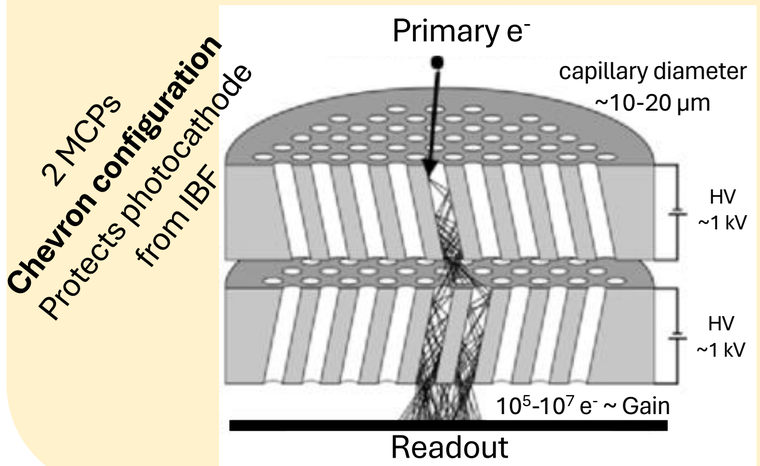
Timing Resolution of an LAPPD Prototype Measured with CERN PS Test Beams

Jinky Agarwala
On behalf of INFN Genova, INFN Trieste and the EIC ePIC collaboration

Istituto Nazionale di Fisica Nucleare

LAPPD – an MCP-PMT based Photodetector

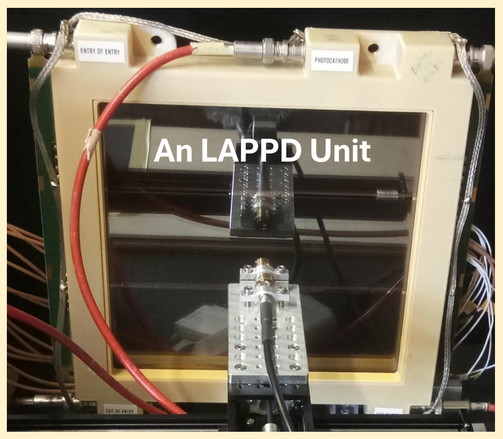
MicroChannel Plates[1] (MCPs) are **vacuum based Photomultipliers**



- Continuous dynode for e⁻ multiplication
- **Operation in strong magnetic field ~ 1T**
- **Excellent time resolution (< 100 ps) for SPE**
- Low noise, High QE, **High gain O (10^6)**
- Good radiation hardness

- **Atomic Layer Deposition (ALD)**
  – efficient technique for increasing detector lifetime
- Commercially available
  – Hamamatsu, Photek, etc.

Large Area Picosecond Photo-Detectors[2] **(LAPPDs)**
- MCP based technology



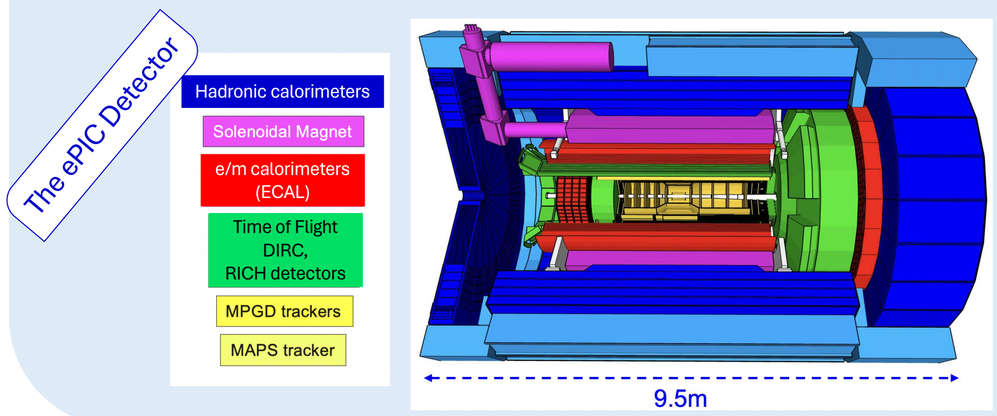
Application:
- **Cherenkov Imaging Devices**
  e.g., RICH, DIRC
- TOF, timing layers of Calorimeters

Large Area Coverage – cost effective solution for PDs in HEP

HRPPDs – in the EIC ePIC

LAPPD – A **potential first step** towards High Rate Picosecond Photo-Detector **(HRPPD)** – technically different from LAPPD **(10 cm vs. 20 cm** size and **DC vs. capacitive coupling**)

