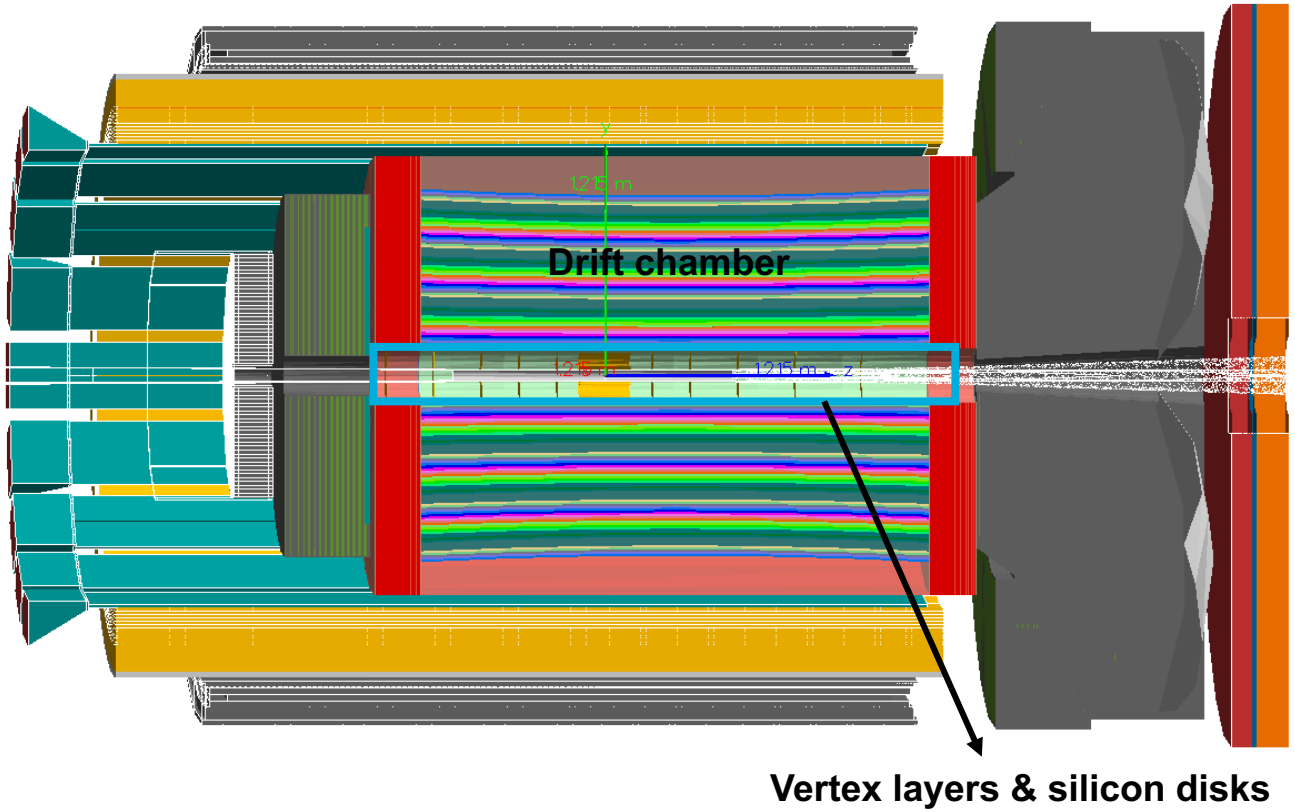


- Transition radiation detector in the backward region
  - Challenge: material budget
- Options for forward PID
  - Low+high momentum detector
  - Different gas radiator
  - Challenge: space limitation

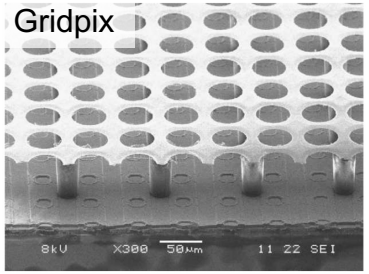


Concepts of the 2nd Detector (Central) – Tracking

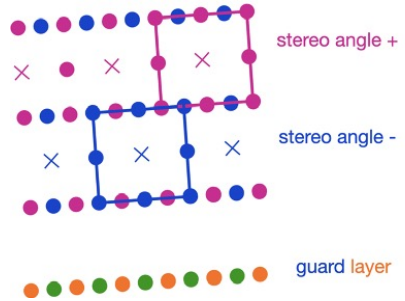
Hcal/muID not shown

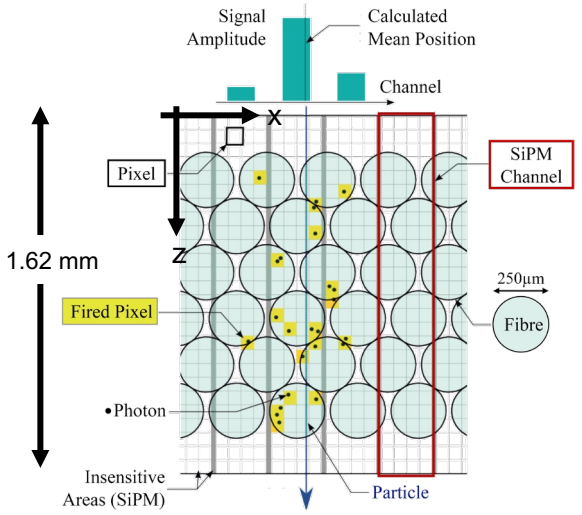


- Mixed-tracking technologies
  - Inner silicon tracker for vertexing
  - Large volume of non-silicon detector for tracking, e.g.
    1. Gas detector (TPC or drift chamber)
    2. Scintillating fiber



IDEA drift chamber





LHCb SciFi

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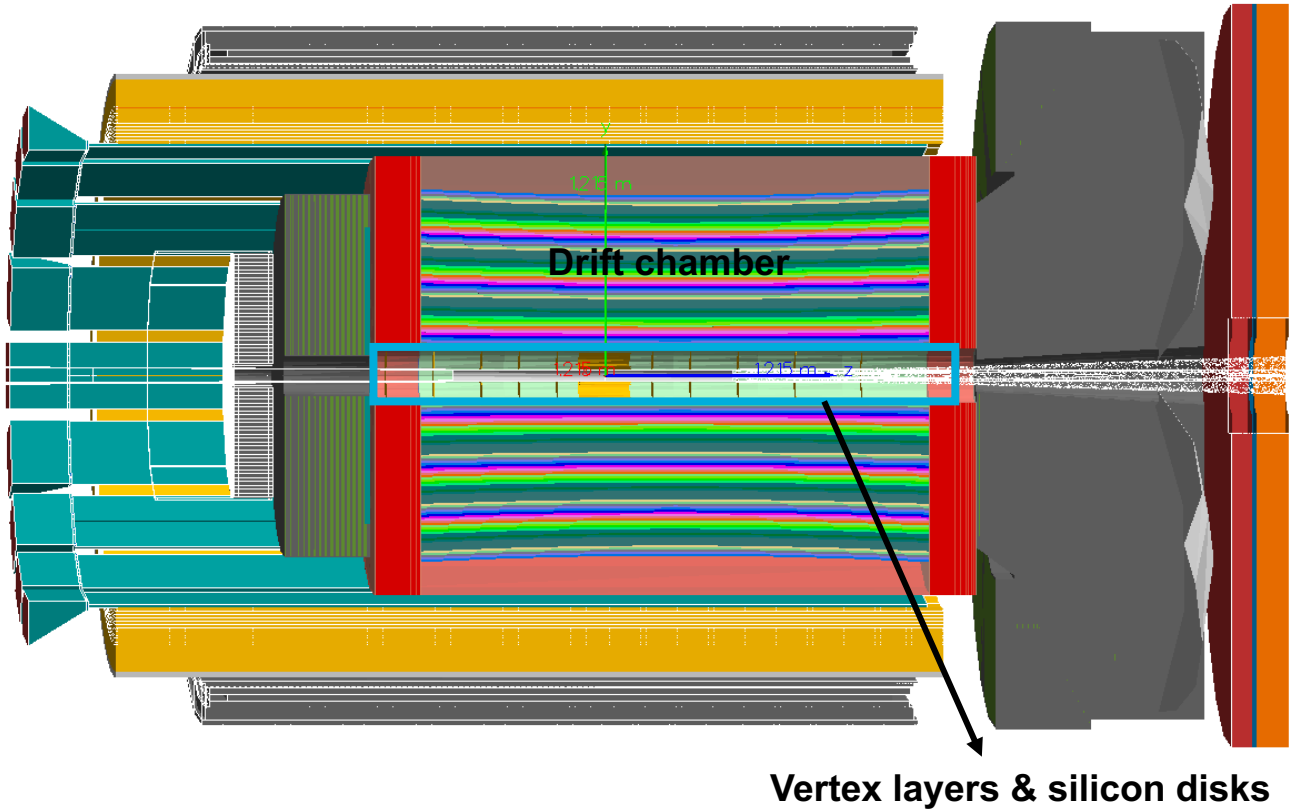

