Sensors and Readout for mRICH

R. Montgomery on behalf mRICH team

Photosensors for mRICH

- Operate within ~1T field
- Single photon sensitivity, gain >1.0e6
- Pixelisation 3mm x 3mm
- Active area compatible with mRICH module size
  - introduce minimal losses in acceptance due to sensor active area or tiling effects
- mRICH acrylic lens filters shorter UV wavelengths (reduces smearing of θ_C from Rayleigh scattering)
  - photosensor sensitivity in >350nm range, sensitive to aerogel emission spectrum

- Two possibilities being considered
  - HRPPD
  - SiPM

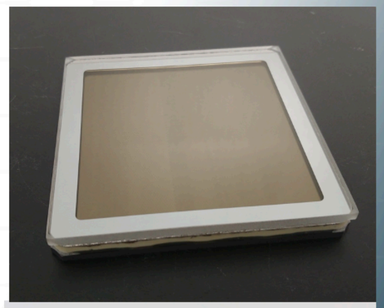
- Both options still require development
  - Developments already on-going within EIC and wider communities
  - mRICH requirements are synergistic with and can benefit from wider efforts

INCOM HRPPD

- 10cm x 10cm active area - compatible with mRICH module footprint → 1 HRPPD per mRICH module
- Via readout board design, possible to have required 3mm x 3mm pixels

HRPPD – High Rate Picosecond Photodetector

- **10 cm x 10 cm MCP-PMT**
  - Chevron pair of ALD-functionalized MCPs **(10 µm)**
  - Glass/Ceramic package
  - Capacitive (CC) or Direct (DC) Coupling
  - **100 cm²** active area (only spacers on edges)
- **High Gain (~10^7)**
- **Bialkali Antimonide Photocathode**
  - Sodium-Potassium-Antimony Na_2KSb
  - **>30%** QE at 365 nm
  - **>95%** spatial uniformity
- **Timing Resolution**
  - SPE: **~23 ps** (Vagnoni, INFN for 10 um pores)
- **Position Resolution**
  - **< 0.6 (mm)** (dependent on readout board)
  - DC version has 1024 2.5 x 2.5 mm pixels



Available today!

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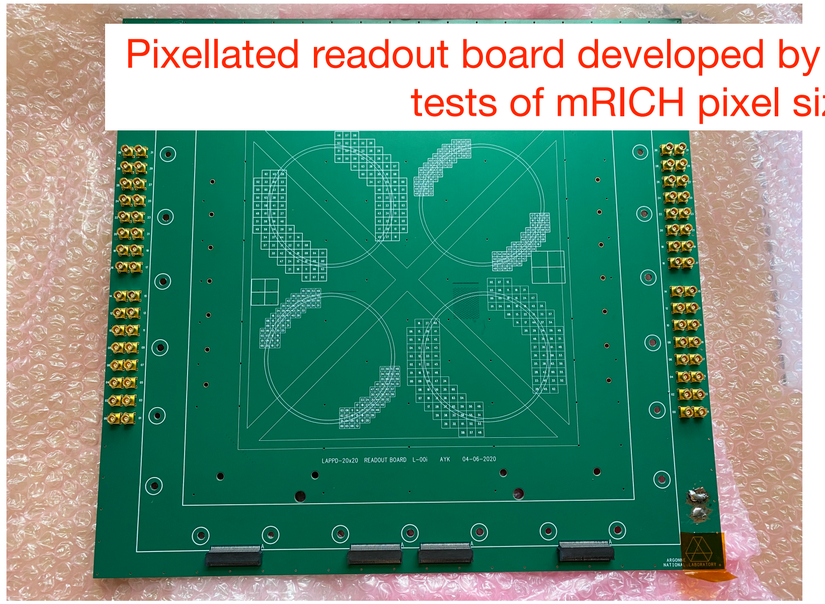
LAPPD Workshop – October 26, 2022

