EIC@IP6 meeting, PID session

An introduction

First of a set of sessions about subdetector sector

- GOAL: start collecting input for the WG PID being formed
- Who has been addressed?
  - All the presenters of EoI with reference to PID at the EIC@IP6 kick-off meeting
- CHARGE, addressing these points:
  - which is the contributions you can bring to the PID activity towards the proposal in the next months
  - what are the most relevant and urgent questions in the PID sector
  - how do you see globally PID for Detector 1
- AGENDA for this SESSION:
  - A set of short contribution
  - Time for questions and discussion

CONTRIBUTIONS

Addressed:

- Mohanty Bedangades bedanga@niser.ac.in *message via e-mail: planning to collaborate*
  Marco Contalbrigo marco.contalbrigo@fe.infn.it contribution by Roberto Preghenella
  Zein-Eddine Meziani zmeziani@anl.gov contribution by Junqi Xie
  Thomas Hemmick thomas.hemmick@stonybrook.edu contribution by Thomas Hemmick
  Greg Kalicy gkalicy@jlab.org contribution by Greg Kalicy
  Wei Li wl33@rice.edu contribution by Wei Li
  Murad Sarsour msar@gsu.edu contribution by Murad Sarsour
  Anselm Vossen anselm.vossen@duke.edu *message via e-mail, see here below*
  Yi Yang yiyang@ncku.edu.tw *not ready to contribute today*
  Zhenyu Ye yezhenyu@uic.edu

Anselm Vossen's message

At this point my postdoc Chris Dilks started helping with the simulations working with Cristiano and Evaristo. He is working on porting the simulation code to fun4all, but this effort could be redirected.

So in the next few months, we can contribute this ~0.25-0.5 FTE on simulations in a way that benefits the project.

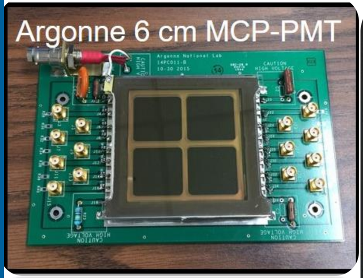
INFN interest in collaborating to PID for EIC@IP6
divisions of **BA, BO, CT, FE, LNF, LNS, ROMA, TO, TS**

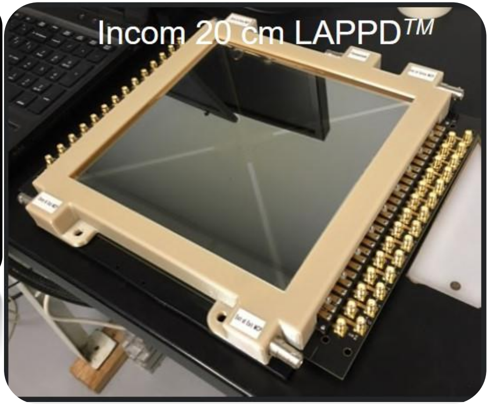
- **which are the contributions you can bring to the PID activity towards the proposal in the next months**
  - advance with **Monte Carlo simulations** for performance studies of a forward RICH detector
    - benefit from existing GEANT4 simulation experience and results (eRD14 dRICH)
    - bring forward RICH PID in context of analytical and parametrised approaches for fast-simulation
    - moving towards implementation of geometry / algorithms for full simulation / reconstruction
    - estimate on man-power resources needed / involved: ~ 5 people from INFN (~ 1-1.5 FTE)
      - ready to contribute within a larger group dedicated to PID Monte Carlo simulation
  - continue detector **R&D on dual-radiator RICH** detector prototype, photodetectors and electronics
    - SiPM irradiation campaign in May and characterisation for radiation-hardness
    - development of timestamp-based FE electronics with streaming-readout capabilities
    - beam tests of the dRICH prototype at CERN in Sep/Oct (though timeline might not fit with the one of proposal)
    - estimate on man-power resources needed / involved: ~ 15 people from INFN (~ 2-3 FTE)
  - continue **R&D on MPGD-based photodetectors** for RICH in windowless approach
    - estimate on man-power resources needed / involved: ~ 5 people from INFN (~ 1-1.5 FTE)

INFN interest in collaborating to PID for EIC@IP6
divisions of **BA, BO, CT, FE, LNF, LNS, ROMA, TO, TS**

- **what are the most relevant and urgent questions in the PID sector**
  - need to have a clearer idea of global EIC@IP6 Monte Carlo **simulation strategy** and combined PID
  - identification of suitable visible-light **photodetectors** for operation in B field and moderate radiation
    - unique effort investigating the SiPM option for photon readout
    - but important have a plan-B available → will contribute to LAPPD R&D (probably not in time for proposal)

- **how do you see globally PID for Detector 1**
  - we believe EIC@IP6 should perform a critical **analysis of PID systems**
    - i.e. TPC / TOF in the barrel of the reference detector (synergic TOF - dE/dx combination for low p_T PID)
  - invest more studies on the use of **multiple (combined) PID information** across the experiment
    - i.e. electron ID via combined use of RICH + TOF + ECAL
  - further **engineering evaluation** of the PID systems and the volumes





DEVELOPMENT OF THE ARGONNE MCP-PMT & LAPPD FOR CHERENKOV DETECTORS

WHITNEY ARMSTRONG, MANOJ JADHAV, SYLVESTER JOOSTEN, JIHEE KIM, ZEIN-EDDINE MEZIANI, CHAO PENG, JUNQI XIE

Medium Energy Physics
Argonne National Laboratory
9700 S Cass Ave., Lemont, IL 60439

ARGONNE MCP-PMT FOR EIC

The **Electron-Ion Collider (EIC)** demands excellent particle identification (PID) over a wide range of momenta. Cherenkov (RICH) detectors are essential for high momenta PID.

Key Issue: Photodetectors

- **Photo Detectors:** The most important challenge is to provide a low-cost, highly-pixelated photodetector working in the high radiation and high magnetic field environment.
- This problem is not yet solved.

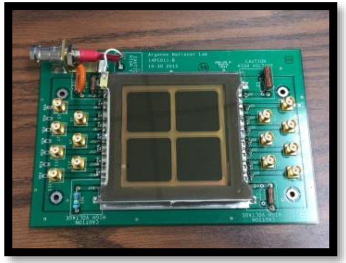
- **Large-Area Picosecond PhotoDetector (LAPPD)**
  - Promising but still not fully applicable for EIC needs.

An order of magnitude lower price per active area comparing to current commercial MCP-PMTs.

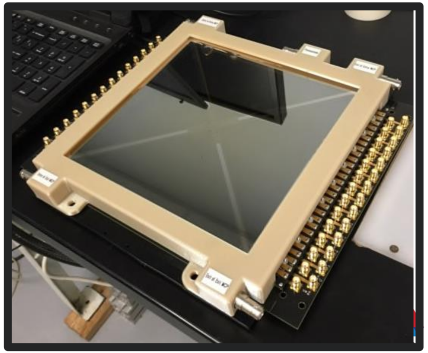
- **Optimize LAPPD design relying on ANL MCP-PMT fabrication and characterization expertise**

  - Magnetic field tolerance
  - Fine pixel readout
  - Fast timing

R&D testbed: 6x6 cm^2 @ ANL

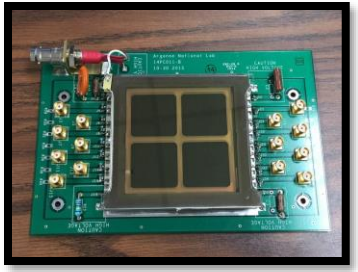


Commercialization: 20x20 cm^2 @ Industrial partner (Incom, Inc.)