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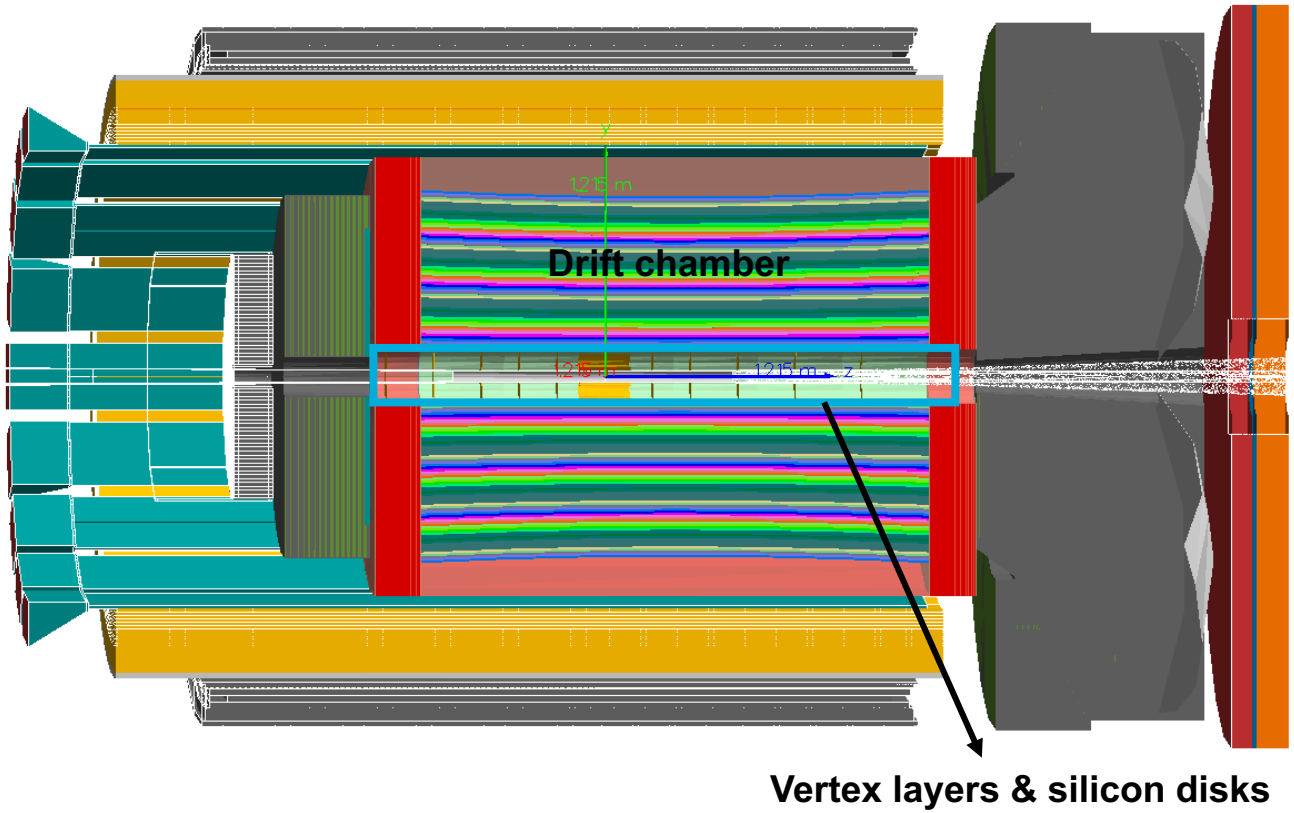

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- Pros
  - More hits for better pattern recognition, redundancy, resistance against backgrounds
  - Could provide PID at low momentum using dE/dx
- Cons
  - More material budgets
  - Worser spatial resolution compared to pixelated silicon sensor
  - TPC may be too slow to separate tracks from background

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 of the hadron calorimeter

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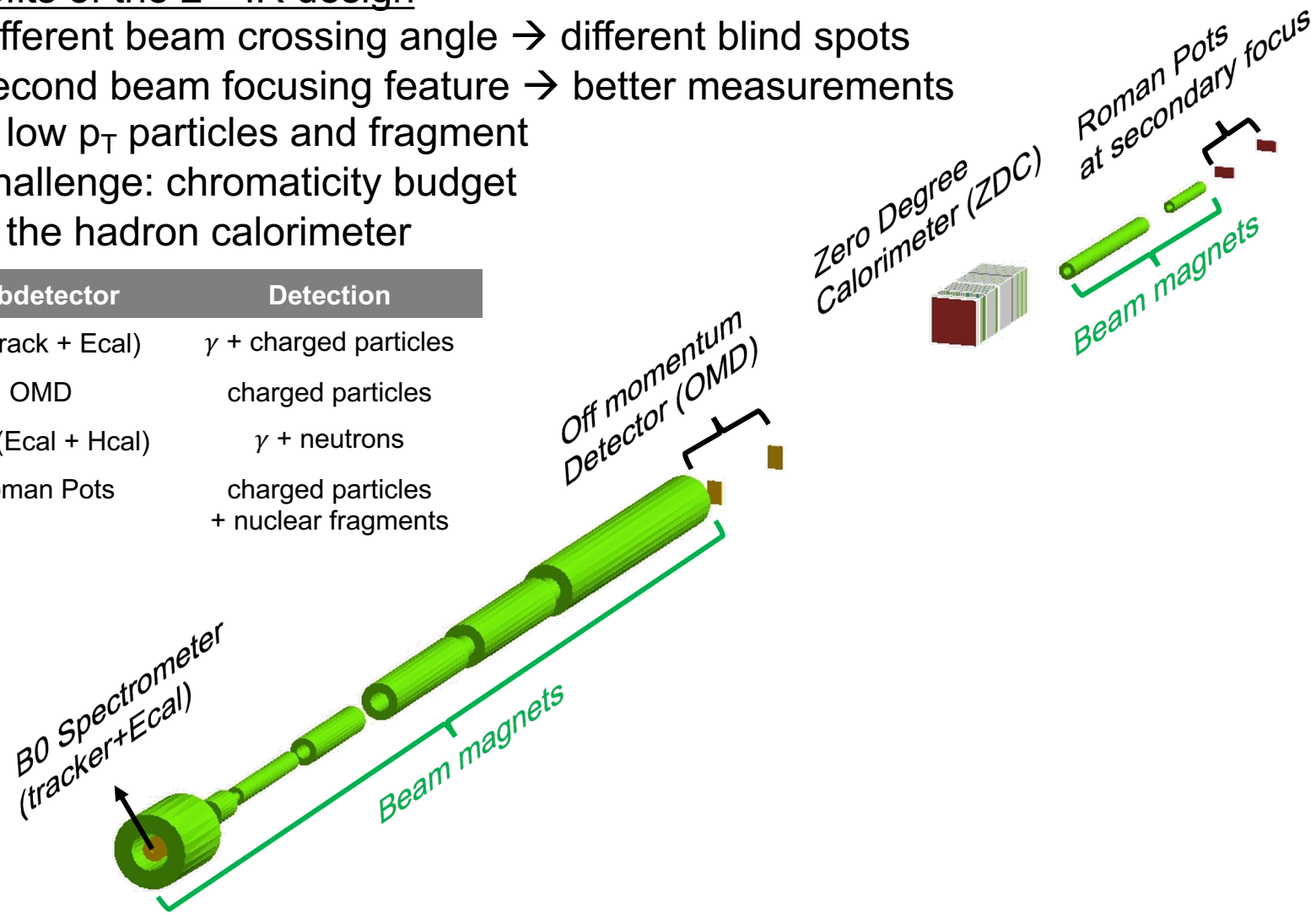