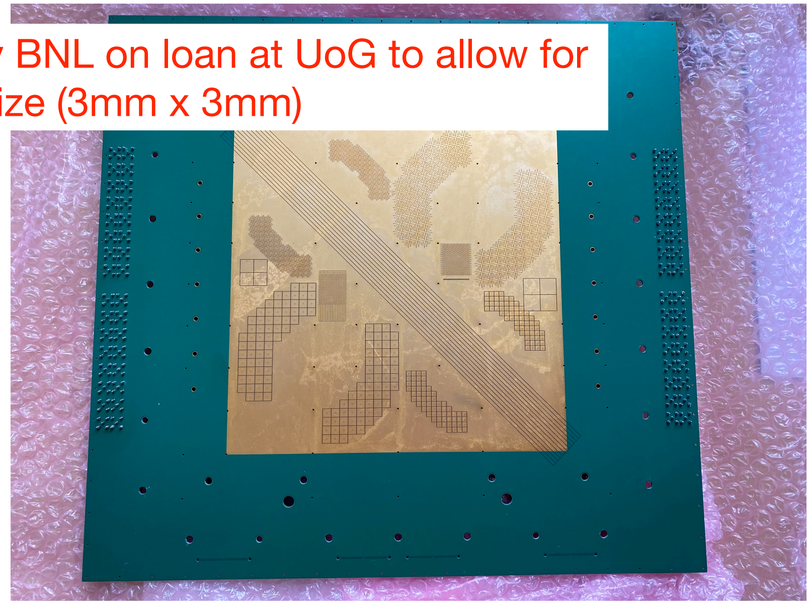
Slide from INCOM

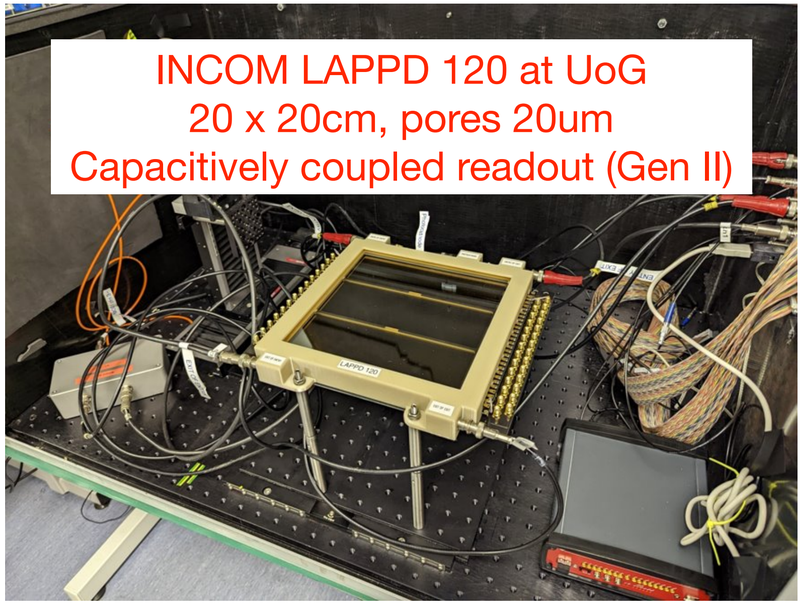
Parameter	LAPPD / HRPPD
Gain	1.00E+07
SPE Timing Resolution	<50 ps
MPE Timing Resolution	8 ps
Pixel Size	Any / 2.5 mm X 1024
Spatial Resolution	<1 mm
Room temp Dark Noise	≤2 kHz/cm²
Radiation hardness	>1E15 15 MeV protons
Single-Photon readout	Yes
Magnetic Field Tolerance	1.4 T demonstrated
@ Degrees from Normal	TBD
PC QE @365 nm	30%
PC QE @450 nm	>20%
PDE @450 nm	TBD (≥20% = 70% OAR X 30% QE)
Demonstrated Tile Life	TBD (> 5 C/cm²)

Table from INCOM

HRPPD





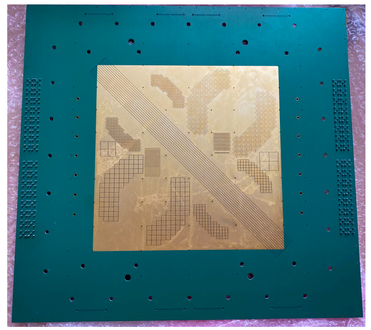


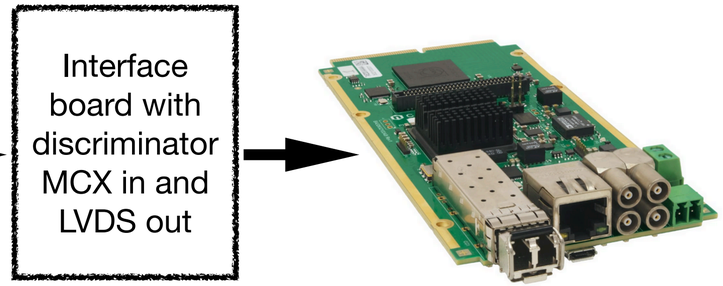
- mRICH are collaborating with eRD110 on HRPPD and its readout moving forward, in order to evaluate HRPPD performance for mRICH