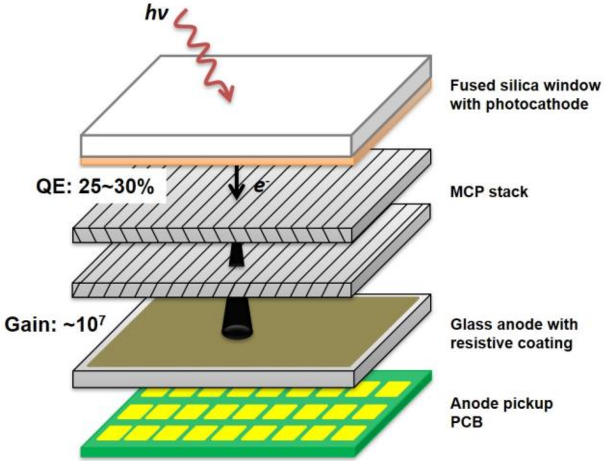


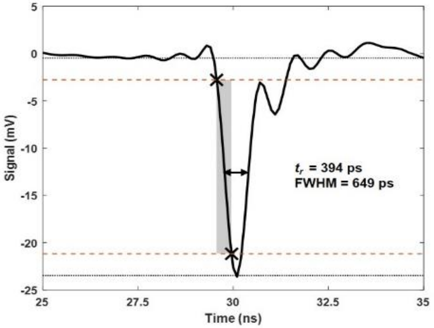
RECENT ACHIEVEMENT IN MCP-PMT PERFORMANCE

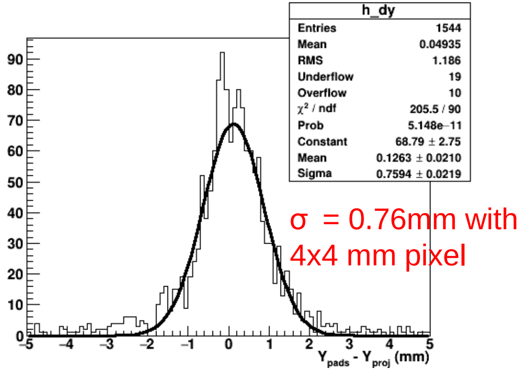
ANL **low-cost** MCP-PMT with 10 μm pore size MCPs and reduced spacing

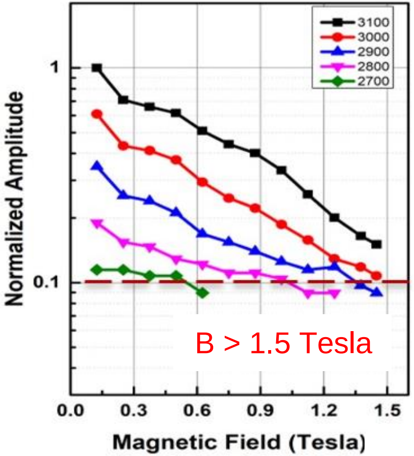


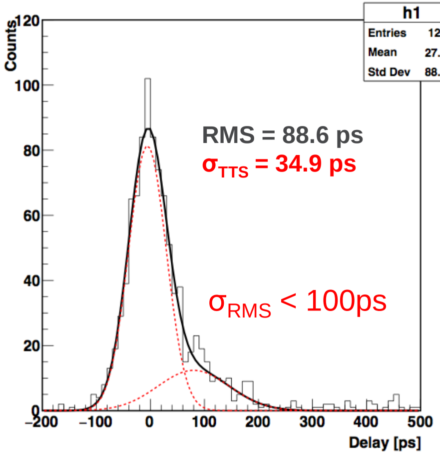
R&D testbed: 6x6 cm^2 @ ANL







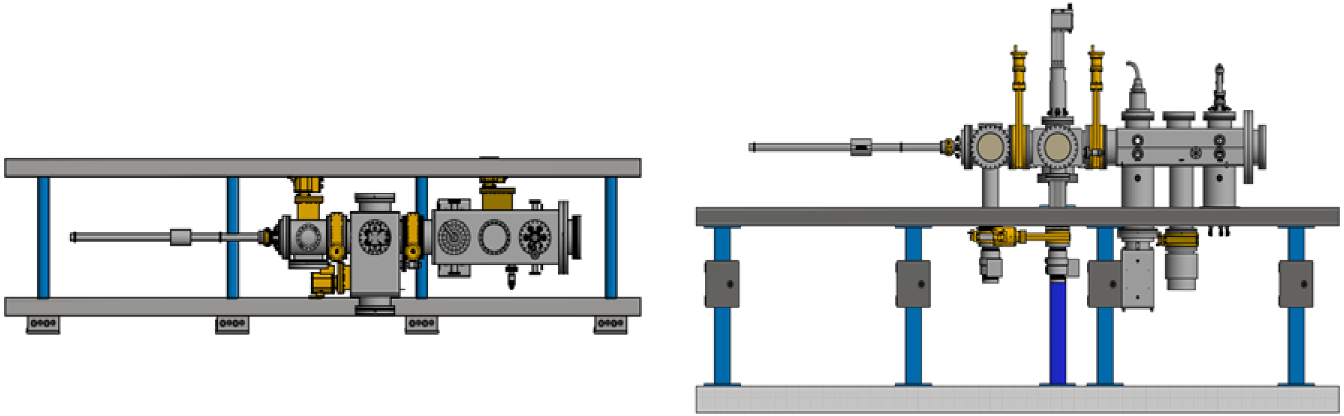




J. Xie et al 2020 JINST 15 C04038

NEW ARGONNE 10X10 CM² MCP-PMT FABRICATION SYSTEM

- ✓ Large practically applicable device size: designed for 10x10 cm^2
- ✓ High and uniform QE: uniform heating and substrate rotate mechanism



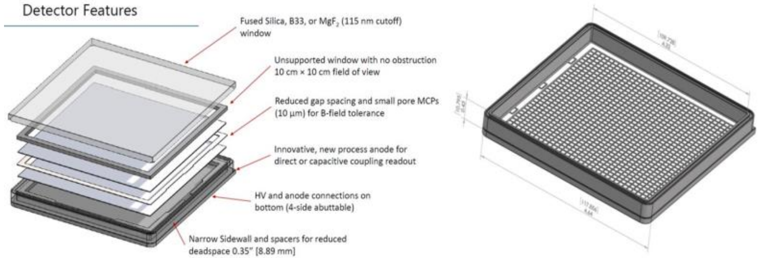
Construction is ongoing under **ANL-PSE Equipment Project Funding** support.
Aim to complete commissioning of the full system within FY21.

Beneficial projects:

- ❑ Pixelated, magnetic field tolerant MCP-PMT for **Electron ion collider**;
- ❑ Radio-pure MCP-PMT for **Neutrino less double beta decay**;
- ❑ Pixelated, fast timing MCP-PMT for **Medical isotope detection;**
- ❑ ……

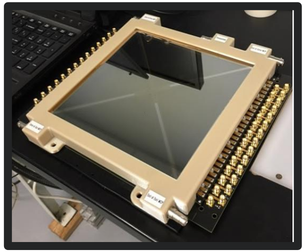
INCOM PIXELATED GEN-II AND –III LAPPD STATUS

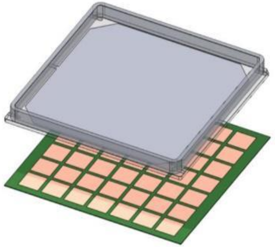
SBIR phase II “**Large Area Multi-Anode MCP-PMT for High Rate Applications**” was awarded.

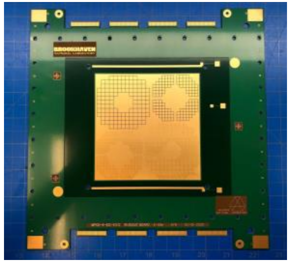


- The results of the ANL R&D study on 10 µm ALD-MCP-PMTs were integrated in the HRPPD design. The sensor is read out using low temperature co-fire ceramic anode (suitable for DIRC application).
- Expecting first HRPPD delivery of summer 2021.

SBIR phase I “**Application Specific High Fluence Anode Design**” was awarded.