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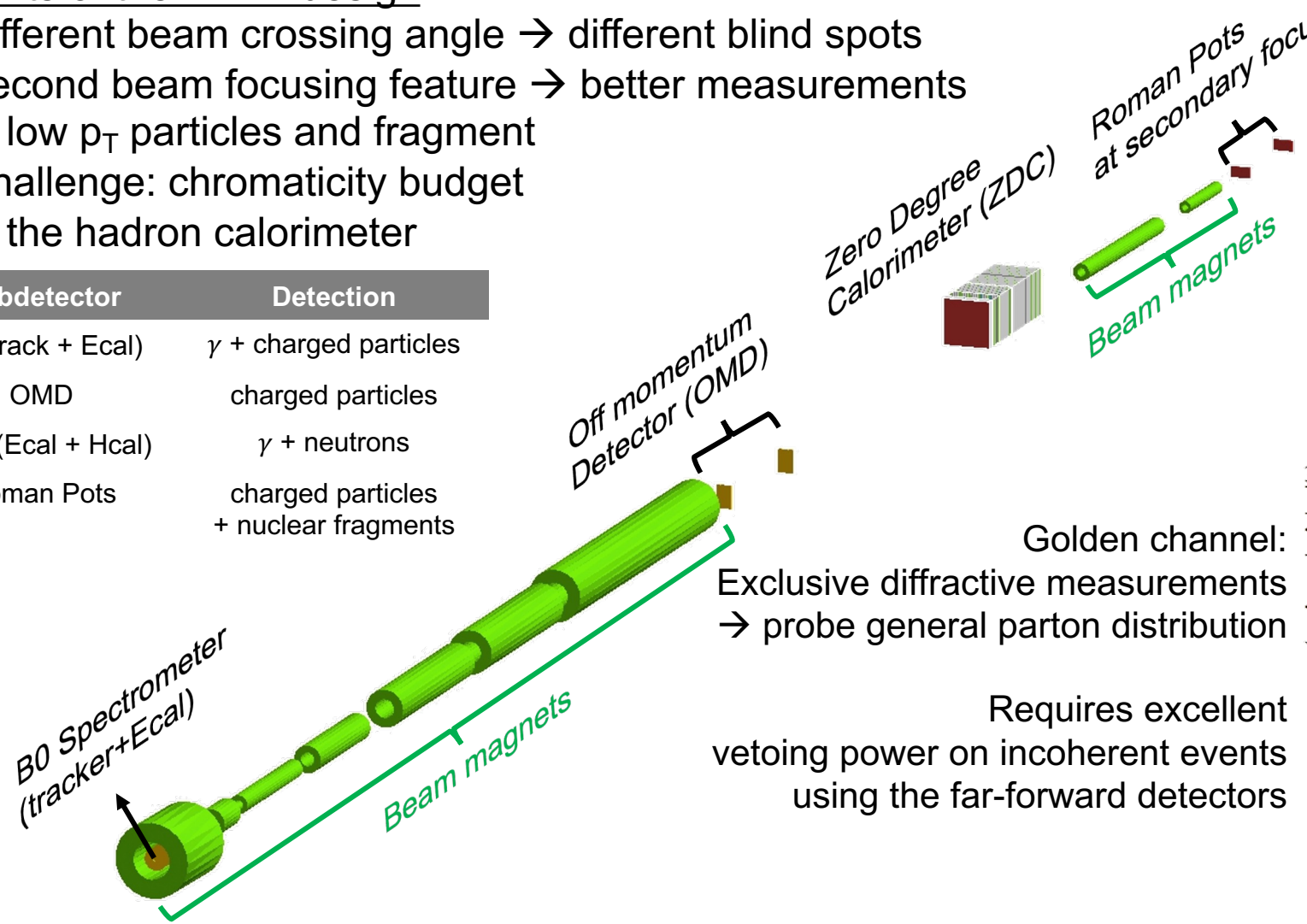
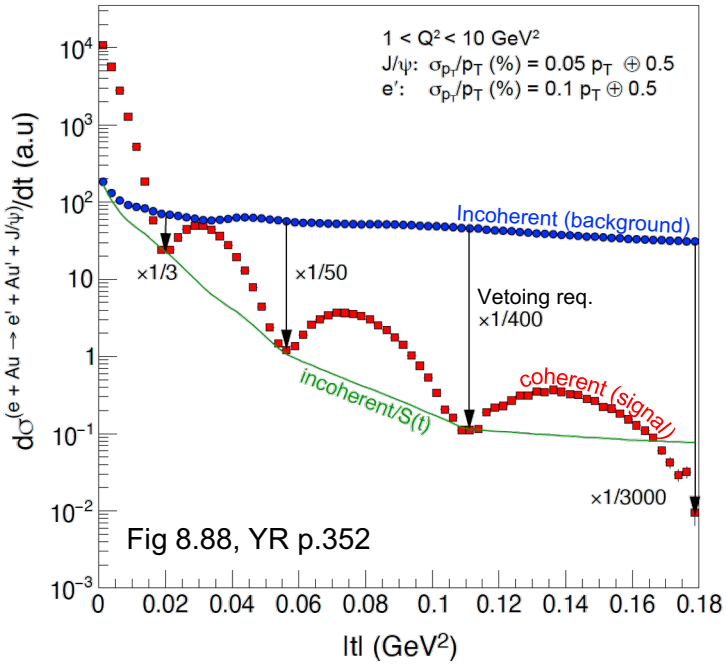


Golden channel:
Exclusive diffractive measurements
→ probe general parton distribution

Requires excellent
vetoing power on incoherent events
using the far-forward detectors



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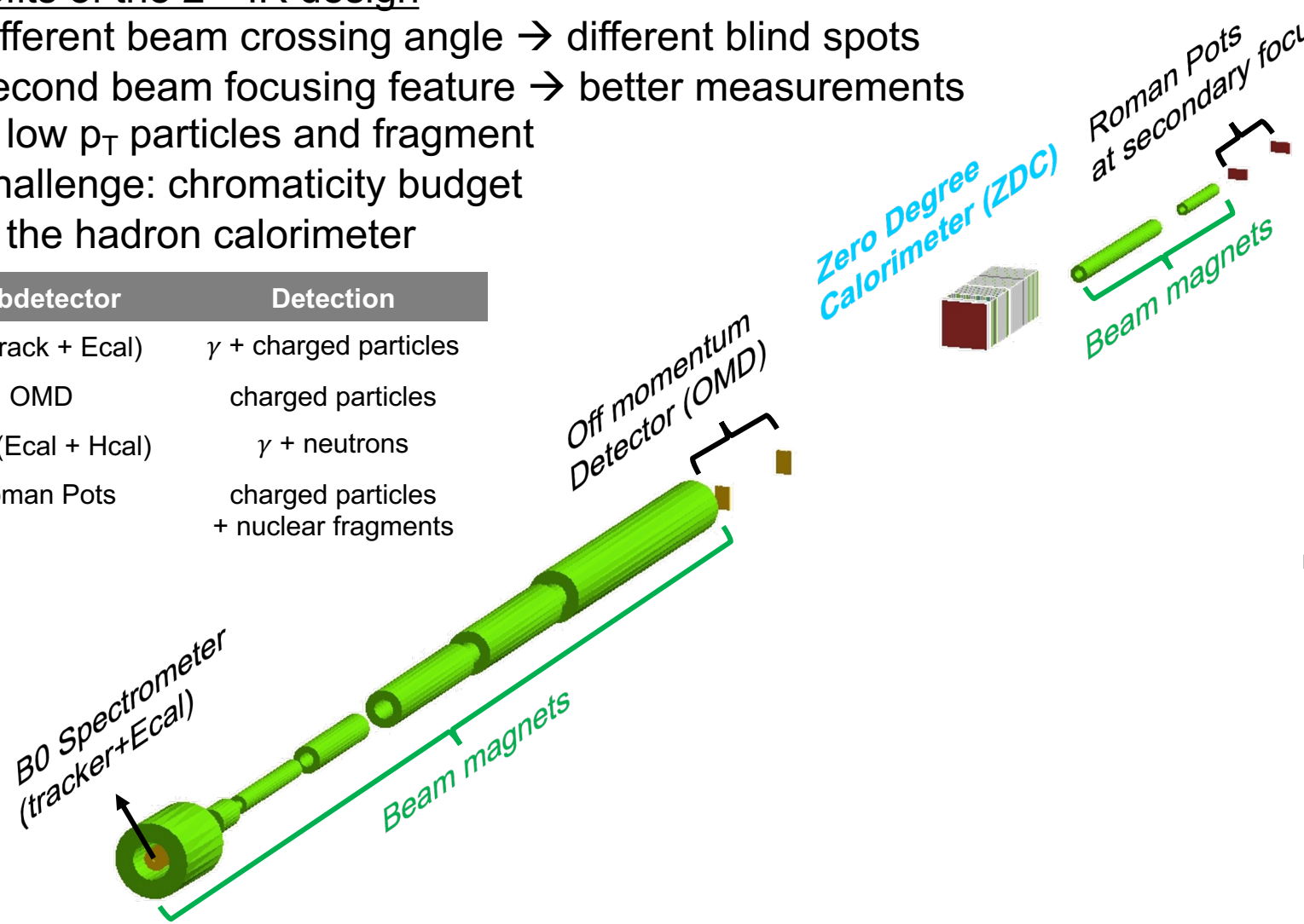

