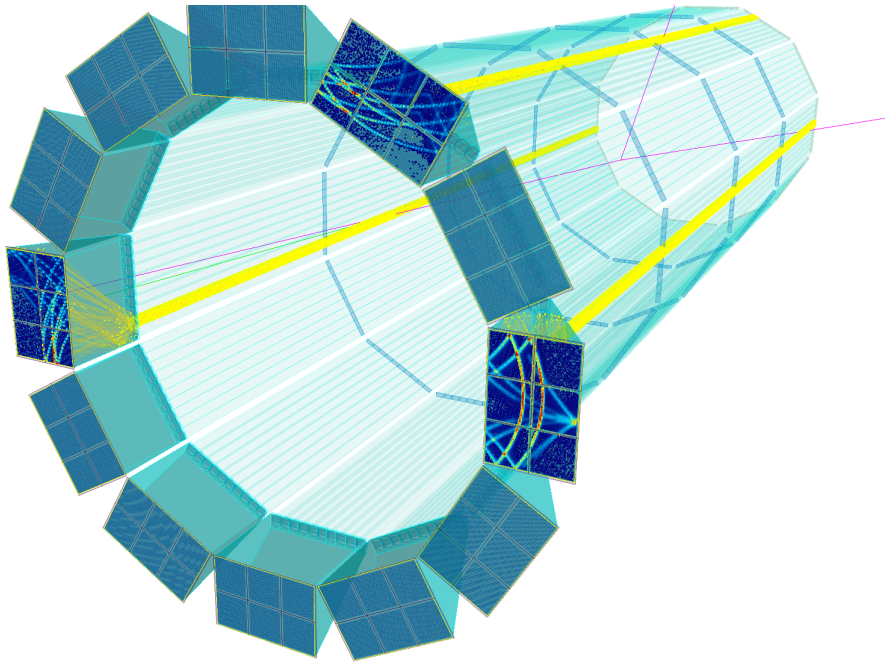
ePIC hpDIRC Sensor Requirements



Greg Kalicy

CUA

August 10th, 2026

ePIC TIC Meeting

CUA GSI Jefferson Lab Old Dominion Stony Brook University University of South Carolina Wayne State University William & Mary University of Glasgow

HPDIRC PHOTOSENSORS

hpDIRC requires efficient single photon detection, with excellent timing and spatial resolution, at high photon rates and multiplicities, with low dark count rates, in a large magnetic field

→ Microchannel-Plate PMTs (MCP-PMTs) currently the best option

Initial sensor candidate during Yellow Report times: commercial 2'' MCP-PMTs from Photonis or Photek

Earlier versions (larger pixels) used in beam tests, properties implemented in our simulation

Increasing concerns about Photonis and Photek (capacity and capability to meet specifications)

EIC project PED effort with Incom on HRPPD (large 4'' MCP-PMTs) development

Driven by pfRICH, with use in hpDIRC and our unique specs in mind

Successful production of several HRPPD prototypes, evaluation at BNL and in CERN testbeam

Also: ongoing side-by-side comparison of properties of HRPPD, Photek, and Photonis MCP-PMTs in Glasgow

