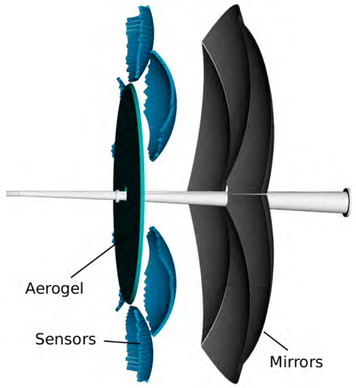
PID Subsystems: preTDR Efforts and Progress

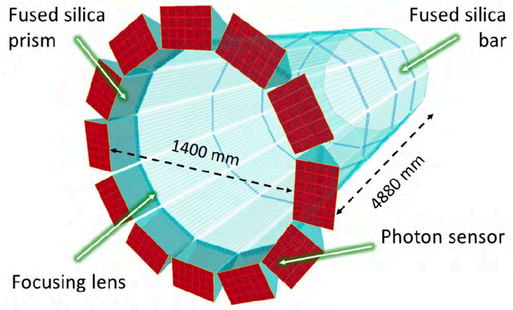
Thomas Ullrich

TIC Meeting

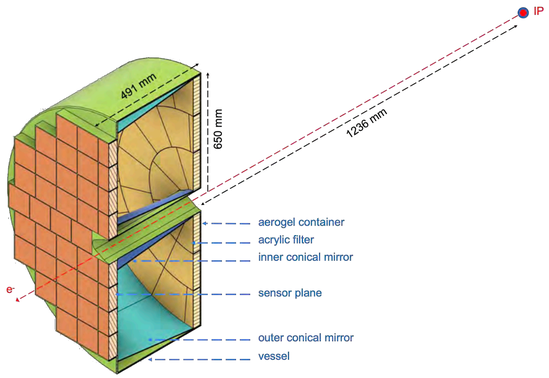
November 25, 2024



dRICH



hpDIRC



pfRICH

ToF not included today

Upfront: PreTDR (Version 0.1) Status

- All Cherenkov PID DSCs received a healthy amount of constructive comments
- All are addressed as reported in the TIC meetings
- Balance between adding more details and staying in the allocated page limits
- Next Steps:
  - Refining text
  - Updating plots (some are still preliminary or place holders)
  - New simulations and hardware improvements/changes flow into the writeup

Overall the PID part of the preTDR is in Good Shape

N.B.: Preliminary Design Review for Cherenkov PID detectors beginning of March '25