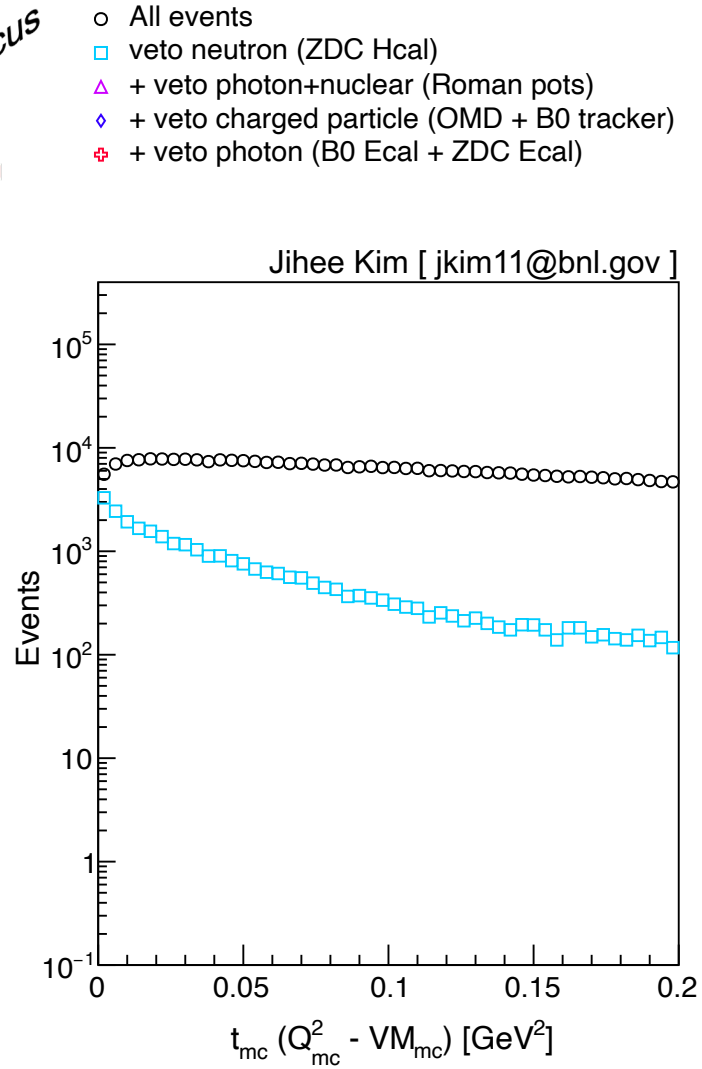

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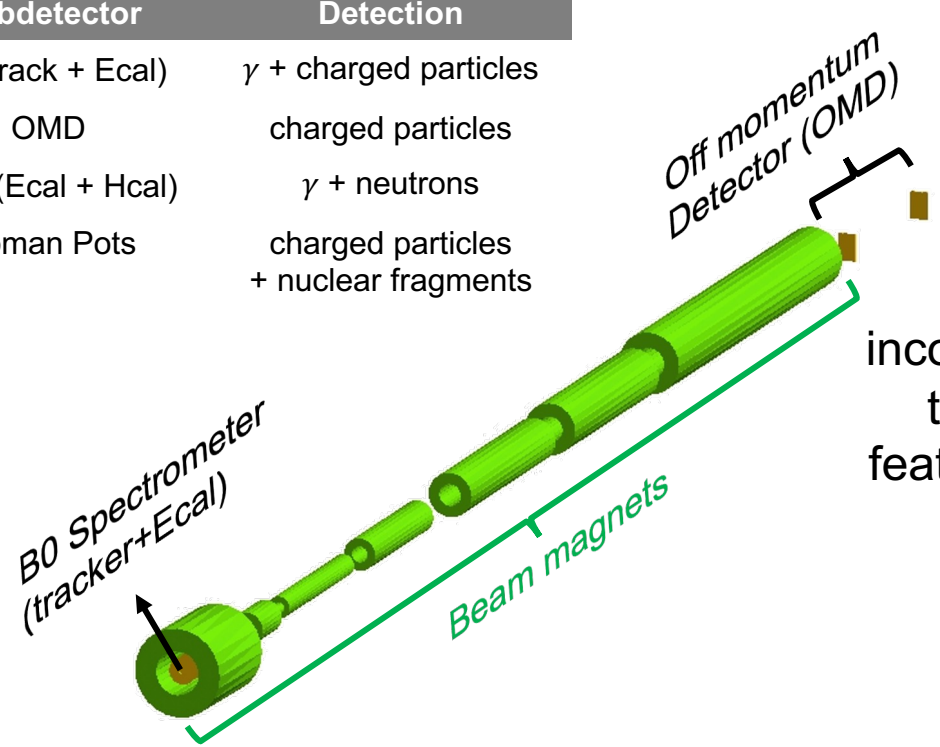
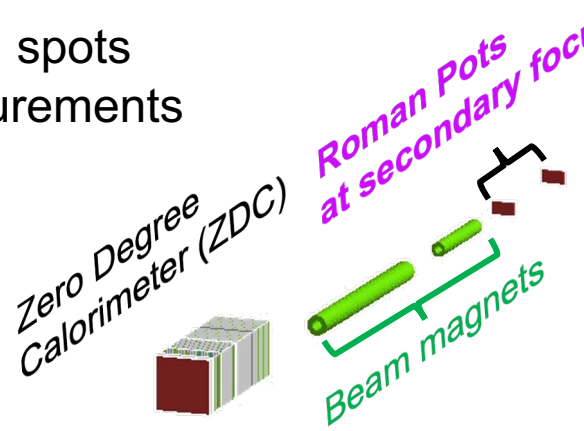
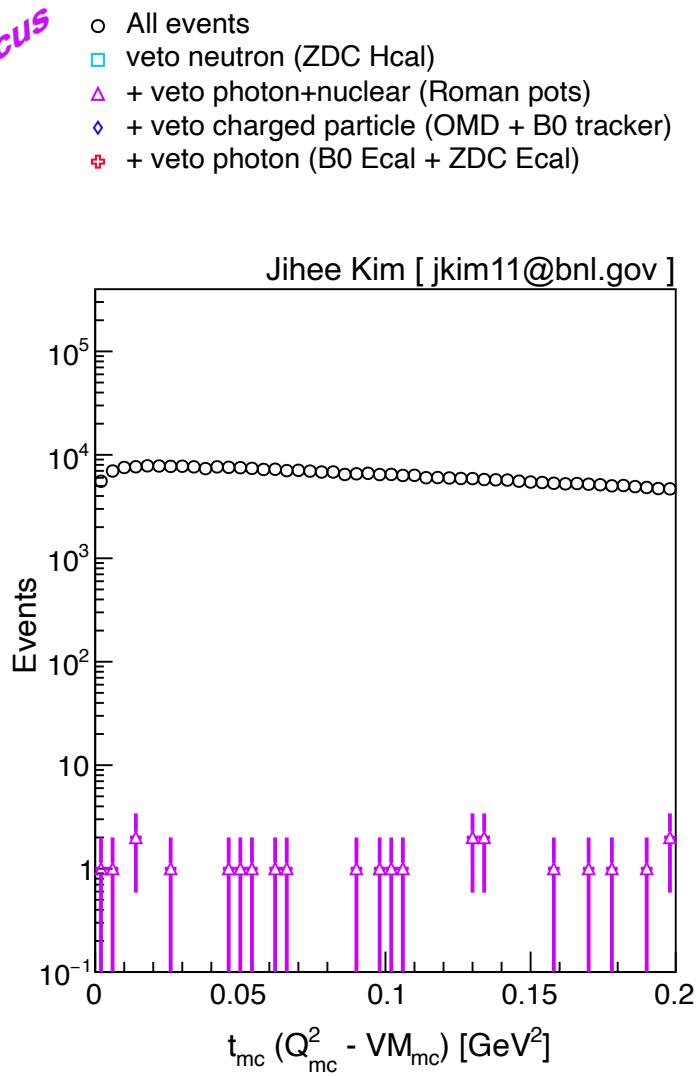