- Currently have 20cm x 20cm Gen-II LAPPD under test at UoG
- (UoG team: F. Thomson; B. Seitz; R. Montgomery)
- Current readout: MCX cables to 16 channel waveform digitiser (CAEN DT5730B)
- Tests so far with plastic scintillator, next is laser (have PiLas ps laser, several wavelengths, and fs laser)

- Next steps:
  - Upgrade to higher density ASIC readout at UoG (short-term planning to test picoTDC ASIC from CERN/CAEN)
  - Obtain DC-coupled HRPPD and readout board for pixellated HRPPD tests (e.g. rental or via eRD110 support)
  - Obtain mRICH aerogel tiles to test in a cosmic set up at UoG

HRPPD





A5203 ★ Coming Soon

64/128 Channel picoTDC unit for FERS-5200

Request a quote

Data Sheet | Downloads

Features

- 64/128-ch TDC unit for **high-resolution timing** applications housing the CERN picoTDC
- Part of **FERS-5200**, the CAEN platform for the readout of **large arrays of detectors** (SiPM, MA-PMTs, Gas Tubes, Si detectors, ...)
- Timing resolution: **LSB = 3.125 ps, RMS typ. ~ 7ps**
- LVDS-compliant input, possibility to use single-ended analog/NIM/TTL through dedicated adapters
- Acquisition of rising/falling edge **timestamps** enabling **ToA** and **ToT** measurements
- **Scalability** and **easy-synch**: up to 128 cards (**8192 channels**) can be managed and synchronized by a single **DT5215** Concentrator Board, thanks to the optical **TDLink**

- **Generally**:
- Front-end readout for HRPPD still needs development in general
- For EIC need high channel density/low power solution is needed (mRICH/pf-RICH/DIRC)
- mRICH will be 68 HRPPD and 69 632 channels
- Several activities within community which are relevant/ applicable to mRICH (e.g. pfRICH/BNL, NALU Scientific ASIC, EICROC OMEGA ASIC for EIC)

- Foresee no reason for those developments not to work with mRICH
- Moving forwrd, plan to collaborate with eRD110 to evaluate readout for mRICH and also to test pixellated HRPPD and readout

- **Currently in parallel at UoG:**
- Also preparing test of picoTDC ASIC from CAEN with LAPPD in (est. in April)
- Developing interface board to connect LAPPD to picoTDC

HRPPD

1) **The Sensors** - Incom offers both capacitively coupled and direct readout sensor solutions
2) **Frugal Price** –At a volume of ~200 units, $20k / device is achievable (**$52/cm²**)
3) **Manufacturing Scale-up** - Incom has the experience and infrastructure to fully support manufacturing scale-up to ensure high quality tile delivery well in time for EIC and other program needs.
4) **Technical Specifications** - LAPPD / HRPPD already meet most photosensor requirements
5) **Critical Developments** - A Pending SBIR Application will address critical developments for EIC and other physics programs

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LAPPD Workshop II– October 26, 2022 2

Slide from INCOM on LAPPD/HRPPD Oct 2022

- Don't foresee issues with manufacture/scalability
- mRICH will require 68 modules
- From INCOM:
  - Currently producing HRPPD in low-volume production (1 or 2/month)
  - Short term could expect 8/month
  - Followed by at least 32/month once demand high enough
  - Expect capability to deliver quantity needed for EIC on time (mRICH/pf-RICH and DIRC)
  - Est. full manufacturing price EIC for HRPP $200 to $100/cm² (high volume funded scale up $26/cm² for LAPPD)