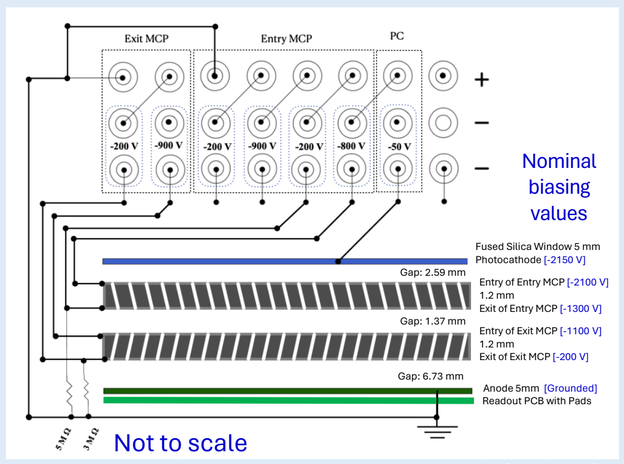
- ePIC[3] @ the Electron Ion Collider[4] (EIC): Ultimate **QCD** exploration
- NSAC LRP 2023: "... the EIC as the highest priority for facility construction."
- HRPPDs in ePIC: photosensors for **Cherenkov Imaging PIDs**
  - **proximity focusing RICH** and **TOF information** (backward Endcap)
  - **high performance DIRC** (Barrel)



The LAPPD Sensor

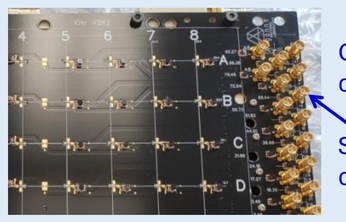
LAPPD unit no. 124 of type "**Generation II** (resistive Anode)" by Incom.
- Bialkali PhotoCathode (PC)
- Two MCP (20 μm-diameter capillaries) layers
- Resistive Anode - coating with Cr layer
- Capacitively coupled readout[5] sensors (8x8 square pads of 1 inch) on PCB

- active area ~20 x 20 cm^2

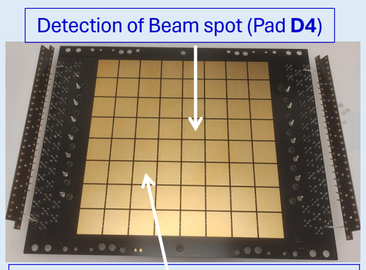


Not to scale

LAPPD electrodes connected to **Daisy Chain HV Power Supply (CAEN DT1415)**

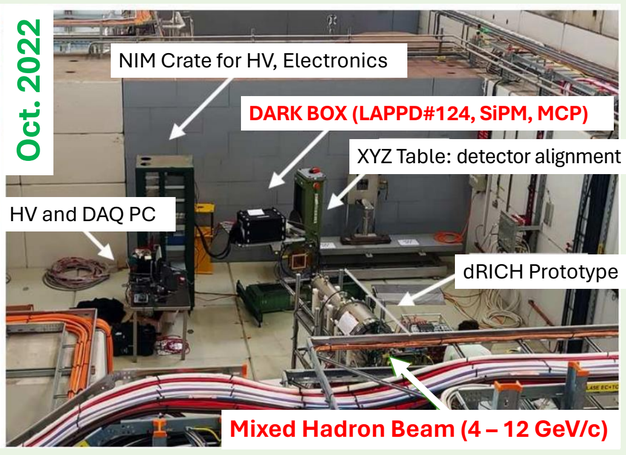


Detection of Beam spot (Pad **D4**)



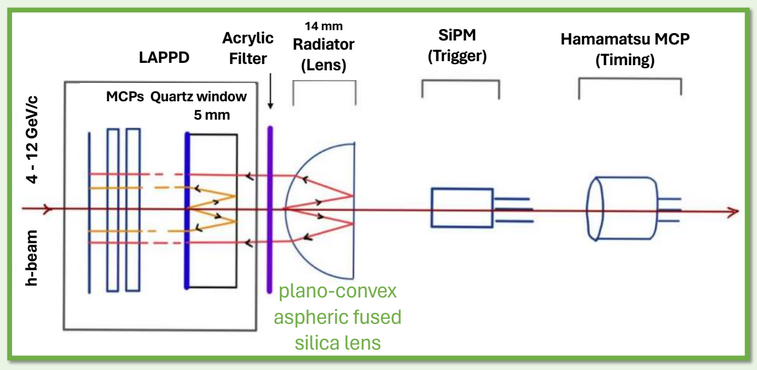
Detection of SPEs in Cherenkov Ring (**F6**-One of the Pads)