Significant impact on incoherent event vetoing with the second beam focusing features and the Roman pots



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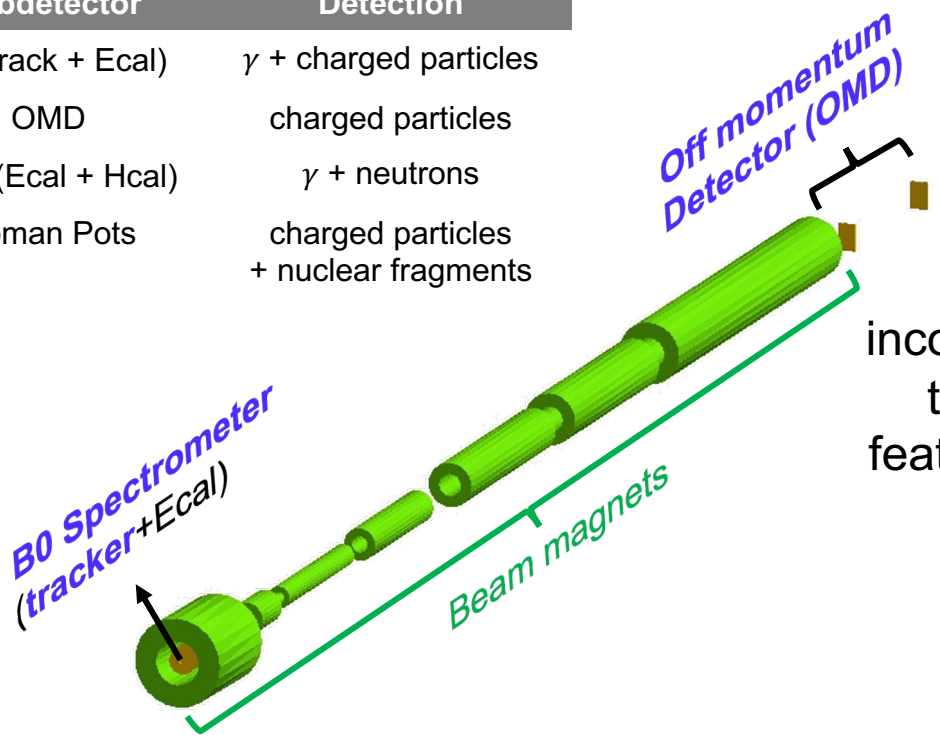

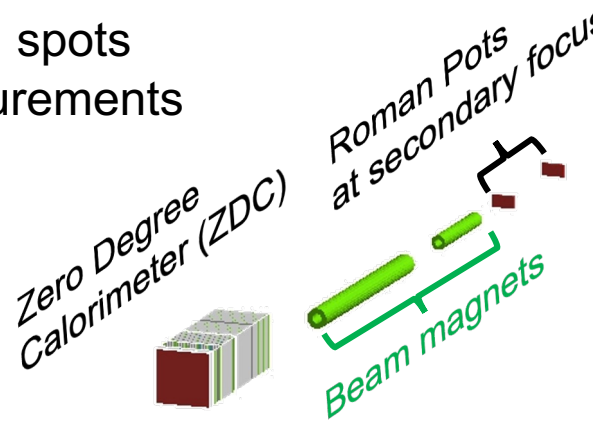

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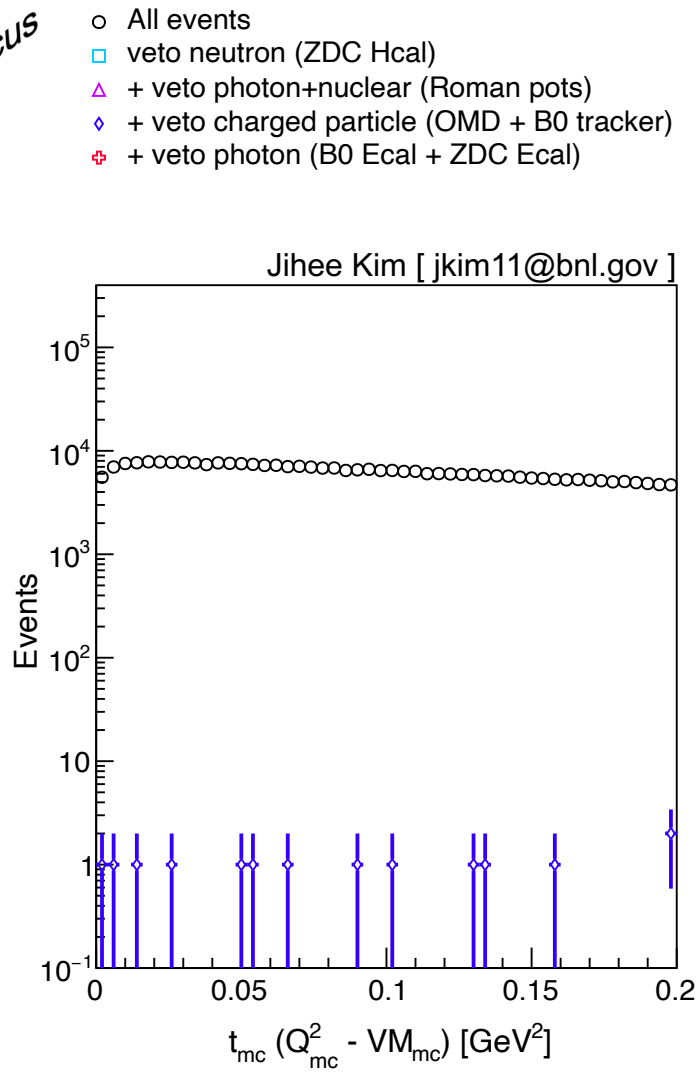

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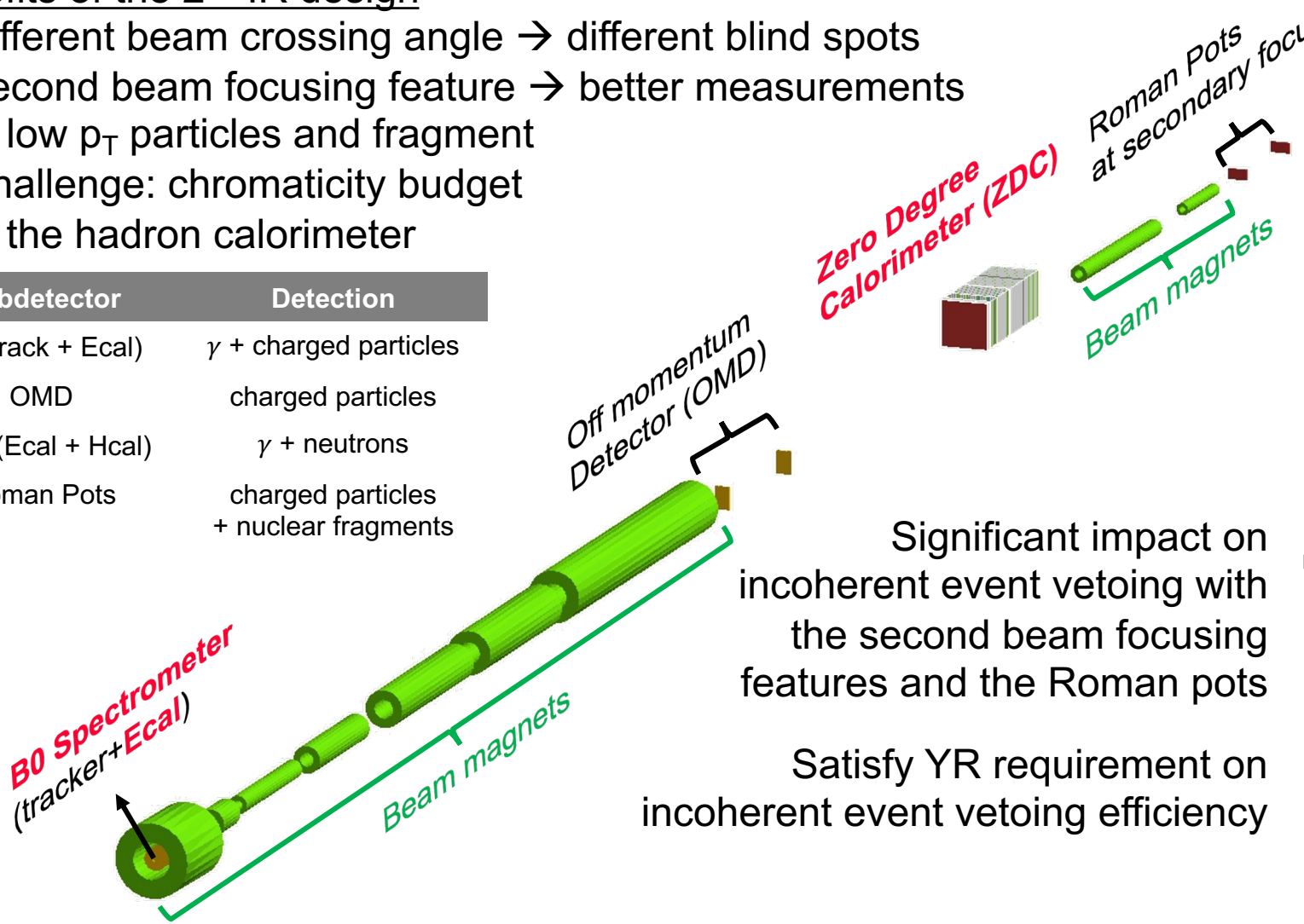