Current assumption: HRPPD will also be selected as hpDIRC sensor

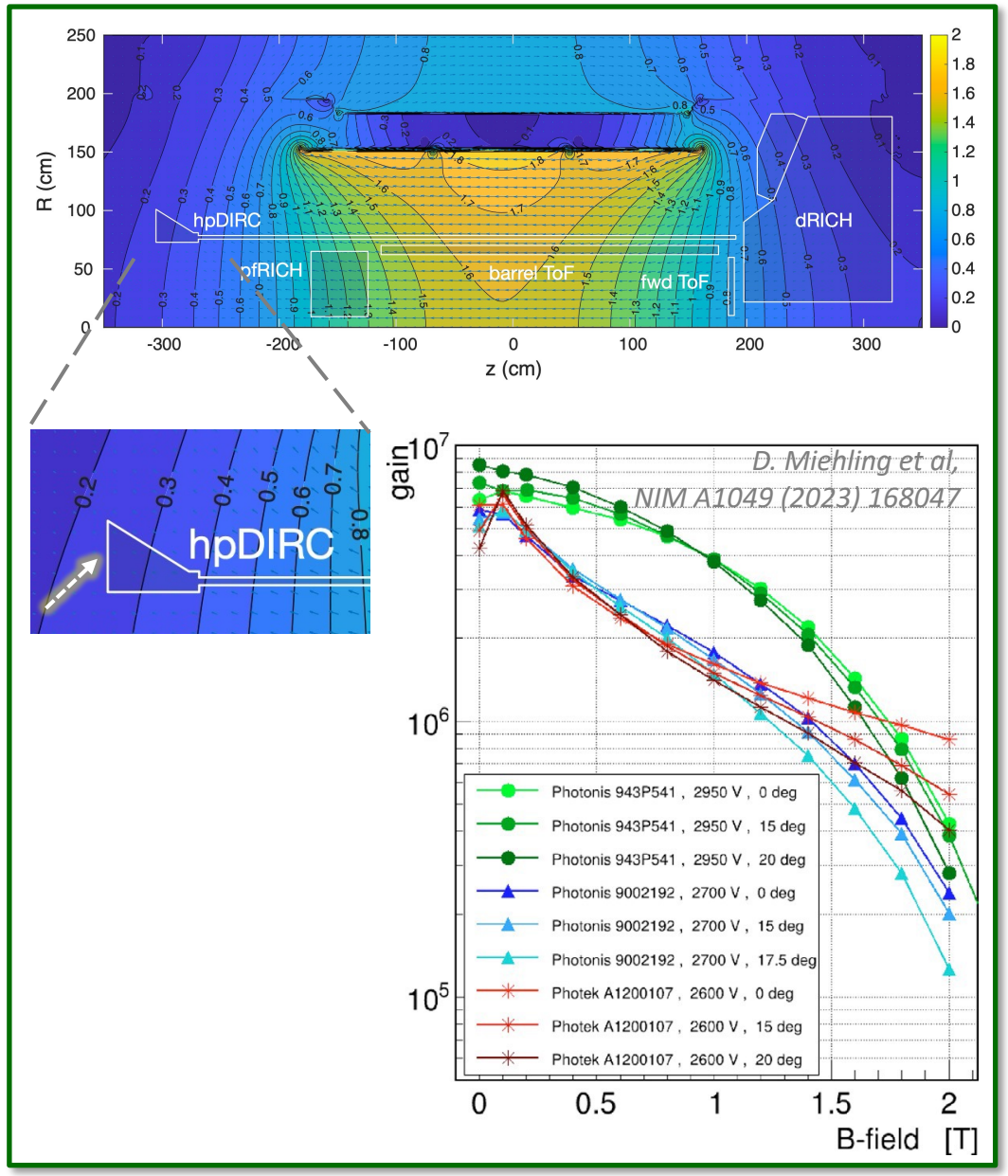
A few key performance issues remain to be studied/improved: collection efficiency and "ringing"

Final series production specifications currently under discussion

HPDIRC PHOTOSENSORS

hpDIRC sensor requirements in a nutshell:

- **Single photon sensitivity in ePIC magnetic field**
  - Uniform and stable 10^6 gain at up to 0.3 T and 30° field angle
  - Low dark count rate, goal: <1 kHz/cm^2
- **Fast timing for single photons**
  - Good single photon timing precision at ≤10^6 gain, goal: rms < 100 ps (for full-chain resolution, sensor plus electronics)
- **High photon detection efficiency**
  - Large active area ratio for tiled sensors: goal > 75%
  - Uniform and high PDE in visible range: goal > 25% at ~400 nm *(PED contract to increase collection efficiency from 70% to 90%+)*
- **Tolerance for large numbers of photons at high rates**
  - Small, DC-coupled pixels, goal: pixel pitch < 3.5 mm
  - Long lifetime: goal total integrated anode charge > 5 C/cm^2
  - Tolerance for high photon rates, goal: > 0.5 MHz/cm^2
  - Tolerance for high occupancies, goal: up to 200 photoelectrons per event per 4'' HRPPD sensor *(ongoing "ringing" study, see Brian's talk)*