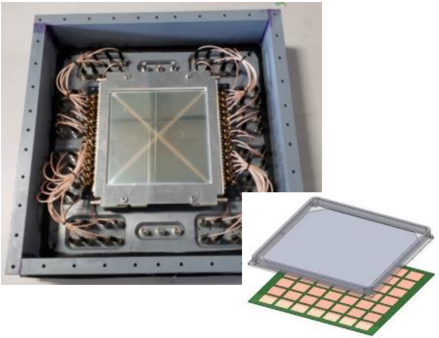
- To explore Gen-II pixelated LAPPD and its readout for EIC RICH sub-systems (mRICH, dRICH (and possibly DIRC?))
- One Gen-II LAPPD was on loan to EIC consortium since Dec 2020, preparing for March 2021 Fermilab beamline test with mRICH module for LAPPD pixelization and mRICH physics performance validation.

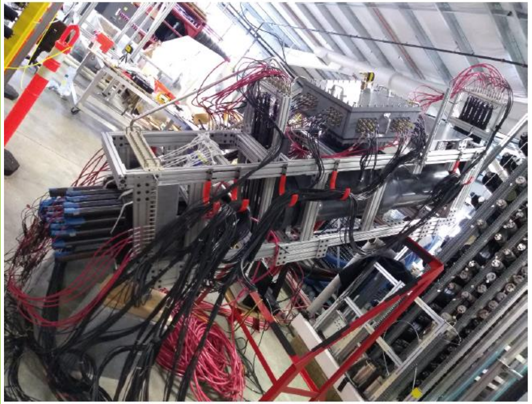
TEST OF PIXEL LAPPD AT JLAB HIGH RATE ENVIRONMENT

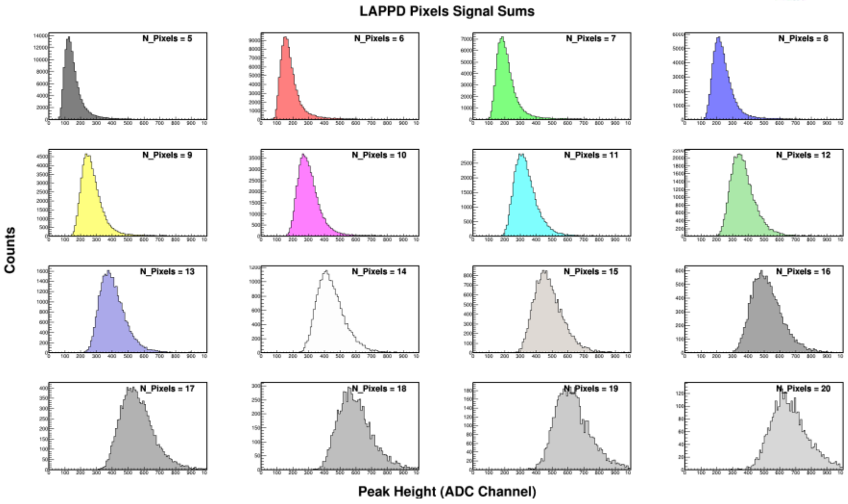
Received Gen-II LAPPD

Window material	B33 glass (with wavelength shifter coating)
Readout anode	**Capacitive coupled 25mm x 25mm pixel**
Quantum Efficiency	**Mean: 15%, Maximum: 17%**
Gain	9.5×10^{6} with MCPs @ 875V
Time resolution	79 ps

Detector package:
Cherenkov tank (CO_2 at 1 atm)
scintillator planes
calorimeter blocks
Photosensors: LAPPD or 4x4 MaPMTs







- The JLab Hall C confirms that the LAPPD works at high rate environment.
- With pixelized readout, utilizing geometrical information of pixels could improve the separation.

- which is the contributions you can bring to the PID activity towards the proposal in the next months;

ANL has devoted much effort on developing low-cost MCP-PMT/LAPPD to achieve EIC-YR requirement. Currently, a 10x10 cm MCP-PMT facility is under construction at ANL, testing of MCP-PMTs and LAPPD in beamline are routinely completed and planned. ANL team will continue to develop applicable MCP-PMT for its application in EIC detector, and address its commercialization with industrial partners.

- what are the most relevant and urgent questions in the PID sector;

Low-cost, pixelated photosensor working in a high magnetic field is critical to all PID sub-systems. The success of an applicable MCP-PMT with low cost will dramatically reduce the detector cost. It is urgent to ensure all aspects of the photosensors fulfill the EIC-YR requirement, and have a reliable vendor for low-cost, high performance photosensors.

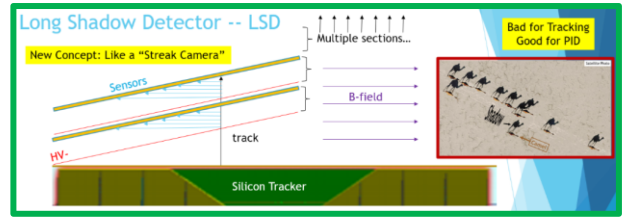
- how do you see globally PID for Detector 1.

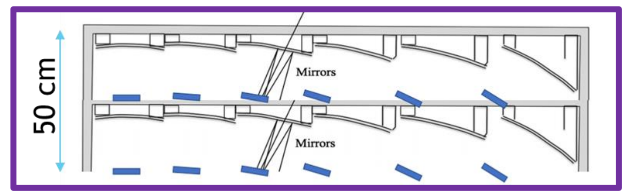
Multiple EIC-PID sub-systems based on Cherenkov imaging and TOF were proposed and are under prototyping to identify particles at different momenta ranges. One can foresee an affordable large area sensor that would be useful for RICH detectors and/or TOF for PID.

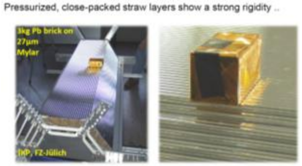
Subsystem Interest – Particle ID

Please indicate the items of interest for potential equipment cooperation:

- Subsystem 1: R&D for Innovative Barrel PID leading to 3σ 10 GeV π-K separation
  - DIRC is the best currently known technology for Barrel PID.
  - Two presentations were made for options to be added to a DIRC/TOF-based system:
    - https://indico.bnl.gov/event/9687/contributions/41772/attachments/30695/48189/THemmick_LSD.pptx
    - https://indico.bnl.gov/event/9687/contributions/41773/attachments/30687/48178/Preliminary_Barrel_RICH_for_PID_WG.pdf
- Subsystem 2: dRICH
  - dRICH efforts have leading contributions from INFN.
  - SBU is an interested participant working with INFN.
- Subsystem 3: DIRC
  - DIRC efforts are led by CUA, GSI, ODU.
  - SBU is an interested participant working with CUA, GSI, ODU.







Contributions to PID activity in the next months;

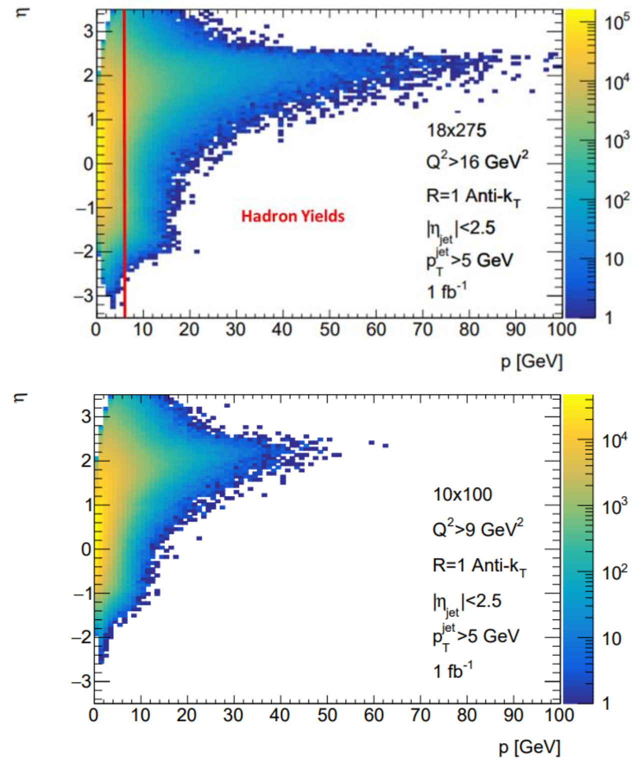
- Cluster Counting:
  - Garfield simulations ongoing
  - Three pronged
    - Efficacy & Figure-of-Merit of cluster counting in primary ionization trail (no smearing at all)
    - Efficacy & Figure-of-Merit of cluster counting after electron transport (no detection smearing)
      - Low overall diffusion
    - Efficacy & Figure-of-Merit of cluster counting during detection:
      - Position merging/splitting of apparent clusters.
      - Temporal (electronics response) merging/splitting of clusters
      - High gain and fast (not particularly easy in a large-scale application)
- DIRC:
  - Assembly of cosmic test stand
    - GEM-based track vectoring.
    - Cherenkov-based high ~~momentum~~ velocity threshold (minimize multiple scattering)
    - Articulated to scan track angles