Beam test Set-up and TDAQ



CERN PS T10 beam facility shared with ePIC dual-RICH prototype

- Cherenkov light production by hadrons in the LAPPD window and downstream lens
- Light returns at PC after total internal reflections
- Good focusing of Cherenkov ring photons. <2 PE>/pad
- Use of Acrylic (UV) filter to reduce <# PE>/pad

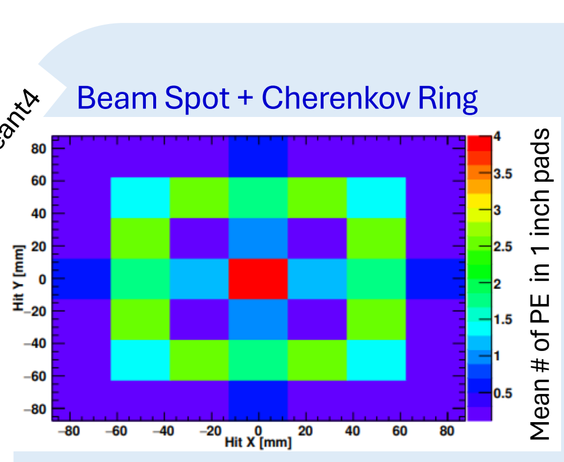


Inside Dark Box	Serving Purpose	# of Channels
LAPPD	Radiator Light Cone & Beam Spot detection	31
SciFi + SiPM	Fast Trigger/ Beam Monitor	2
Hamamatsu MCP	Timing Reference	1

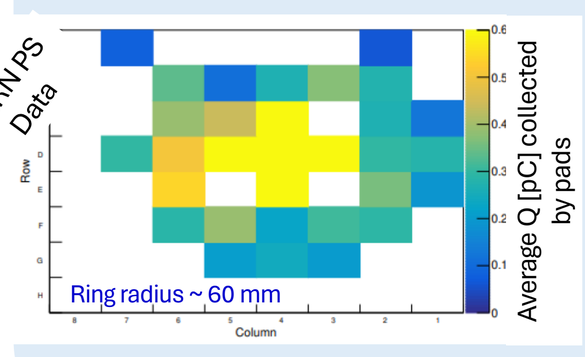
32+2 TR signals read-out & digitized by **CAEN V1742 Digitizer [CAEN WaveDump Software]**

Simulation and Experimental Results on Timings

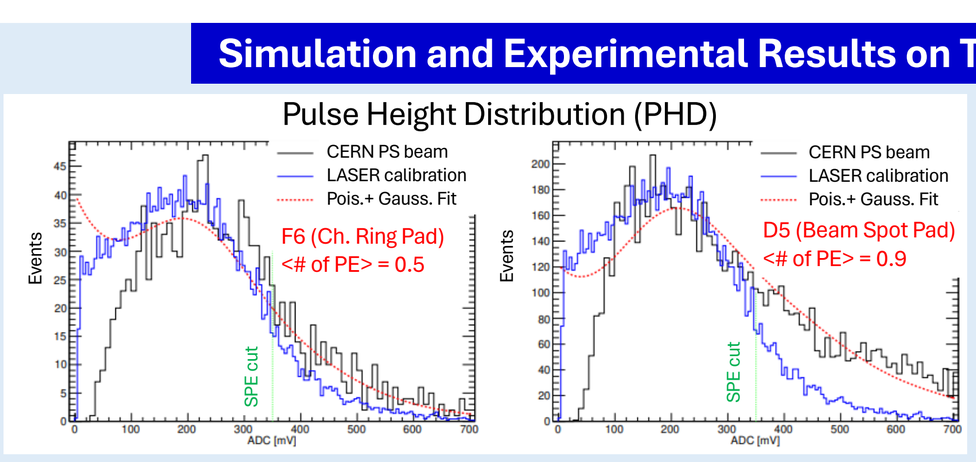
Geant4 Beam Spot + Cherenkov Ring

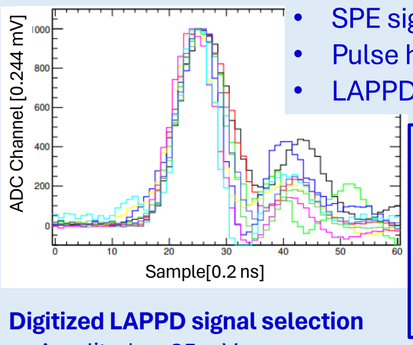


CERN PS Data



Pulse Height Distribution (PHD)