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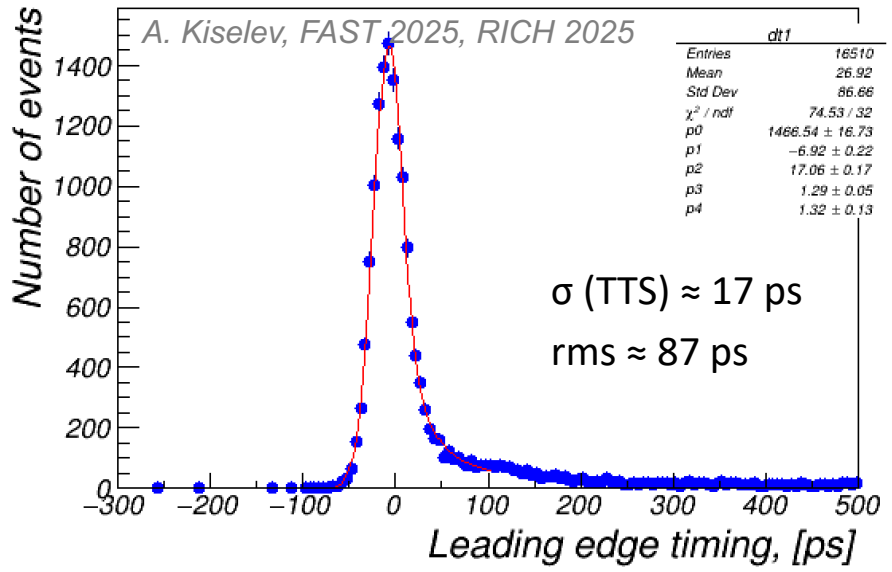
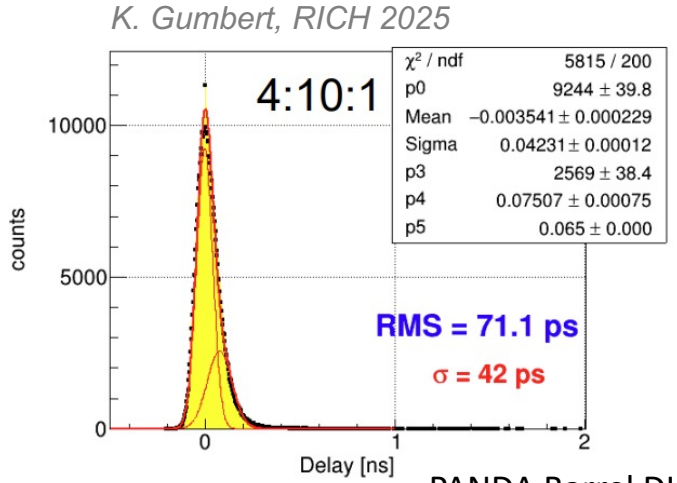
HRPPD prototype test at BNL at 2.5 10^6 gain





PANDA Barrel DIRC series production Planacon XP85112-S-BA at 10^6 gain

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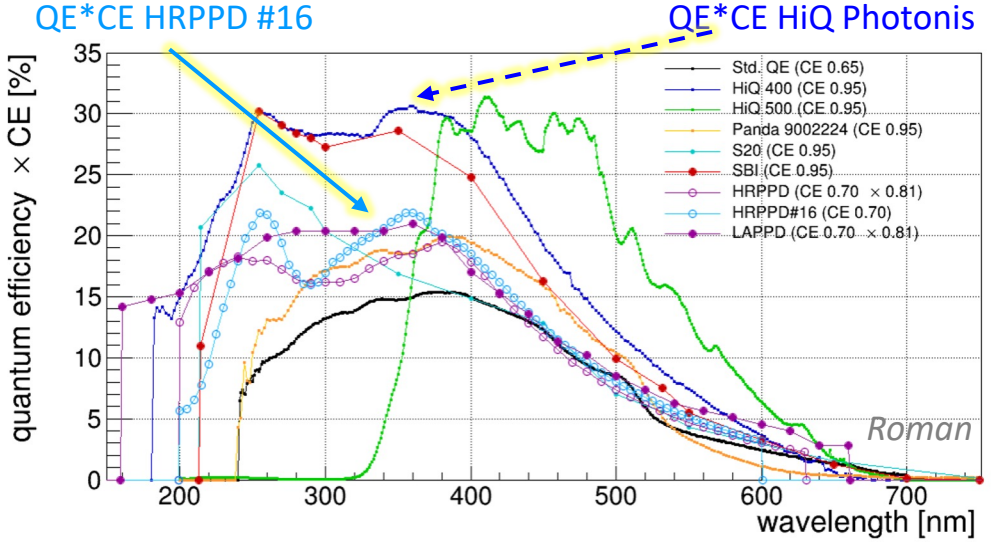