Subsystem Interest – Particle ID

Relevant and urgent questions in the PID sector;

- Dynamic range of PID (barrel & e-arm)
  - Hadrons are significant and interesting beyond 10 GeV/c.
  - Hadrons are significant and interesting below 0.5 GeV/c.
- Photon Sensors for Cherenkov Devices
  - Magnetic field tolerance is a significant issue.
  - Reasonably well controlled at 1.5T central field (~1T at sensor)
  - Open challenge at 3.0T central field.
- eID Assistance to Calorimeters
  - Request in the YR from calorimeter group is ~4 GeV
  - Easy in hadron direction; more challenging in e-direction
- "Crack" Placement
  - Many detector systems prefer normal particle incidence.
  - "Normality" would drive the crack in barrel-end cap to 45°
    - $\theta=45^{o}$ is $\eta=0.88$.
  - Technology changes are most natural at the crack
    - Forward η crack looks OK.
    - Backward η crack challenging at highest energy.
    - CAUTION: Optimization varies with collision energy.

Yellow Report – Jets



Subsystem Interest – Particle ID

Detector 1 is within the scope of the EIC project and should be based on the "reference" detector described by the EIC User Group (EICUG) in the Yellow Report (YR) and included in the EIC Conceptual Design Report (CDR). This detector must satisfy the requirements of the EIC "mission need" statement based on the EIC community White Paper and the National Academies of Science (NAS) 2018 report. US Federal funds are expected to support most but not all of the acquisition of Detector 1. It is currently planned to be located at Interaction Point 6 (IP6) on the Relativistic Heavy-Ion Collider.

Detector 2 could be a complementary detector that may focus on optimizing particular science topics or address science topics beyond those described in the White Paper and the National Academies of Science (NAS) 2018 report. Detector 2 would reside at a different Interaction Point from Detector 1 and is currently not within the EIC project scope. Routes to make Detector 2 and a second interaction region possible are being explored.

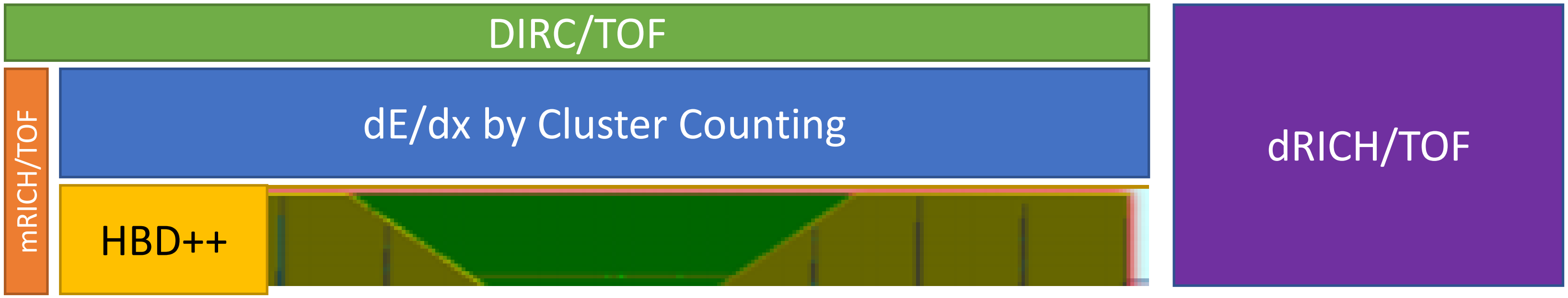
How do you see globally PID for Detector 1.

- Language of the call for proposals defines the term "Detector 1"
  - Yellow Report based.
  - White Paper and NAS report fully delivered.
  - "Detector 2" may pursue "niche" interests while "Detector 1" is defined as comprehensive
- Reference detector is not yet "Just Add Engineers"
  - Significant challenges & decisions remain.
- Dynamic Range will require layers in basically all directions.
  - TOF needs level-arm; dE/dx has band crossings; Cherenkov has threshold.
  - Comprehensive → Layers of complementary technology.
  - Easy to use up available funds (and material budget) if you invite everyone to the party
  - Dual capabilities/functions are attractive:
    - Example mRICH with LAPPD readout = TOF & RICH
    - Is LAPPD viable as on-axis readout of gas RICH?
      - Minimize emission term.
      - Get a TOF measurement?

Subsystem Interest – Particle ID

All Singing and All Dancing

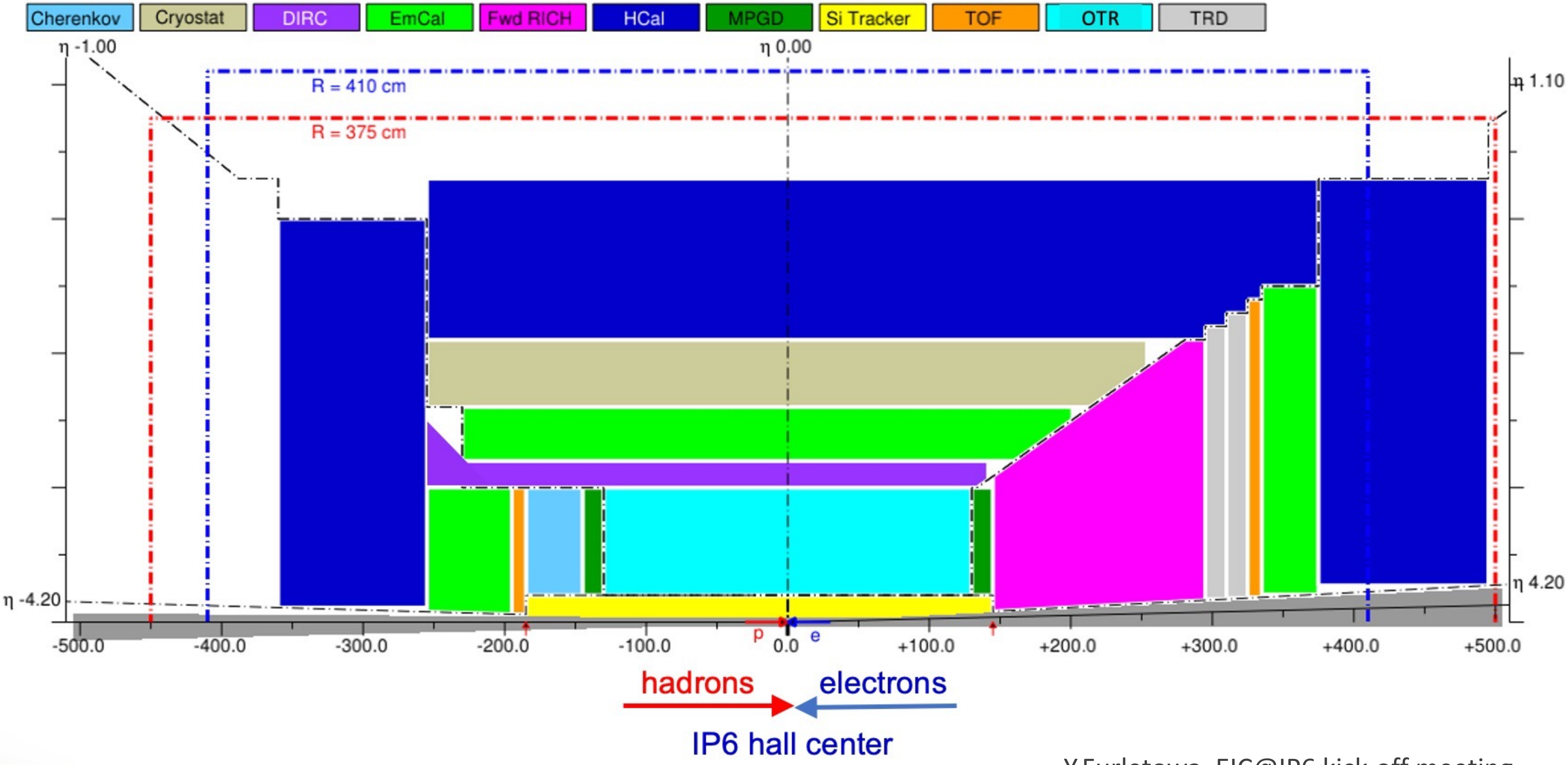
- **and no place to get the signals out**
- **and maybe cannot afford.**
- **you must start somewhere.**