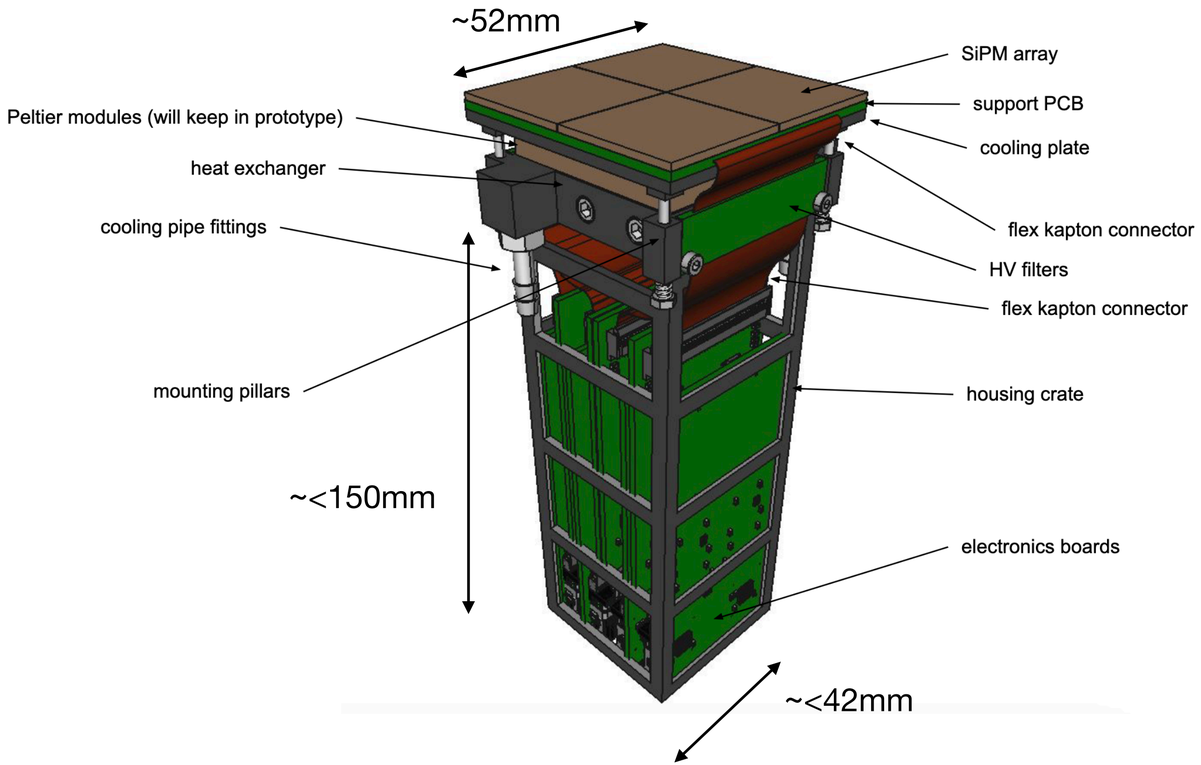
Photosensors - SiPM

- SiPM considered as alternative/back-up option
  - Cheaper sensors (although do need to add cooling/annealing costs)
  - Insensitive to **B** field
  - Several manufacturers (Hamamatsu, FBK, Ketek, Broadcom, Sense), scalability/ production not expected to be an issue
  - Arrays with 3mm x 3mm pixels available, four-side tile-able for no dead-space
  - Higher PDE in aerogel range/visible light (e.g. ~40%)
  - Excellent single photon timing achievable (e.g. <100ps)
  - Several existing, scalable, readout ASICS commercially available

Photosensors - SiPM

dRICH SiPM prototype optical readout unit

Similar modular design could also work for mRICH



From: *Pietro Antonioli and Roberto Preghenella (INFN Bologna)*
Presentation at dRICH GD/I meeting 02/27/23
https://indico.bnl.gov/event/18494/

- Closely following dRICH SiPM developments
- Previously collaborated with dRICH colleagues using their SiPM successfully in mRICH test beam
- dRICH must detect Cherenkov light from aerogel (and gas) in similar **B** field
- Also aim for 3mm pixels
- SiPM solution which works for dRICH could potentially also work for mRICH
- Radiation tolerance is outstanding topic
  - May need annealing for single photon detection in high radiation environment
  - Under study by dRICH
- Larger dark counts in SiPMs at room temp
  - Would require cooling, also under study by dRICH

Summary

- Both HRPPD and SiPM feasible solution for mRICH readout

- HRPPD considered as baseline choice currently
- HRPPD and readout still under development within community
- Largest outstanding question is front-end readout
- Have started to collaborate with - and will continue to collaborate with - eRD110 on evaluating HRPPD and its front-end readout for mRICH
- For use in mRICH, expect no fundamental difference necessary for HRPPD and its readout compared to existing developments within wider EIC/ePIC community

