eRD6: PID detector R&D towards an EIC detector

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(on behalf of the Trieste-EIC group)
What is needed at high $p$ at EIC:
- Gaseous radiator
- Focusing system (mirrors)
- Wide phase space acceptance

Poor worldwide panorama
- Presently only 2 running high-$p$ & wide acceptance RICHes:
  - COMPASS
  - LHCb (2-counter system)
- Further future projects:
  - EIC
  - Empowering the physics reach at CpeC (not presently in the project baseline)

The challenges at EIC (and, in general, at colliders with hermetic experimental setup):
- Short radiator (No more than 1 m-long radiator at EIC)
  - More detected photons per radiator unit length, increased space resolution
- Presence of magnetic field
  - A wide family of PDs excluded
R&D MOTIVATION: h-PID @ HIGH p 2/2

Options to match the quest:

1. Windowless RICH

**CF$_4$ windowless RICH concept, test-beam results**

M. Blatnik et al., IEEE NS 62 (2015) 3256

“Cheap” photon detectors, delicate FE, expensive mirrors, challenging radiator gas transparency

By a thin-film reflecting mirror

Pad-size $\sim$ 5 mm, n$_{\text{det ph.s}}$ : 10

Frequency vs $\theta_C$

32 GeV

28 mrad

2. Photon detectors in the visible light (wide range) B-tolerant

- 2 realistic possibilities
  - Hamamatsu MCCP arrays
    - But noise rate : 1.8 M counts/ m$^2$ in a time window of 10 ns
  - LAPPDs
    - But are they reasonable mature ?
    - In particular the second version, where pads can be used (pads is a MUST) ?

Costs: 0.5-0.8 M$\$$ / m$^2$

25.8 mm x 25.8 mm
1. Windowless RICH

- Make use of our experience with COMPASS RICH to advance with MPGD-based PDs adequate for the Windowless RICH approach

- *This is our activity within eRD6 (discussed in this talk)*

2. Visible light photon detectors

- Start getting some experience with the mentioned photon detectors

- *A proposal for AIDA++ (European project) in preparation together with partners: INFN-Trieste, INFN-Bari, Charles University, USTC, INCOM (mentioned for complete information)*
The starting point

COMPASS MPGD PDs

GOAL of the prototype:

**increased space resolution**

- Pad size 8 mm x 8 mm → 3 mm x 3 mm (pitch 3.5 mm)
- To preserve the expandability of the detector size → all services in the same area of the active pads (very dense connectors)

Some key parameters

- **Pad size 8 mm x 8 mm**
- **Current spark rate:** ~1 h / 1.5 m²
- **Recovery time after a spark:** ~ 10 s
- **Noise level < 900 e-equivalent**
  - APV25 with extremely accurate FE boards
- **Gain ~ 14 k**
- **10 detected ph.s per ring at saturation**
- **Time resolution ~ 14 ns**
THGEM tested, Stand alone

THGEM post-production treatment

MM with miniPADs

Gain uniformity: ~5%

MM tested, Stand alone
NON-OPTIMIZED ANODE PCB LAYOUT

Different amplitude from different pads!

The PCB layout is the same for each group of 128 pads:

The noise pattern reproduced for the various groups is a further confirmation

Different capacity affecting the signal line:
Amplitude uniformity recovered correcting for C

Typical noise level: \( \sigma \sim 3300 \text{ e}^- \)
(COMPASS RICH: \( \sigma \sim 900 \text{ e}^- \))
- **Read-out system:** SRS (from RD51)
- **FE chip:** APV25
- **DAQ:** RAVEN, an original system developed for these studies
  - LabVIEW-based
  - Includes Decoder and on-line analysis tools (pedestal, subtraction, hit maps, spectra)
  - User-friendly via GUIs
  - Used for 1 k ch.s, extendable
  - Good rate capability:
    - For single APV can handle up to 10 kHz
Between radiator and detector, a shutter (iris) with piezoelectric actuator, controlled from remote.
Ar : CH$_4$ = 50 : 50

(analysis of pure CH$_4$ data ongoing)
TEST BEAM DATA ANALYSIS, cont.

Iris open

Open – close
(same number of events)

Iris closed
One more geographical cut:

**Ring region**

**Open – close**

**Cluster size**

Gain from cluster amplitude: 30 K
(lower limit due to high threshold)

Including all surrounding pads with signal above threshold
Illustration of the algorithm

Time plot

\( \chi^2 / \text{ndf} \) = 325.8 / 2
\( p_0 = -328.1 \pm 37.65 \)
\( p_1 = 2.592 \pm 0.2283 \)

10% of max amplitude

“Photon” \( t \)

subtracting the trigger time contribution (random in the 25 ns window):

\[ \sigma_t = 14 \text{ ns} \]
First prototype with increased space resolution

- 2 critical aspects, both clearly traced and understood:
  - Signal lines in the anode PCB layout, C to be equalized
  - Non-ideal noise performance with SRS and read-out boards parallel to resistor board

- Positive outcomes:
  - Single photons clearly detected
  - Good gain
  - Good time resolution
  - Cluster relevance
**PROSPECTS**

- This pad size is the limit with the present approach
- Try increasing space resolution by resistivity:
  - Spread the signal over several pads by the resistive layer

**Pad-size: 1 mm → resolution ~ 200 μm**

- 4-corner read-out scheme

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M. Alviggi et al., NIMA 936 (2019) 408.

X. D. Ju et al., JINST 12 (2017) P10008

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h-PID

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THANK YOU !