Comments:

- Stealing the region of the last silicon in the electron direction for additional E-tagging.
- Assumed mRICH using timing layer (LAPPD) readout.
- What is the possible technology for a cluster counter in the barrel?
- If we CAN cluster count (not easy…requires development) can we use this to extend electron arm
- What subset of these pictures can be AFFORDABLE
- Can we absorb TOF capability into dRICH?
- Should we present and develop two baselines? (Competition makes people work hard and be creative)
  - Better known technology vs more developmental
  - Minimal cost vs maximal performance
  - Some other metric pairing?

HPDIRC IN IP6 PROPOSAL

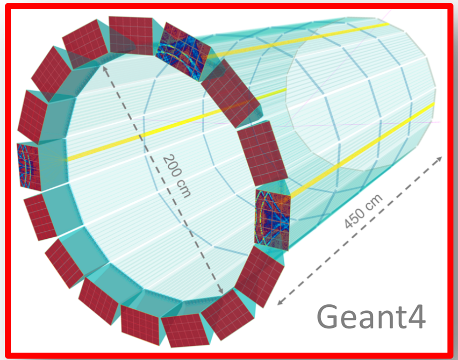


Y.Furletowa, EIC@IP6 kick-off meeting

HPDIRC FEATURES

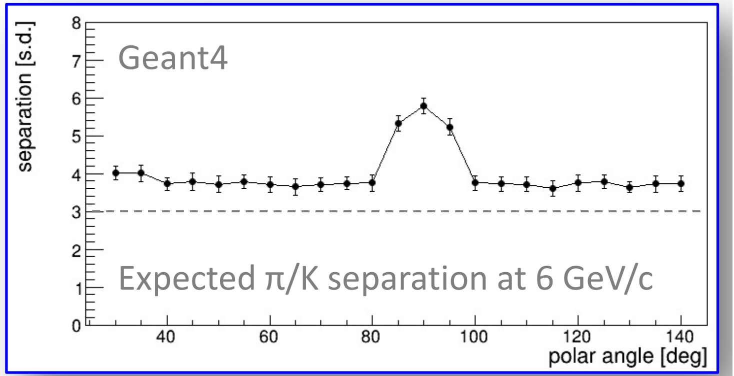
Concept:

- Fast focusing DIRC, utilizing high-resolution 3D (x,y,t) reconstruction
- Innovative 3-layer spherical lenses, compact fused silica expansion volumes
- Fast photon detection using small-pixel MCP-PMTs *(eRD14)* and high-density readout electronics *(eRD14)*



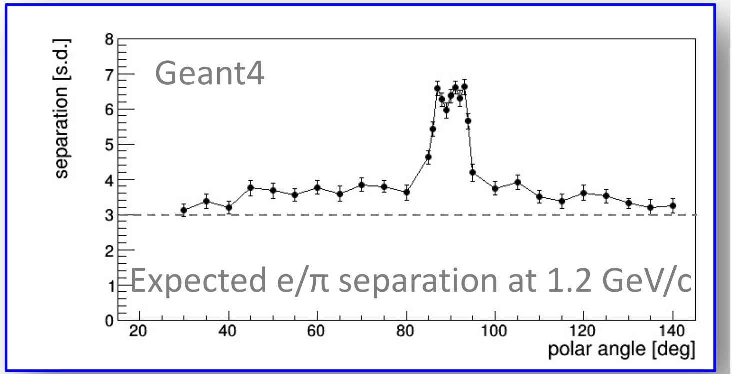
Excellent performance over wide angular range:

- ≥ 3 s.d. π/K up to 6 GeV/c, ≥ 3 s.d. e/π up to ~1.2 GeV/c
- Low momentum π/K identification in "veto mode" down to 0.2-0.3 GeV/c



Features:

- **Radially compact** (8-10 cm; impact on cost of post-DIRC systems)
- **Flexible design** (to deal with sensor in B-field and detector integration)
- **Low demand on detector infrastructure** (no cryogenic cooling, no flammable gases)
- **R&D at advanced stage** (PID performance estimate based on test beam results, excellent agreement between detailed simulation and prototype data, fast simulation available)



hpDIRC Group Contribution

Institutions from EOI:

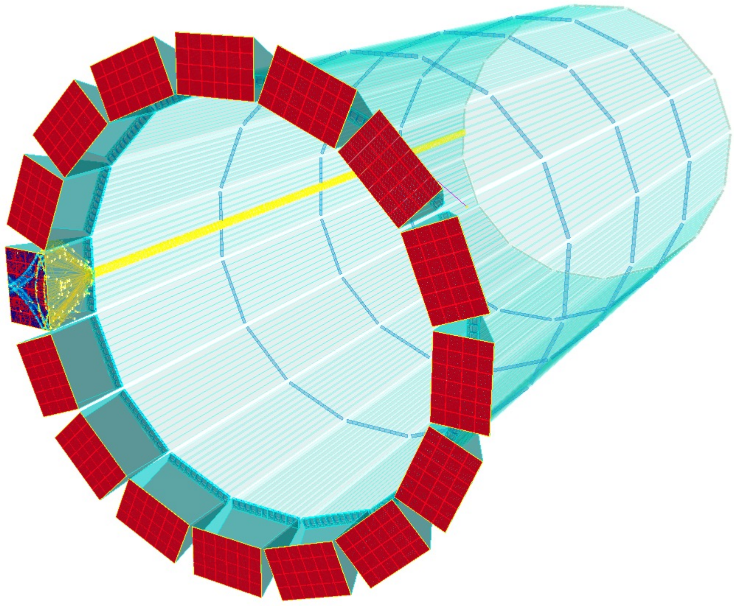
- CUA, GSI, BNL, W&M, USC, SBU, UH, JLab, ODU

Potential contribution to proposal:

- Experience and knowledge from very advanced PANDA Barrel DIRC R&D and recent GlueX DIRC construction, calibration, and operation.
- Supporting integration of hpDIRC to the full detector simulation
- Support for validation of hpDIRC simulation studies
- Work on proposal text