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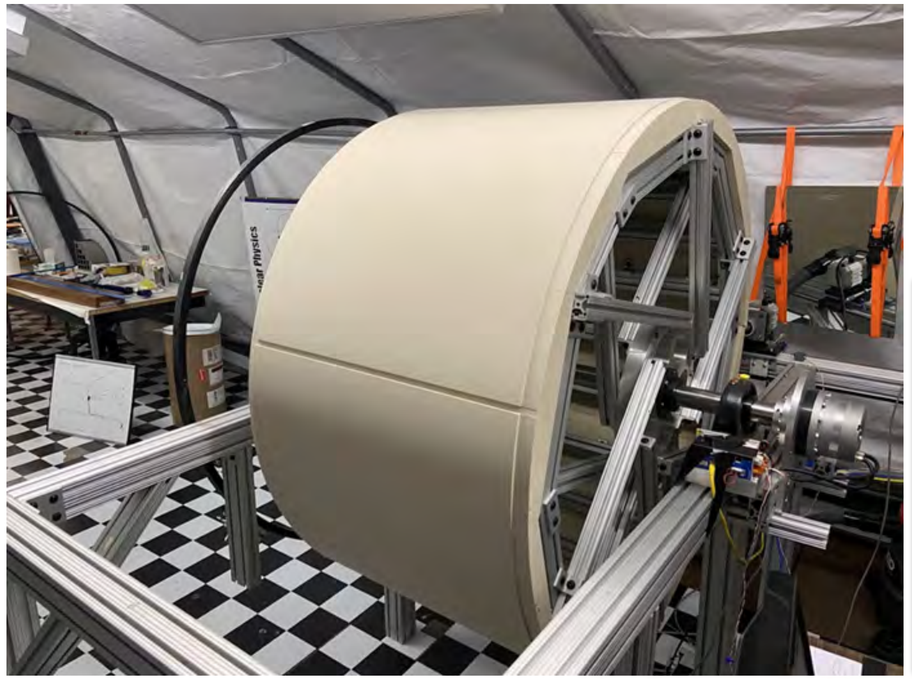
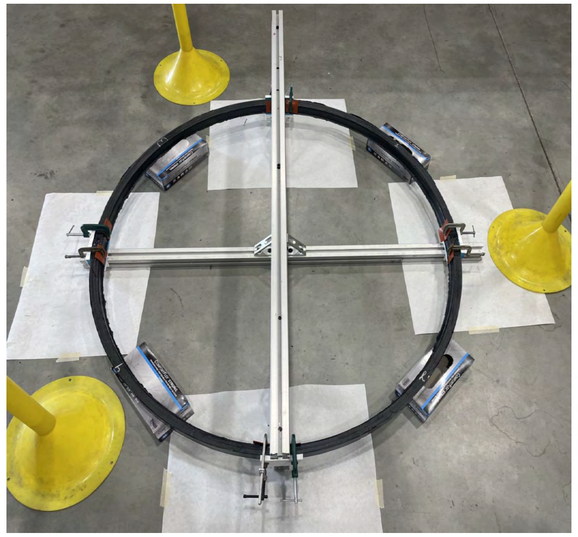
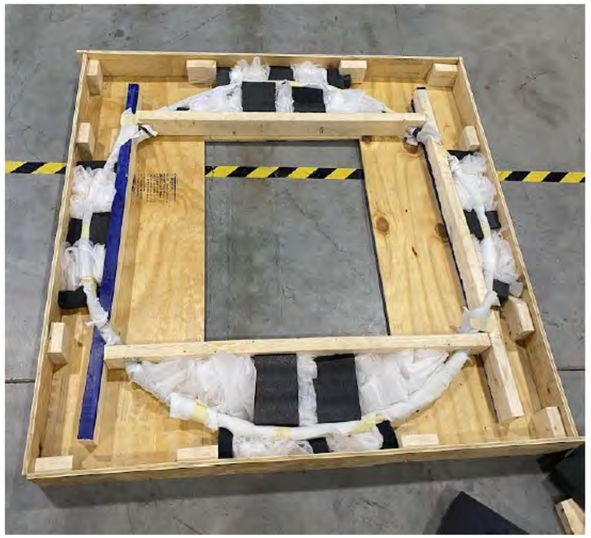
Vessel Fabrication

- Foam form for vessel construction is nearly complete
  - Achieved 0.1 mm circular precision
- New precision milled endring (no. 3) has been produced at Purdue and is currently on its way to SBU
- First two endrings were seen to have significant variation in diameter
  - Endrings nos. 1 and 2 being sent back to Purdue for refurbishment
  - Timeline for vessel completion will be determined once Purdue evaluates first two endrings