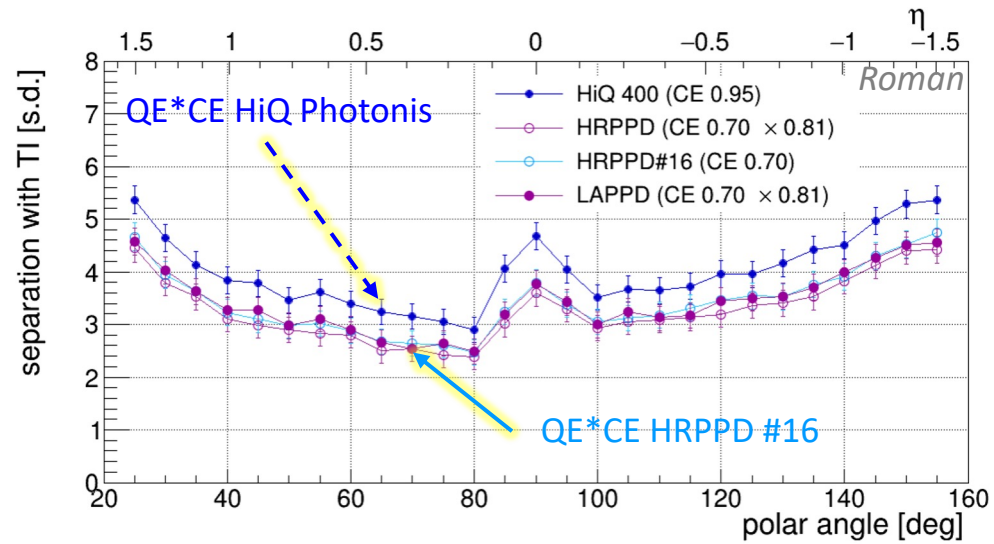

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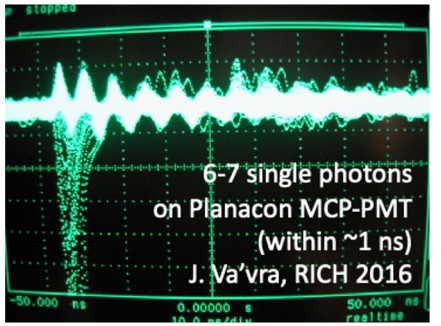
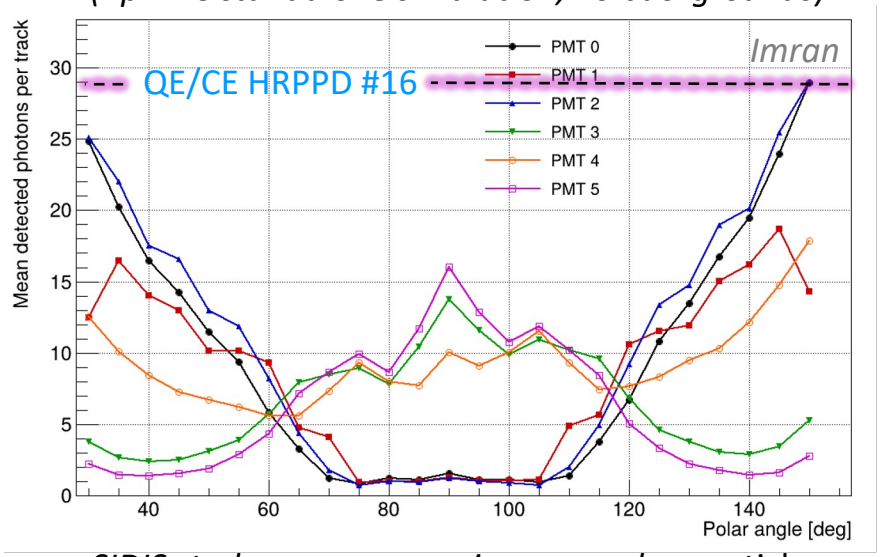
Coherent oscillations or "ringing" can lead to many fake hits, historically a challenge for commercial MCP-PMTs, resolved in recent years

Needs to be checked for HRPPD



Expected number of detected photons per particle (hpDIRC standalone simulation, no backgrounds)



SIDIS study: average maximum number particles per bar box with β>1/n: 0.9…3.9 *(function of Q²)*