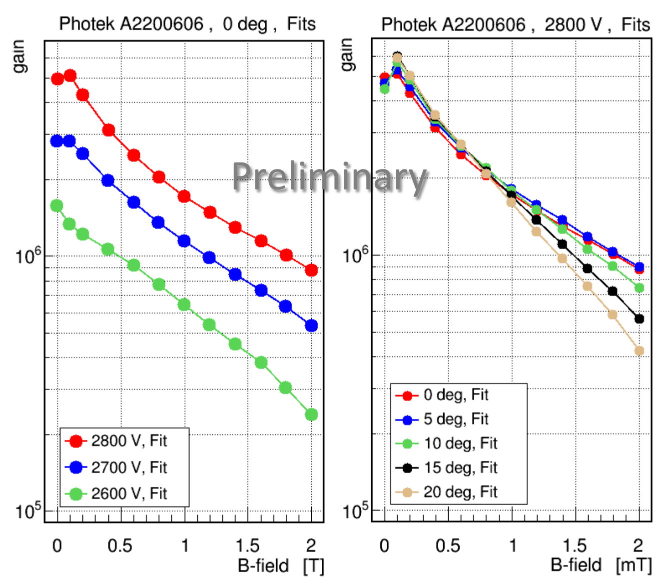
Further R&D:

- hpDIRC EOI team well-positioned to address remaining R&D issues and to work with all interested IP6 groups on the hpDIRC simulation, design, construction, and operation
- eRD14 DIRC team plans to continue working on hpDIRC R&D as part of the EIC PID consortium, will submit proposals for continued funding via directed/project R&D and generic R&D funds

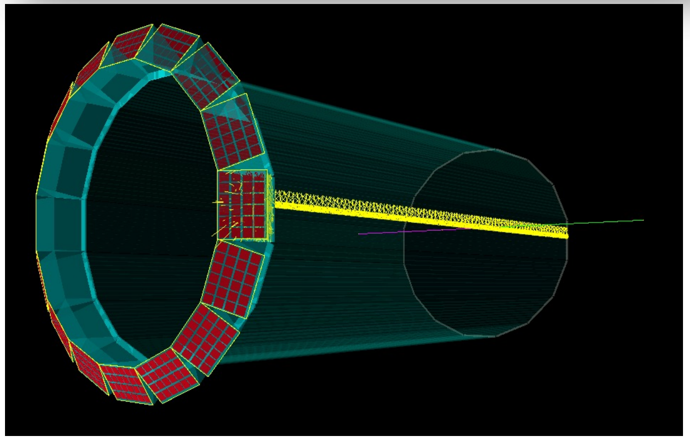


HPDIRC QUESTIONS

1. **What is local magnetic field strength at hpDIRC sensors location?**
   - Small-pore MCP-PMTs shown to be OK for fields up to 2 Tesla
     (see recent result from A. Lehmann et al. for 6µm-pore 2'' Photek AuraTek MCP-PMT)
   - If expected B fields are much higher: investigate SiPM as alternative
     (dark noise, radiation damage, cooling, annealing, integration issues)
   - Ongoing effort within eRD14, study of LAPPD/commercial MCP-PMTs in high B-fields
   - Have EOI members with SiPM expertise and interest to study SiMP use in hpDIRC
2. **What are the final geometrical and space constrains? (to finalize hpDIRC design)**
   - Barrel length and radius will be optimized for detector integration without impact on hpDIRC PID performance
   - Prism shape can be optimized for magnetic field lines
3. **What is the need for barrel PID at high momentum, is an additional system planned?**
   - Improved hpDIRC high-momentum PID could be further investigated with some R&D
4. **Is there interest and budget to investigate option of reusing BaBar DIRC bars?**
   - Effort would have to start soon due to expected phasing out of expertise at SLAC



A. Lehmann et al, shown by J. Milnes, IEEE NSS, Nov. 2020



Thoughts on PID for IP6@EIC

Wei Li

Rice University

IP6@EIC meeting

April 15, 2020

Globally PID for Detector 1:

- Must meet the requirements documented in YR in each of forward, barrel and endcap

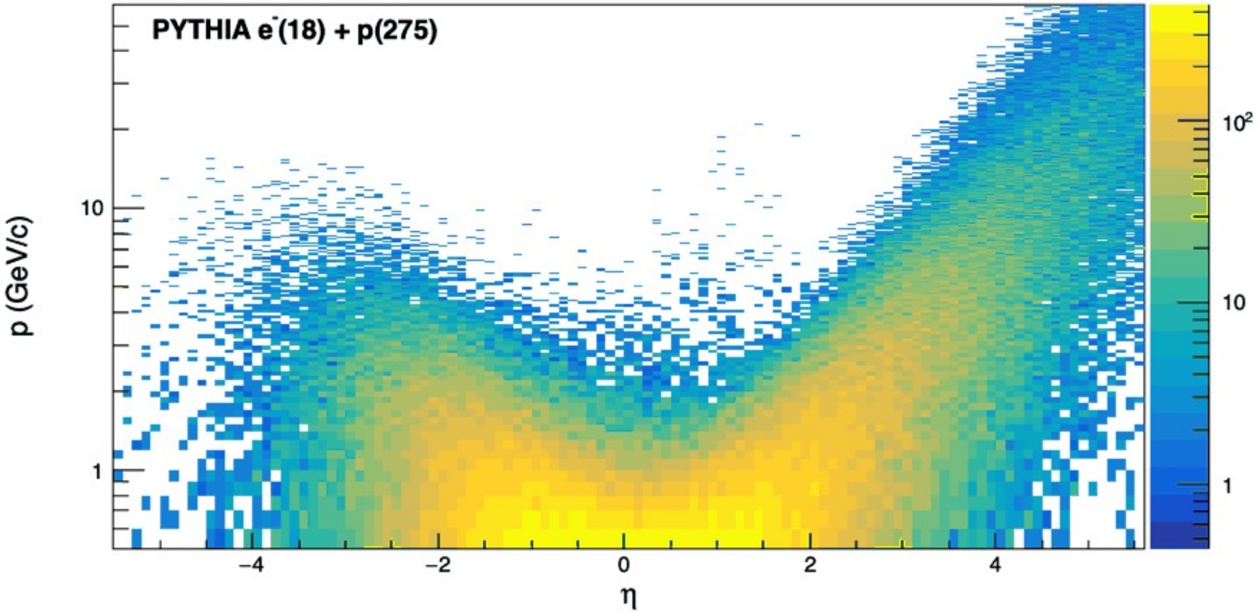
What are p_{min} requirements?

- If p_{min} as low as tracking allows (~ 0.1 GeV), no single technology can meet all requirements

How to get to 10-15 GeV in barrel?

η	π/K/p PID	
	p-Range (GeV/c)	Separation
-3.5 — -3.0		
-3.0 — -2.5		
-2.5 — -2.0		
-2.0 — -1.5	≤ 7 GeV/c	
-1.5 — -1.0		
-1.0 — -0.5		
-0.5 — 0.0		
0.0 — 0.5	≤ 10 GeV/c	≥ 3σ
0.5 — 1.0	≤ 15 GeV/c	
1.0 — 1.5	≤ 30 GeV/c	
1.5 — 2.0		
2.0 — 2.5	≤ 50 GeV/c	
2.5 — 3.0	≤ 30 GeV/c	
3.0 — 3.5	≤ 45 GeV/c	

Table 8.20



We should cover low p, simply because many particles are produced there

A combination of TOF+RICH design can generally meet most of requirements

- π/K 3σ separation:
  - dRICH: 3-100 GeV
  - mRICH: 2-6 GeV
  - hpDIRC: 0.5-6 GeV
  - TOF: 0.1-4 (assuming 20-30 ps)

η	π/K/p PID	
	p-Range (GeV/c)	Separation
-3.5 — -3.0		
-3.0 — -2.5		
-2.5 — -2.0		
-2.0 — -1.5	≤ 7 GeV/c	
-1.5 — -1.0		
-1.0 — -0.5		
-0.5 — 0.0		
0.0 — 0.5	≤ 10 GeV/c	≥ 3σ
0.5 — 1.0	≤ 15 GeV/c	
1.0 — 1.5	≤ 30 GeV/c	
1.5 — 2.0		
2.0 — 2.5	≤ 50 GeV/c	
2.5 — 3.0	≤ 30 GeV/c	
3.0 — 3.5	≤ 45 GeV/c	