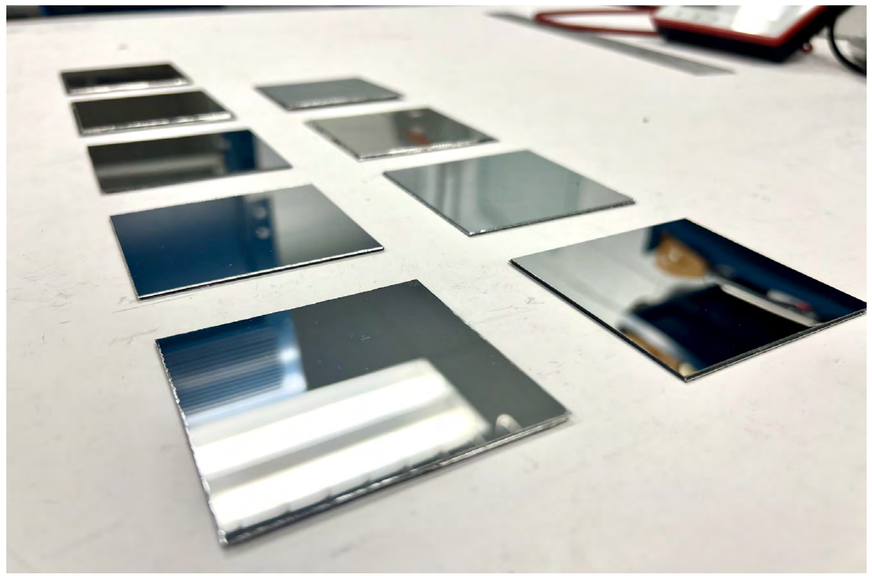






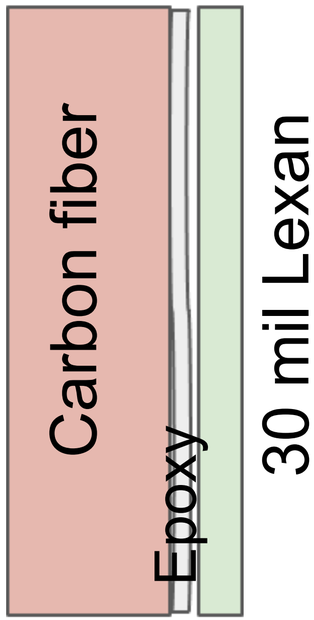
Mirror Production

- The mirror coating test/production for pfRICH has started exactly one year ago
- True Collaboration: Substrate (Purdue) ➟ Evaporation (Stony Brook) ➟ Testing/QA (BNL)
- Substrates are low cost high strength carbon fiber co-bonded with a 30 mil Lexan sheet
- After 26 batches of coating tests milestones were achieved:
  - High reflectivity above 90% between 300 and 600 nm in wavelength at 45 degree of incident angle.
  - Successful coating material and layering schemes: Chromium → Aluminium → SiO_2.
    - These created a strong bond between the metal layers and the substrates.



Recent test batches: Sep - Nov 2024

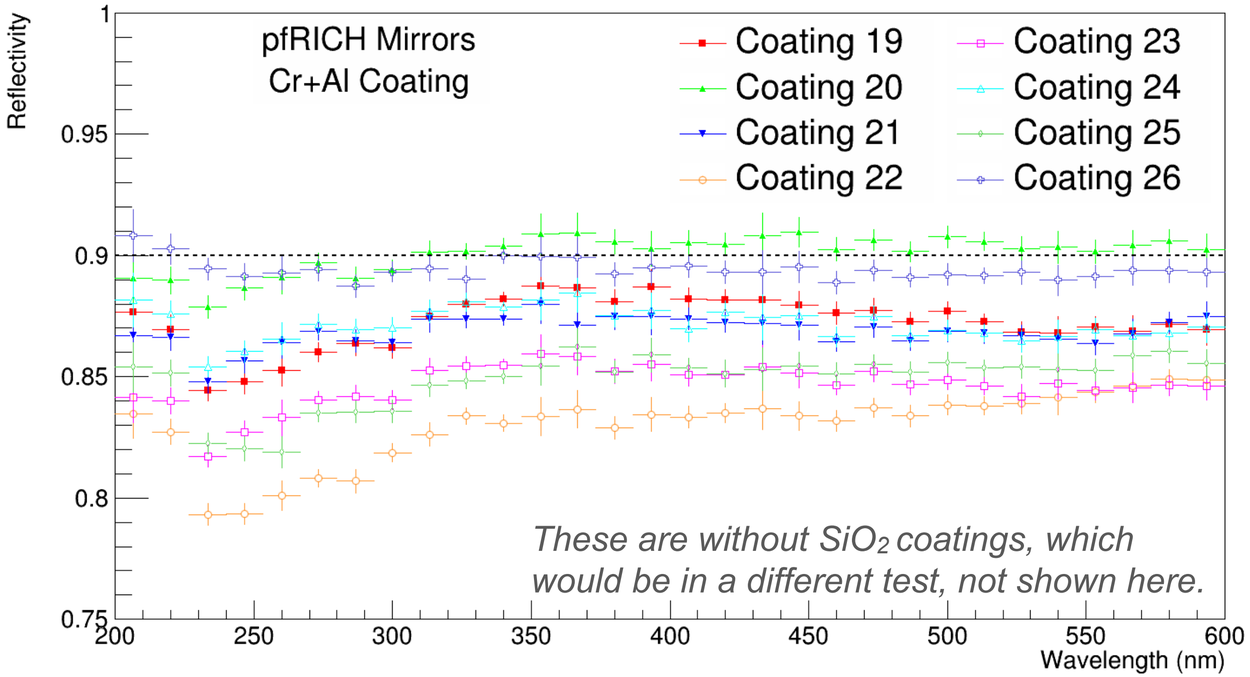
- Established the co-bonding techniques based on Epoxy and its impact on reflectivity - currently finalizing the details and soon making large full scale conical mirror substrates
- The mirror reflection surface is smooth, after investigating issue that related to the pressure imposed on Lexan during the co-bonding. Optimization in progress.



Mirror Reflectivity

- The reflectivity is consistently and quickly tested at BNL after the mirrors are coated (SBU)
- The uniformity of these mirrors is found to be good, by having different samples located at different position on the fixture (see right picture). This leads to 1.5% variations in reflectivity within the same batch.
- Next step is to finalize the coating thickness and the layering schemes, as well as with full-scale mirrors.