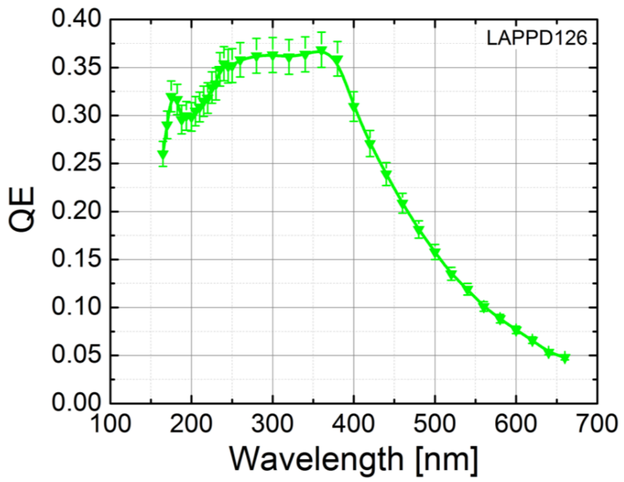
- Closely following dRICH SiPM developments as back-up/alternative
- dRICH-style SiPM solution could work for mRICH
- Previous experience with dRICH colleagues in using SiPM successfully in mRICH testbeam
- SiPM outstanding questions are dark count rates (cooling necessary) and radiation hardness (annealing likely necessary for single photon application like RICH)

- mRICH photosensor options are synergetic with existing on-going developments within EIC project and wider community

Back Up Follows

From Incom on QE

EIC Critical Developments - QE vs Wavelength



- UV grade Fused Silica glass window
  - Cutoff wavelength: **~160 nm**
- Peak at **~365 nm**
- Will Red-shift this spectrum
  - Make the peak wider using other alkali metals
  - Or red-shift the peak using alternate chemistries

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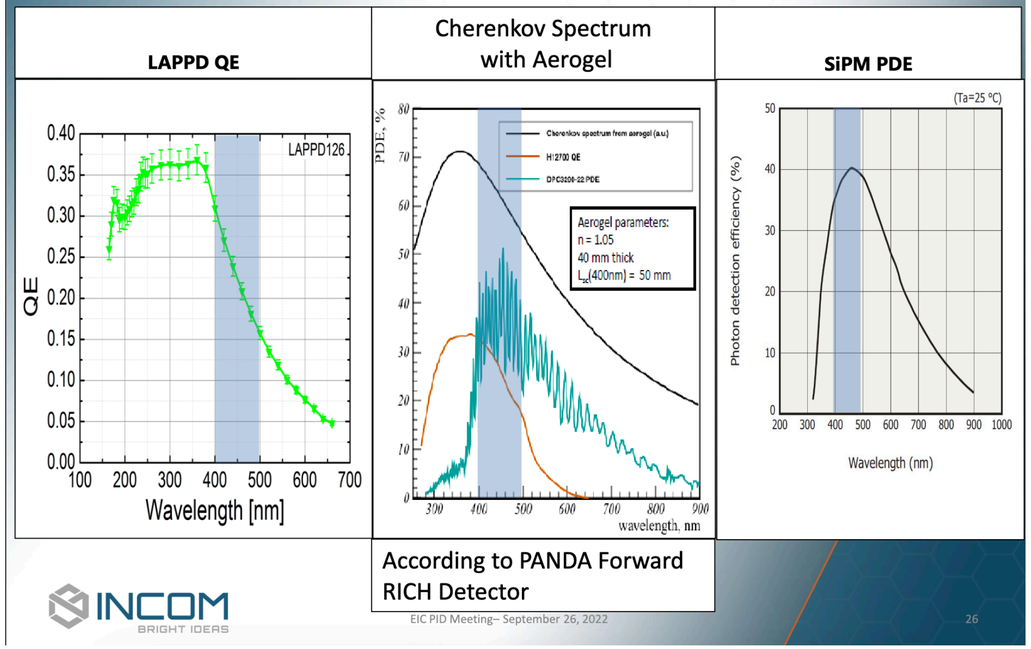
- INCOM considering modifications to improve QE and PDE in aerogel range for EIC
- Red shift QE/PDE spectra
- (QE ≥30% and PDE ≥20% at ≥400nm)
- Steps:
  - Higher QE, funnel shaped MCP pores, electron steering

EIC Critical Developments:
Cherenkov Spectrum with Aerogel



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From INCOM EIC PID Meeting Sep 2022