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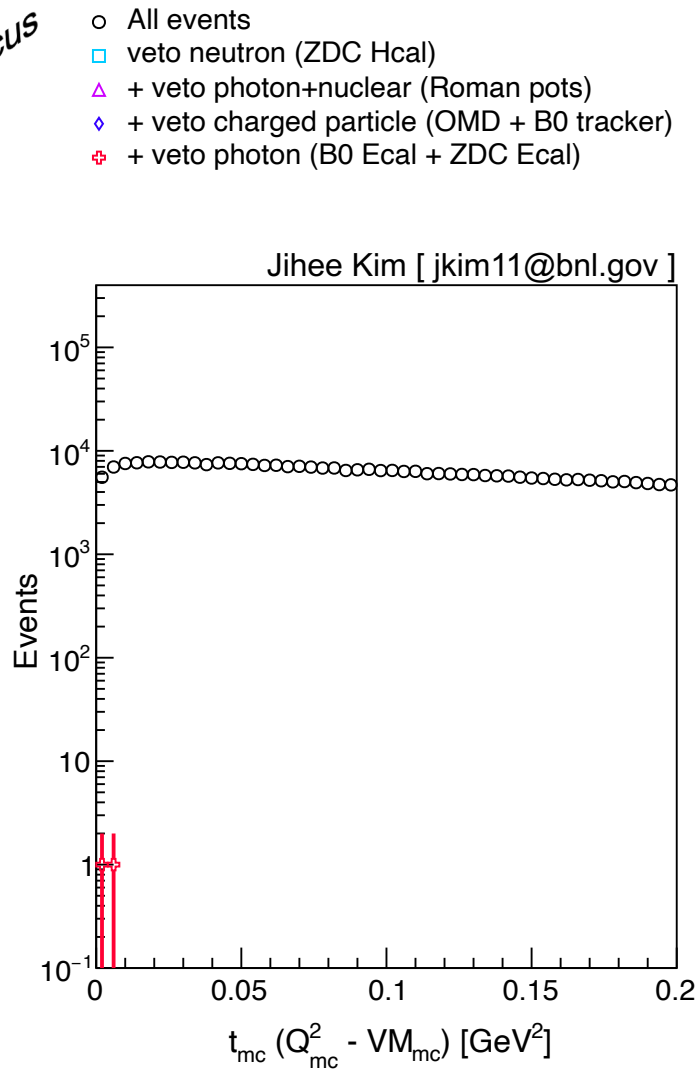
Satisfy YR requirement on incoherent event vetoing efficiency