Best mirror of each batch from #19 to #26



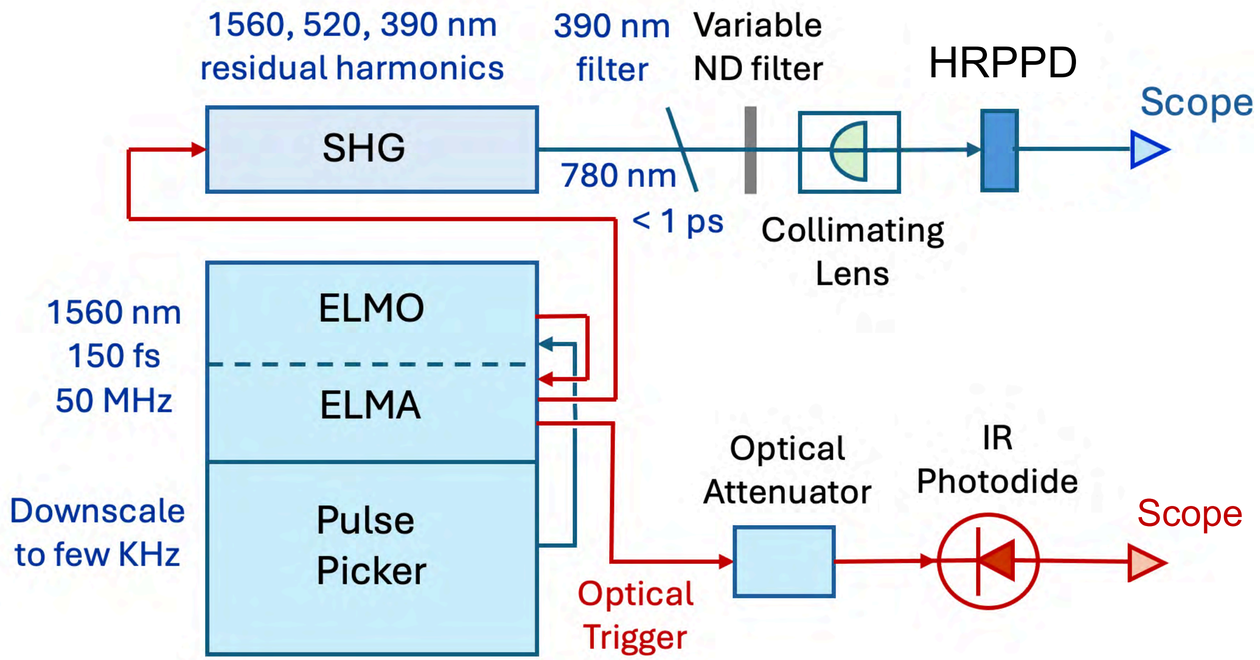
HRPPD Timing: Femtosecond Laser System at BNL