TOF+mRHIC

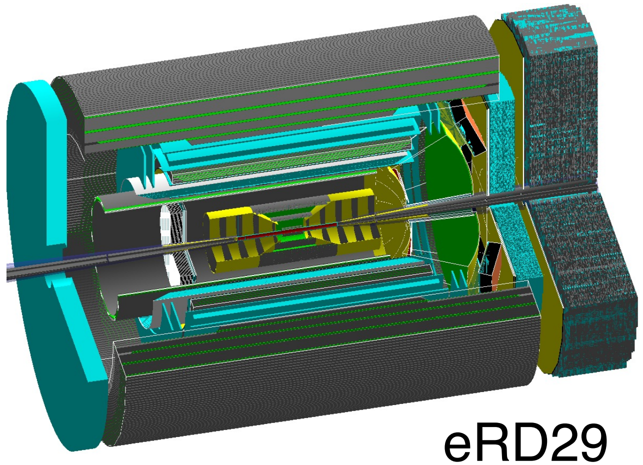
TOF+DIRC or DIRC alone

TOF+dRHIC

Table 8.20

Contributions you can bring to the PID activity towards the proposal in the next months.

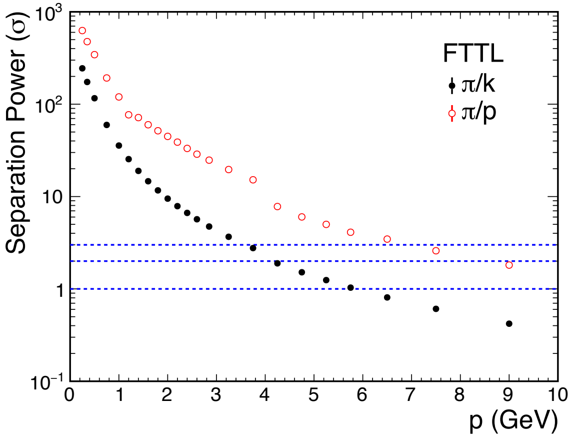
If pursuing PID with TOF, Rice group (and potentially others groups in the LGADs consortium) can contribute to implement the design, perform full simulations, assess impact on physics performance, cost estimate etc.



eRD29

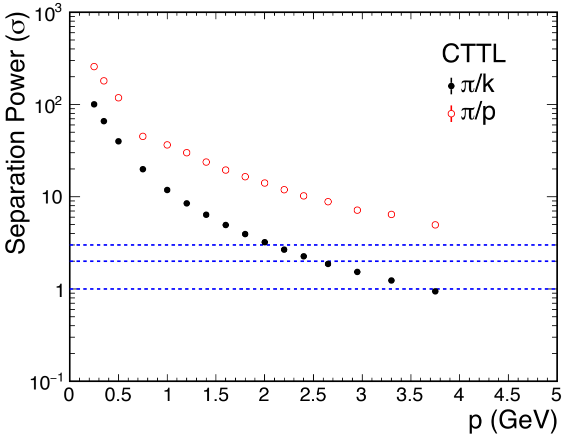
LGADs timing layers in Fun4All (B=1.5T)

Forward:
2 layers at z ~ 2.8 m
(behind dRICH)



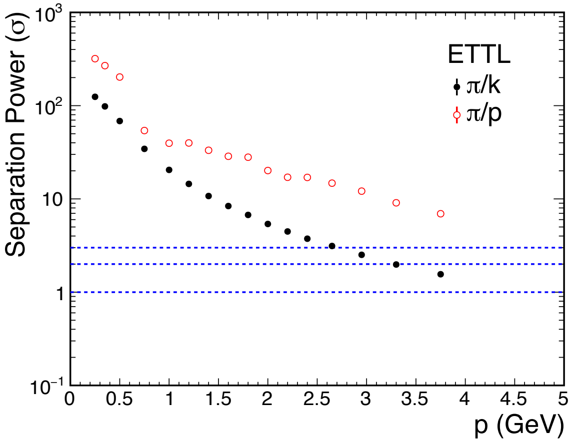
0.2-4 GeV

Central:
1 layer at r ~ 0.9 m



0.2-2.5 GeV

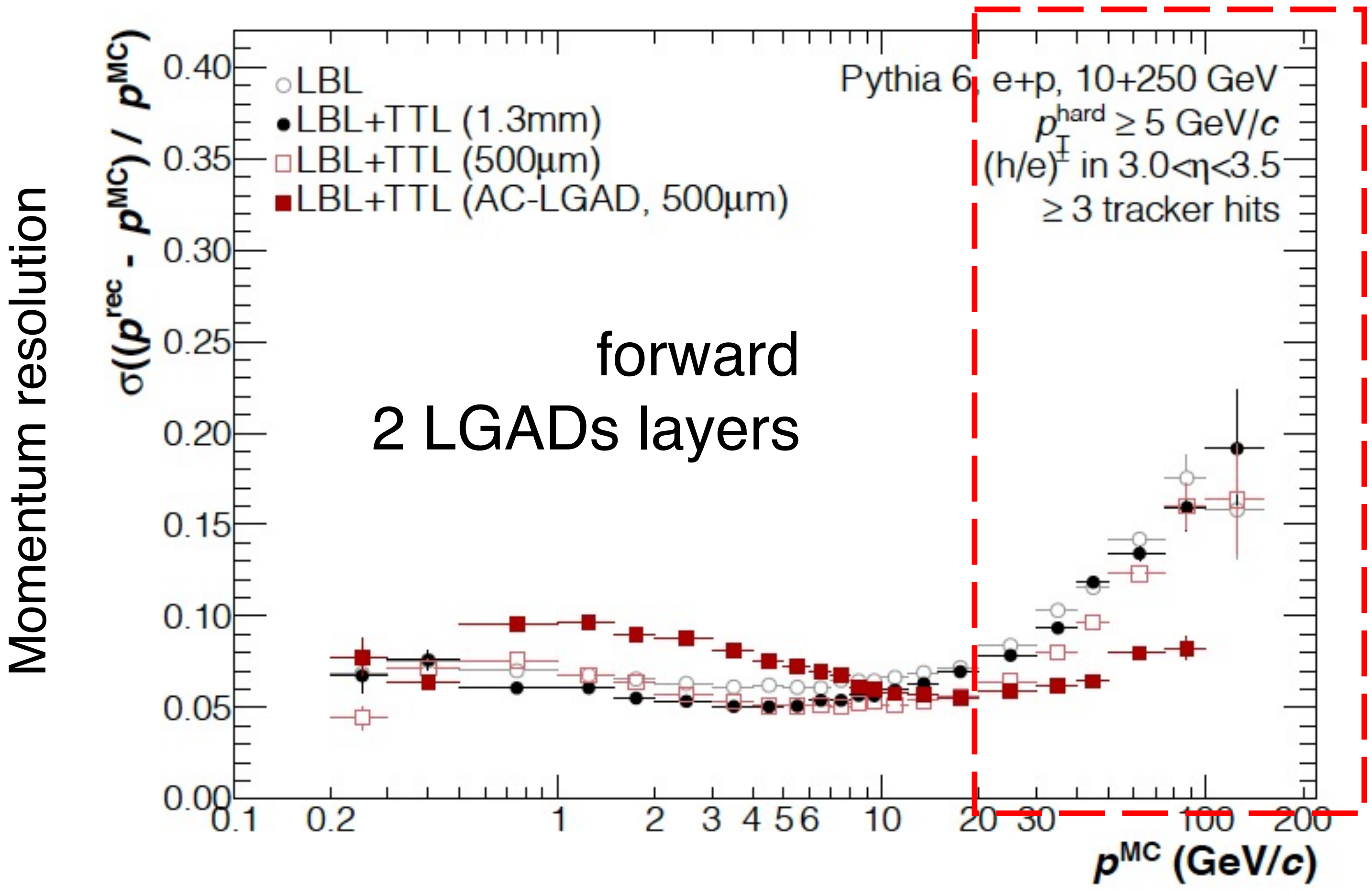
Backward:
2 layers at z ~ -1.5 m



0.2-3 GeV

All uncertainties (t_0, t_f, L) included

Impact on high momentum resolution



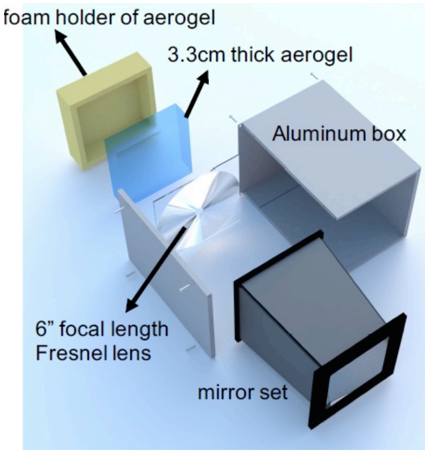
Modular Ring Imaging CHerenkov Detector (mRICH)