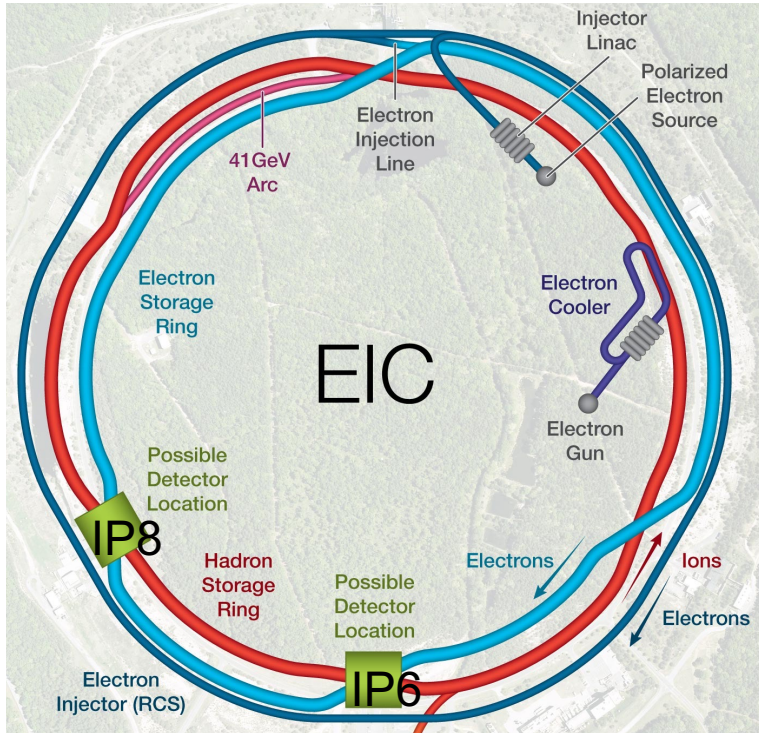
Summary

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

Back Up

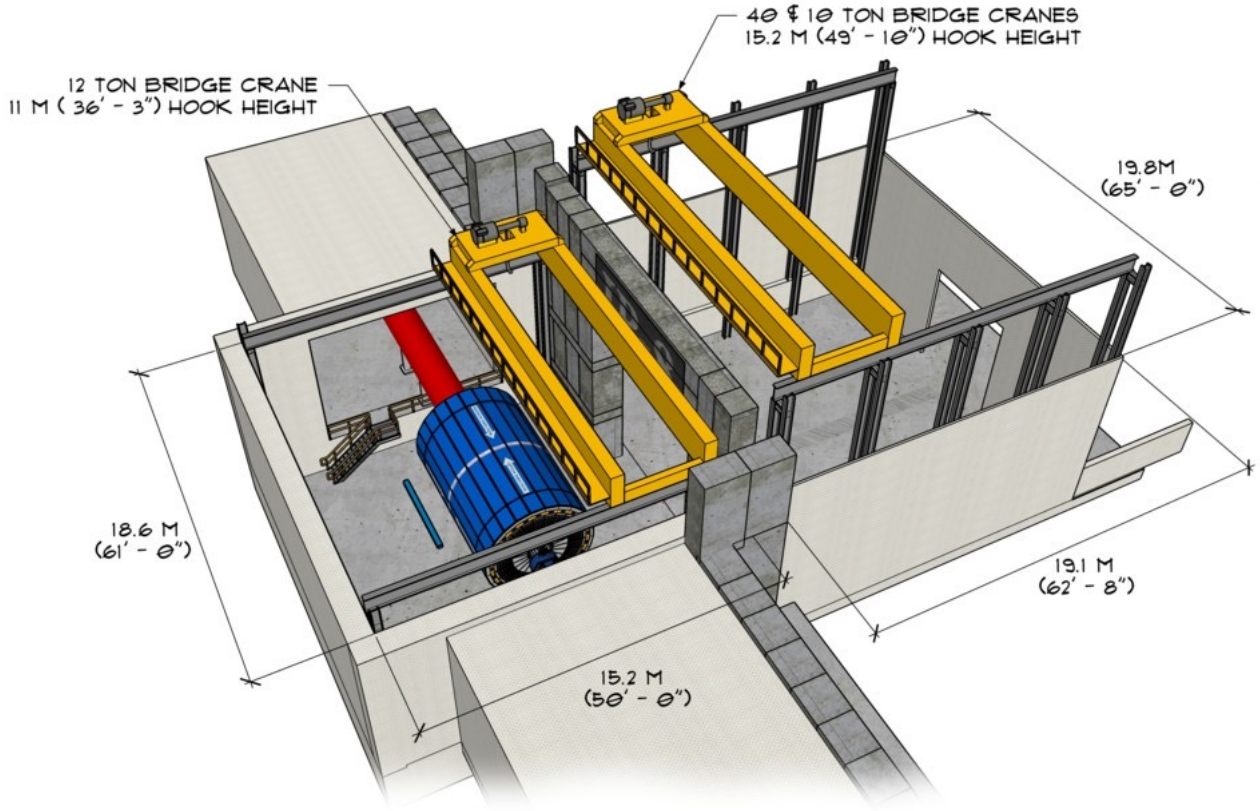
Comparison between IP6 and IP8

	IP6	IP8
Globally	Same accelerator highlights and challenges	
Geometry	Ring inside to outside	Ring outside to inside
	25 mrad	35 mrad → more difficult to get acceptance at high η
	Different blind spots	
	Different far-forward detector acceptances	
Luminosity	Same luminosity capabilities at both IRs, but luminosity will be shared same center-of-mass energy coverage	
IR-Design	$0.2 < p_T < 1.3$ GeV	2^{nd} Focus → improved low p_T acceptance at far-forward Roman Pots x_L ~1 → p_T ~0 (Further study needed for the feasibility of the IR magnets)
Experiment	Complementarity through different subdetector technologies	

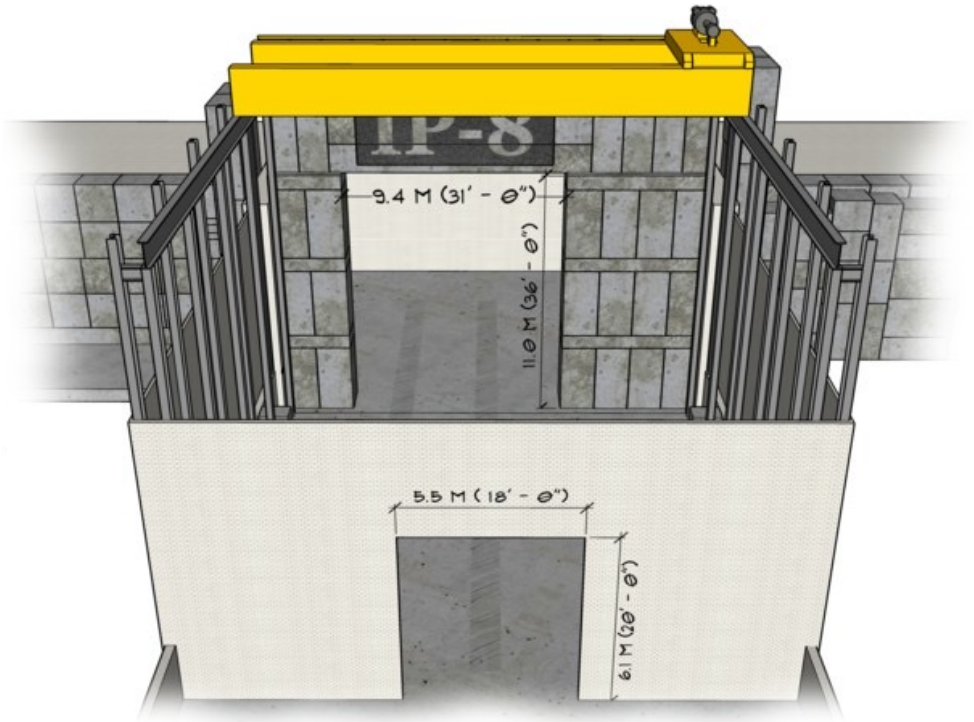


Enhanced low P_T acceptance, DVCS on nuclei, Light ion tagging, Diffraction, improved Gluon imaging by detection of (A-1) nuclei

IP8: Space Constrains



DIMENSIONS FOR IP-8 AND THE ASSEMBLY HALL



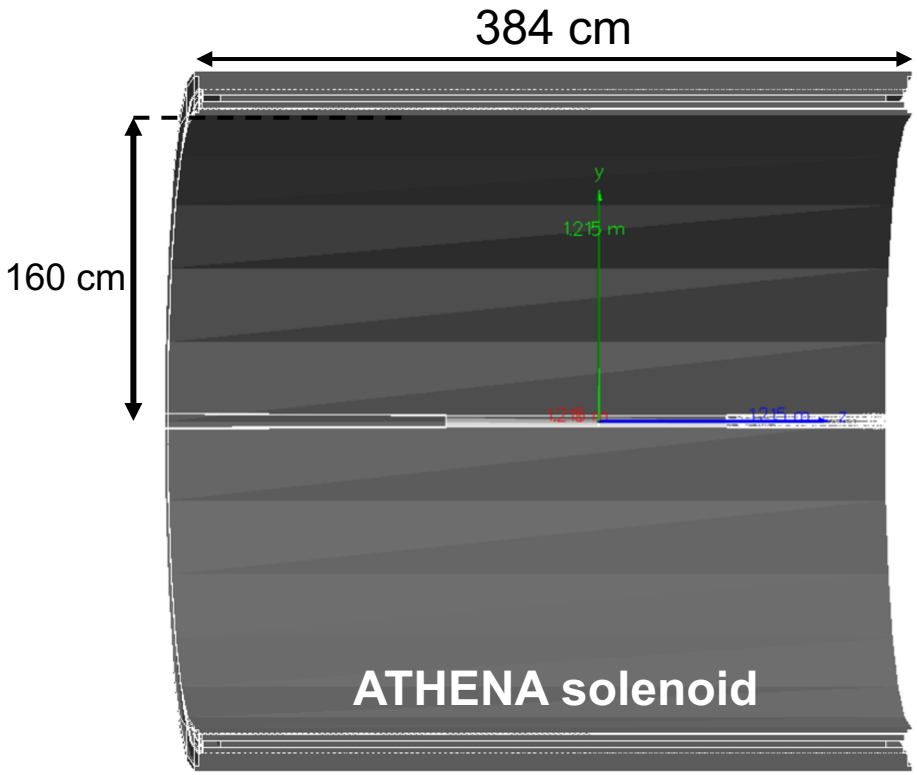
DOOR DIMENSIONS FOR IP-8
AND ASSEMBLY HALL

- The experimental hall in IP8 is wider than IP6, however detector access is still limited by the accelerator systems
- The assembly area for IP8 is significantly smaller than that of IP6

Disassembly of the detector and removal of sub-systems in the IP8 assembly area will require special considerations

Concepts of the 2nd Detector (Central) – Magnet

Hcal/muID not shown

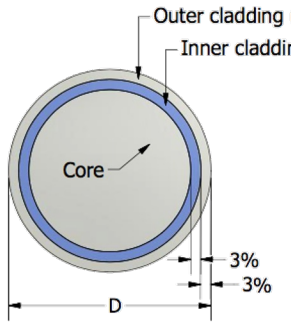


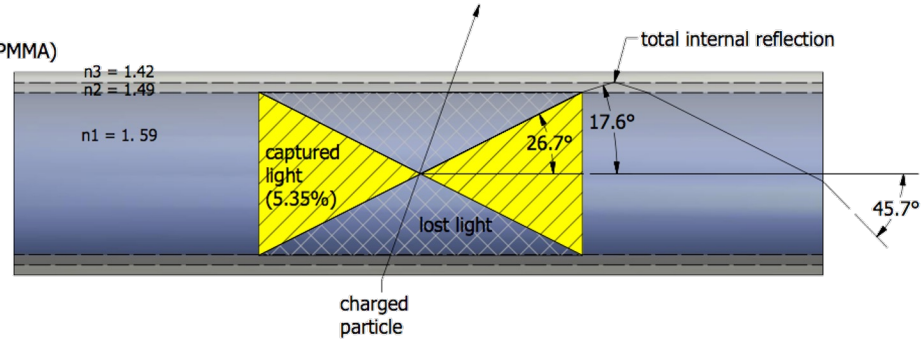
ePIC	2nd Detector
B=2T	B=2T >2T requires R&D
r=1.42 m	r=1.6 m Larger inner volume