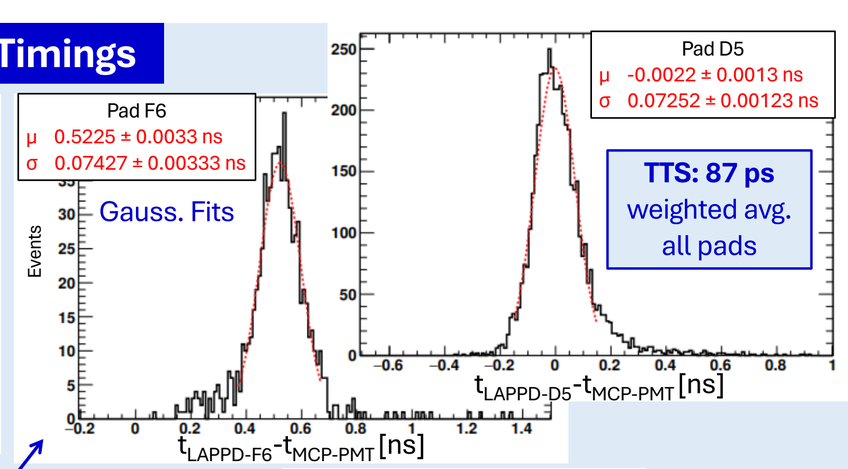




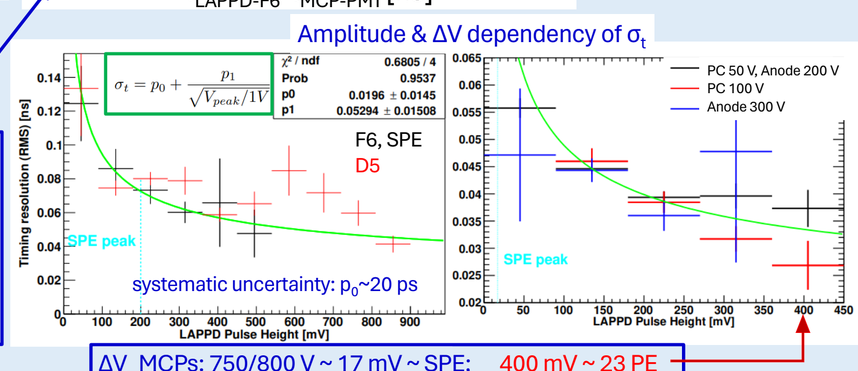
- SPE sig. amplitude: working range of timing studies
- Pulse height ~ charge distribution [pC]
- LAPPD Gain (nominal bias): **6.9 ± 0.7 x 10^6**

Digitized LAPPD signal selection
- Amplitude > 25 mV
- Arrival time ±2 ns from SciFi
- Correct signal shape: cross-talk excluded

Strategy:
- Linear fit: 10-90% peak height of rising edge
- $T_{signal,\ arrival}$: @ 50% peak height on the fit line
- Transit Time Spread [TTS]:
  σ [$T_{signal,\ arrival}$ (LAPPD) - $T_{signal,\ arrival}$ (MCP)]



Amplitude & ΔV dependency of σ_t



ΔV_MCPs: 750/800 V ~ 17 mV ~ SPE; 400 mV ~ 23 PE
σ_1 = 80 ps/√23; σ_2=18 ps (G4); $\sigma = \sqrt{(\sigma_1)^2 + (\sigma_2)^2}$ ~ 25 ps
Strategy is capable of measuring as fine as ~ 25 ps

References

1) T. Gys et al., Micro-channel plates and vacuum detectors. NIMA 787 (2015) 254-260.
2) A. Lyashenko, et al., Performance of large area picosecond photo-detectors. NIMA 958 (2020) 162834.
3) R. A. Khalek, et al., Science Requirements and Detector Concepts for the Electron-Ion Collider: EIC Yellow Report, NIMA 1026 (2022) 122447.
4) A. Accardi, et al., Electron Ion Collider: The Next QCD Frontier - Understanding the glue that binds us all, Eur. Phys. J. A 52 (2016) 268.
5) S. Shin et al., Advances in the Large Area Picosecond Photo-Detector (LAPPD): 8x8 MCP-PMT with Capacitively Coupled Readout, 2022.

We would like to express our thanks to Incom., CERN PS T10 facility, ePIC dRICH group, Eraldo Oliveri (HAM. MCP), Vicenzo Vagnoni (Dig. Timing Calib.), Berthold Jenninger (CAEN DT1415), eRD110 and AIDAinnova.

Contact: jinky.agarwala@cern.ch