EXTRA

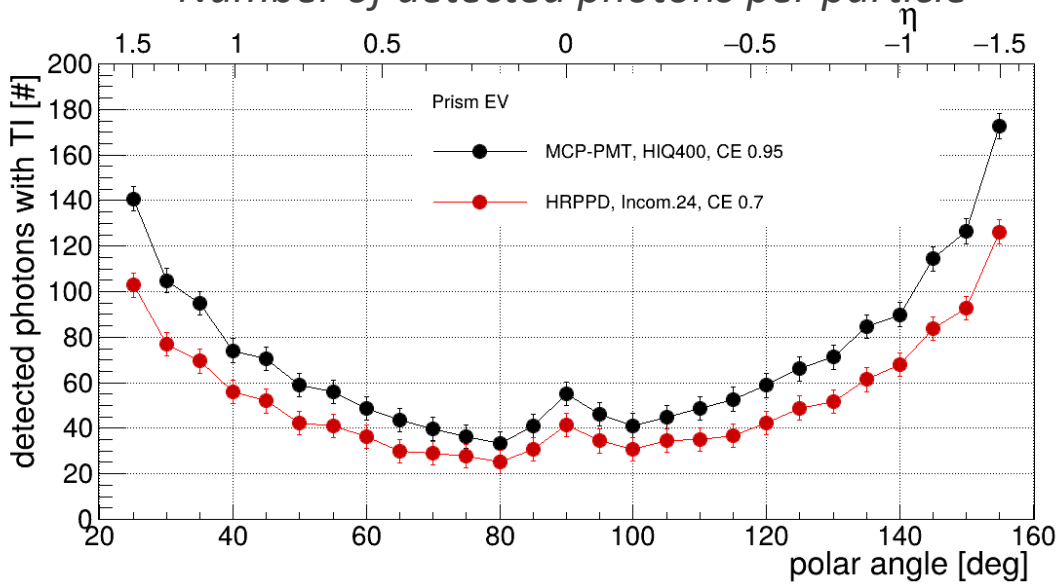
Sensor Efficiency

- PDE (QE x CE) of sensors in our simulation and in past presentations and papers, unless stated differentl, based on measured HiQ400 Photonis tube properties

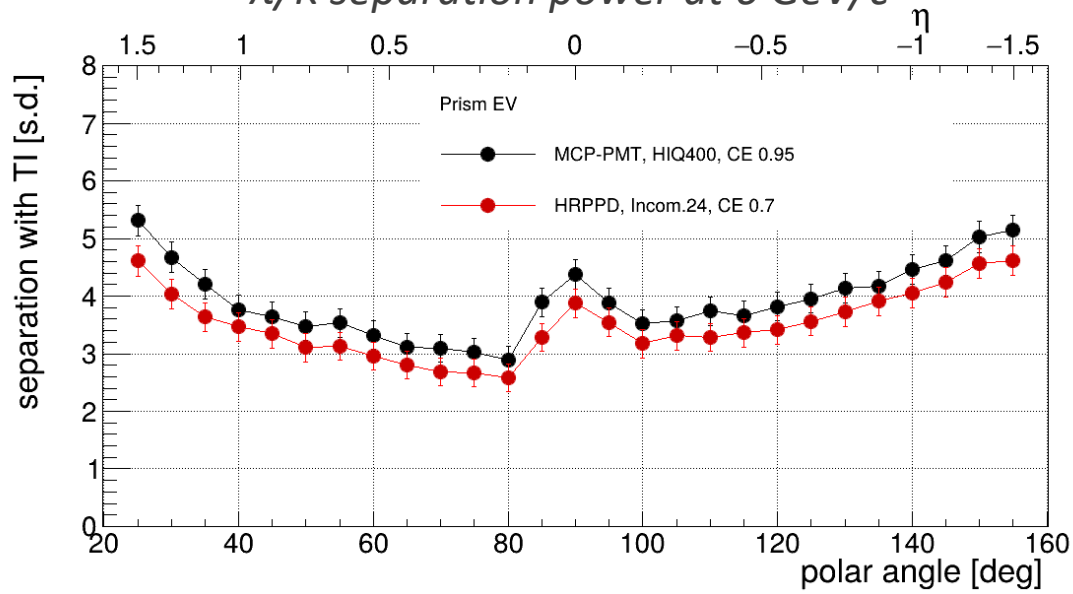
- Current PED contract with Incom includes production of prototypes with higher collection efficiency, potentially increasing PDE by factor 1.4

Impact of PDE on hpDIRC performance

Number of detected photons per particle



π/K separation power at 6 GeV/c



TIME RESOLUTION

- Full Readout Chain (sensors + electronics)

  time resolution assumed to be 100 ps

Impact of time resolution on hpDIRC performance

π/K separation power at 6 GeV/c