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



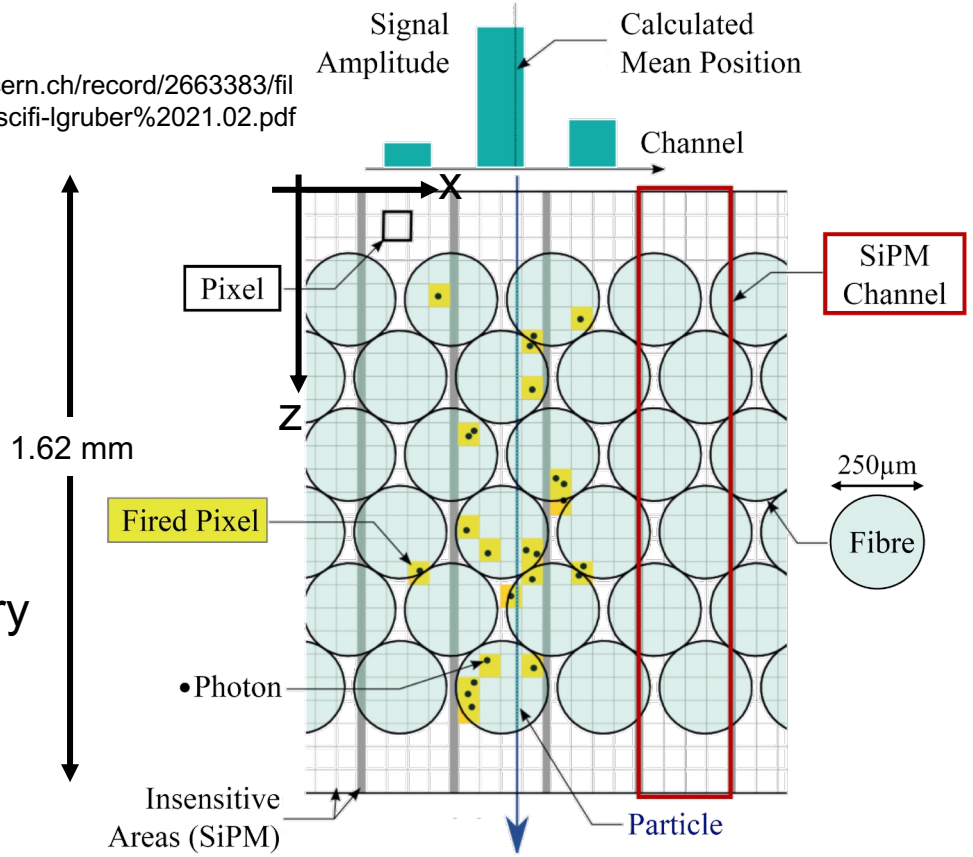


Hamamatsu SiPM (MPPC S13552 – H2017)
- Pixel size ~ 60 um
- <10% noise cluster rate with front-end clustering and -50 ℃ cooling using Novec

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

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



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

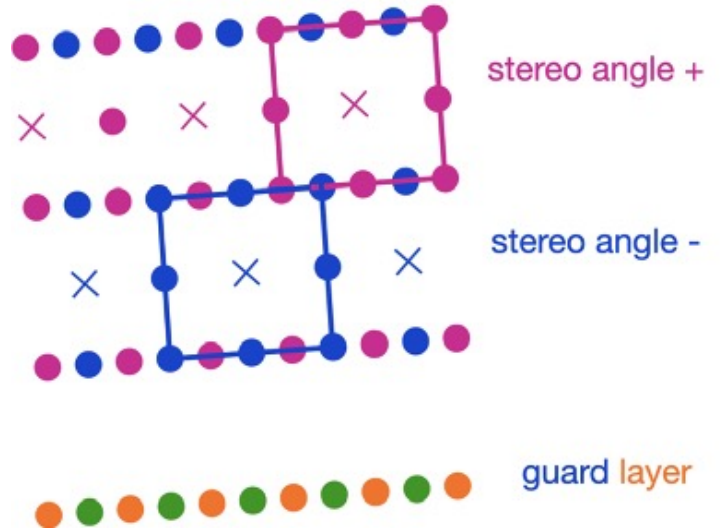
Drift Chamber (IDEA/MEG II)

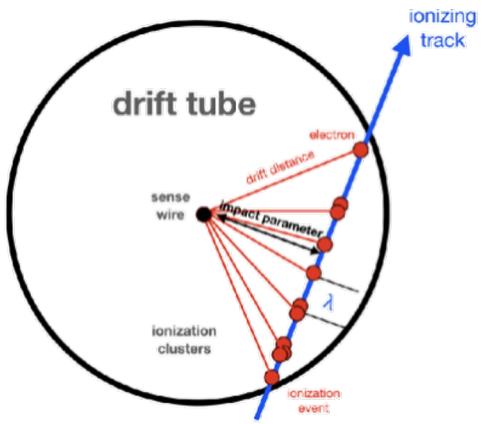
<u>Reduction of material</u>
by storing helium gas in the wire support endplates
IDEA: $0.016X_0$ ($0.05X_0$) in the barrel (forward and backward) region

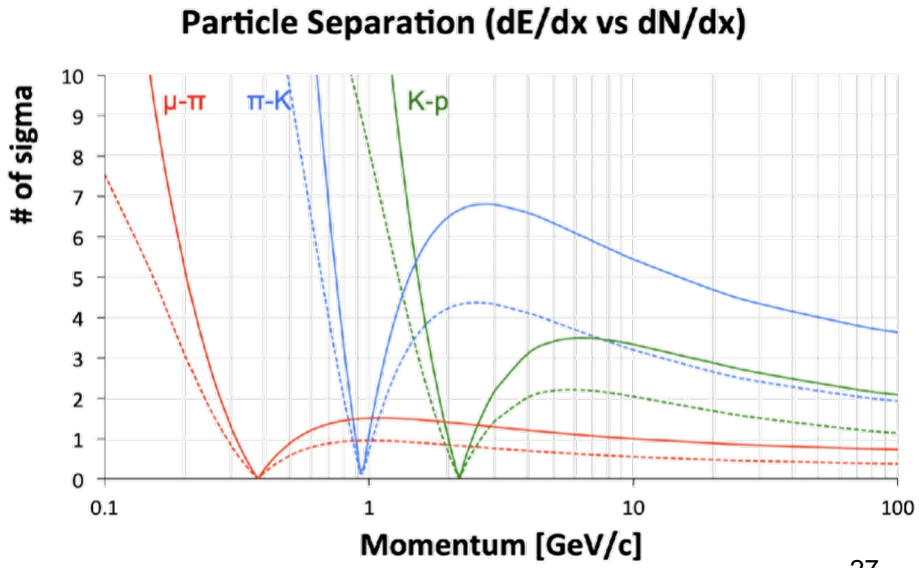
<u>More uniform equipotential surface</u>
A high ratio of the field to sense wires and a high wire density by enmeshes the positive and negative stereo angle orientations
IDEA: 4 m long, r = 35-200 cm, 400k wires, res ~ 100 um

<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

<u>Technology advancements</u>
- 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





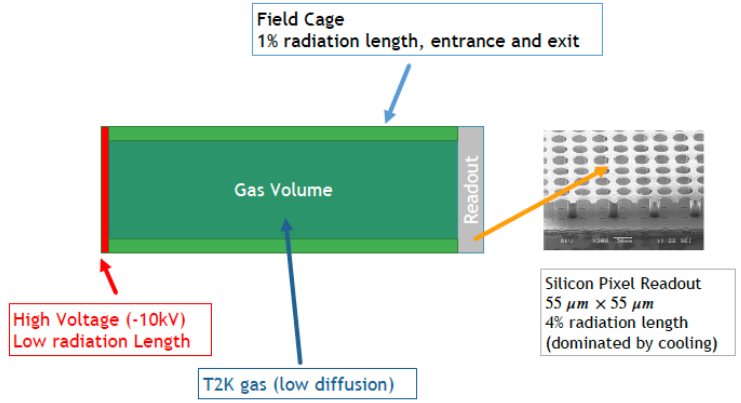


TPC/mini TPC

GridPIX aka miniTPC

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

- Basic idea: Small ΔR 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 μm_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