Murad Sarsour, GSU

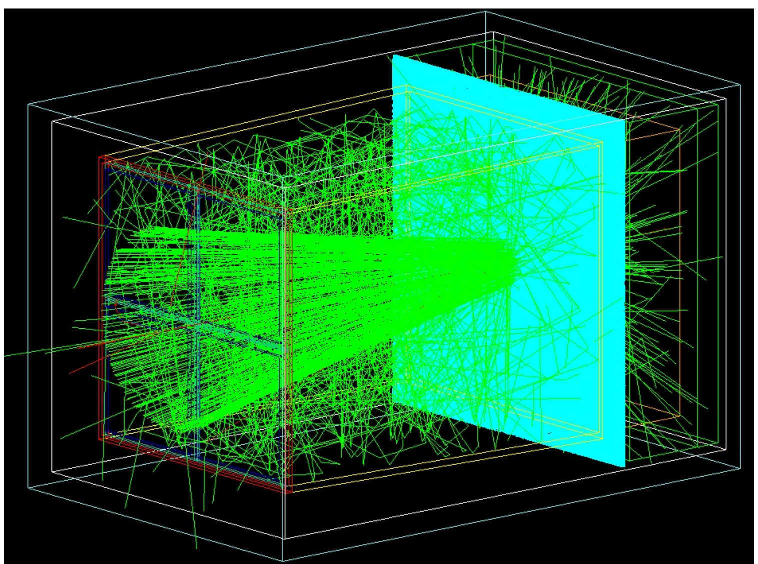
- Which contributions you can bring to the PID activity towards the proposal in the next months?

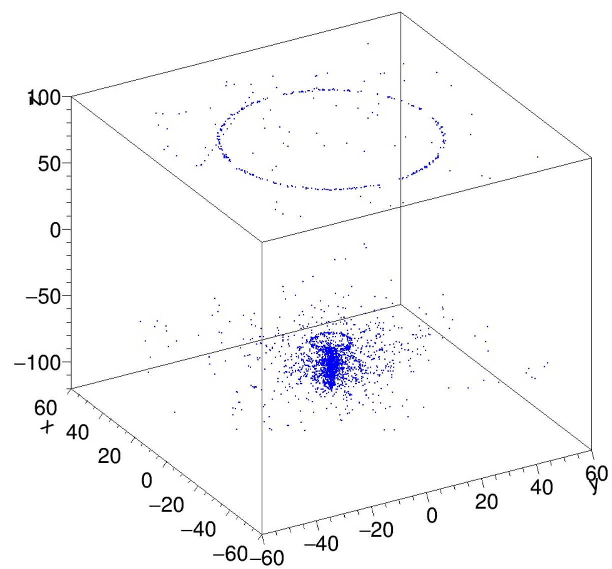
  PID detector in the e-arm: Modular Ring Imaging CHerenkov (**mRICH**) detector

  - modular and compact RICH detector
  - Provides hadron PID capability from 3 to 10 GeV/c for π/K separation and electron PID for e/π separation below 2 GeV/c.
  - Have full GEANT4 (fun4all) and standalone simulation

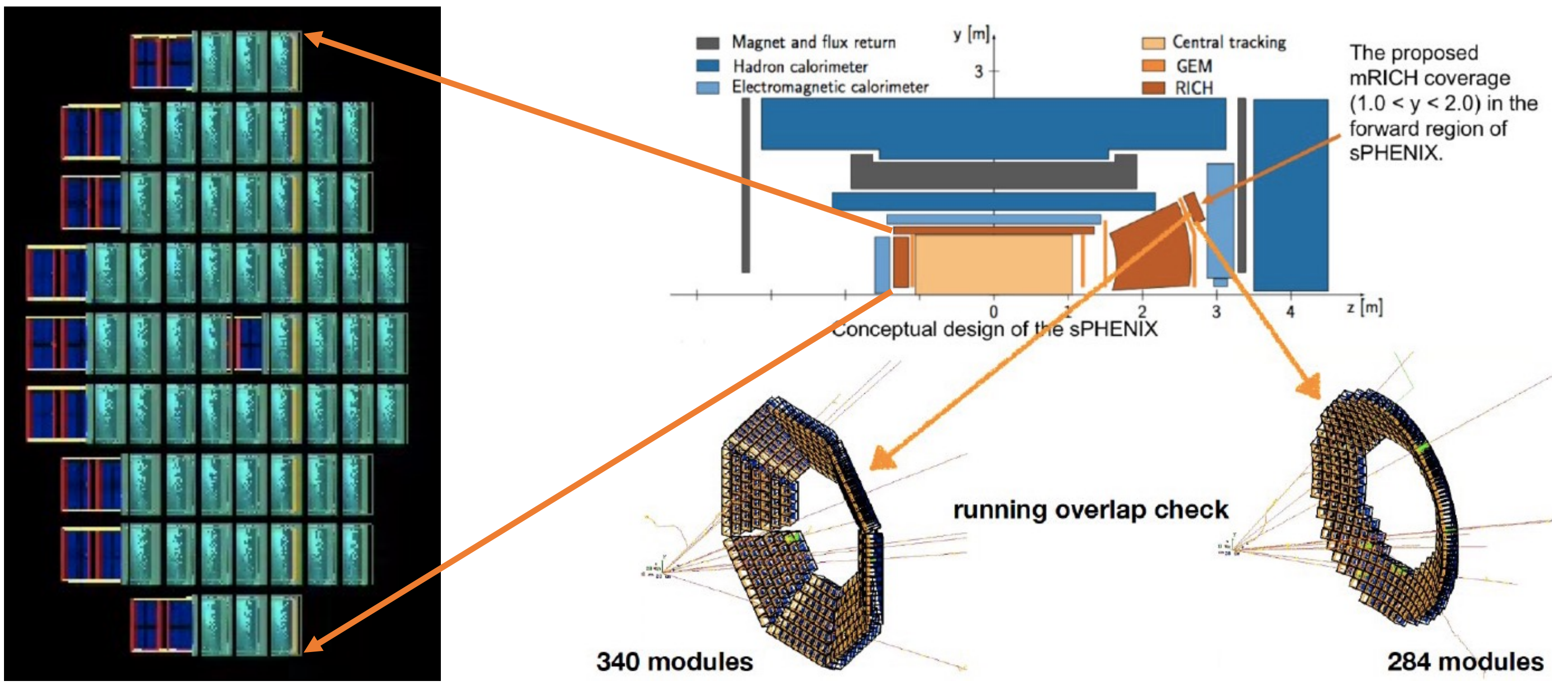


5 Kaons
7 GeV/c





- What are the most relevant and urgent questions in the PID sector?
  - Implementation of mRICH within EIC@IP6 geometry and comprehensive performance study in GEANT4 (fun4all)
  - Flat vs. projective



- How do you see globally PID for Detector 1?
  - Tracking resolution of 3 mrad