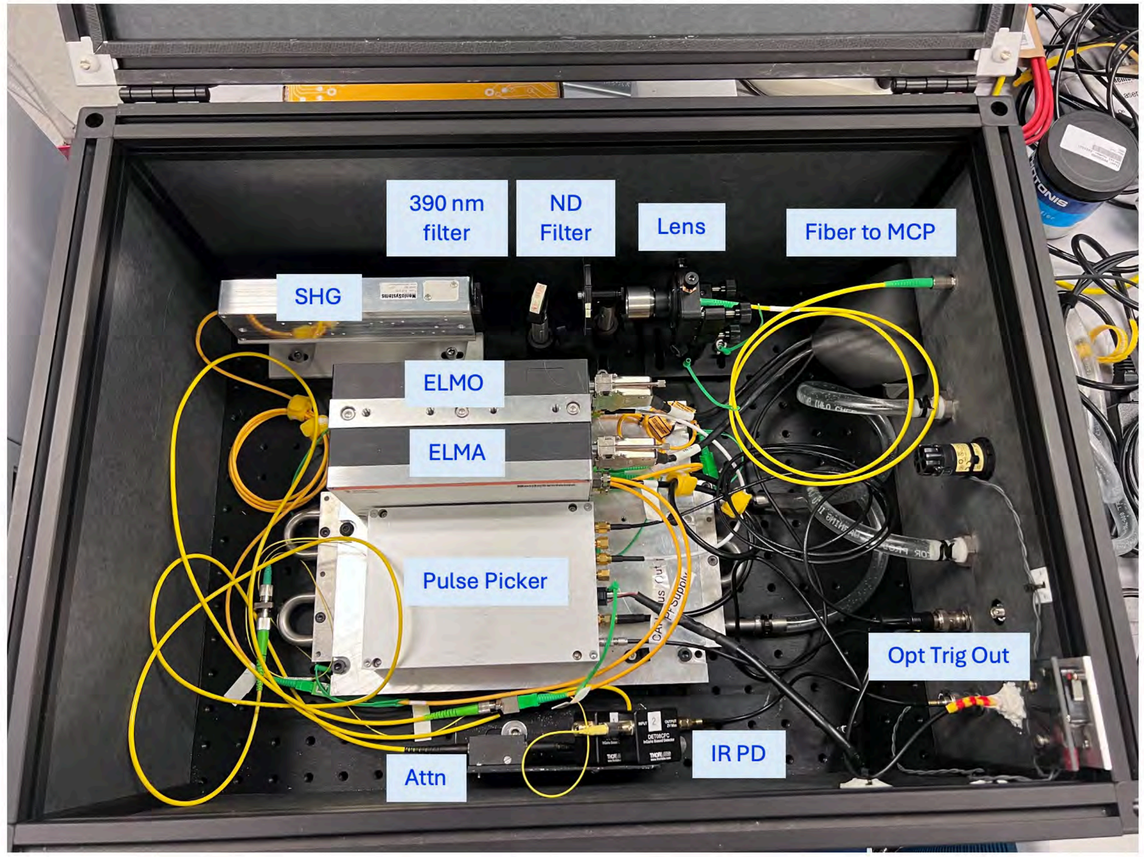
Menlo Systems Elmo 780 Erbium Fiber Femtosecond Laser

ELMO = Primary Laser Oscillator

ELMA = Optical Amplifier

SHG = 2nd Harmonic Generator

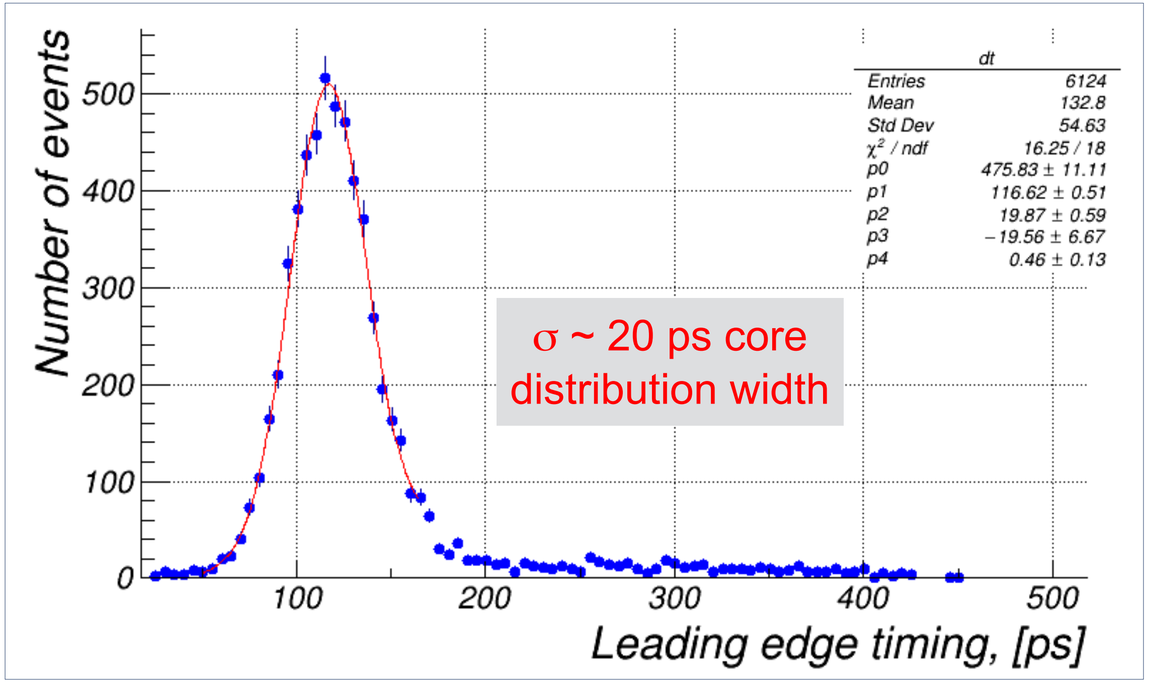


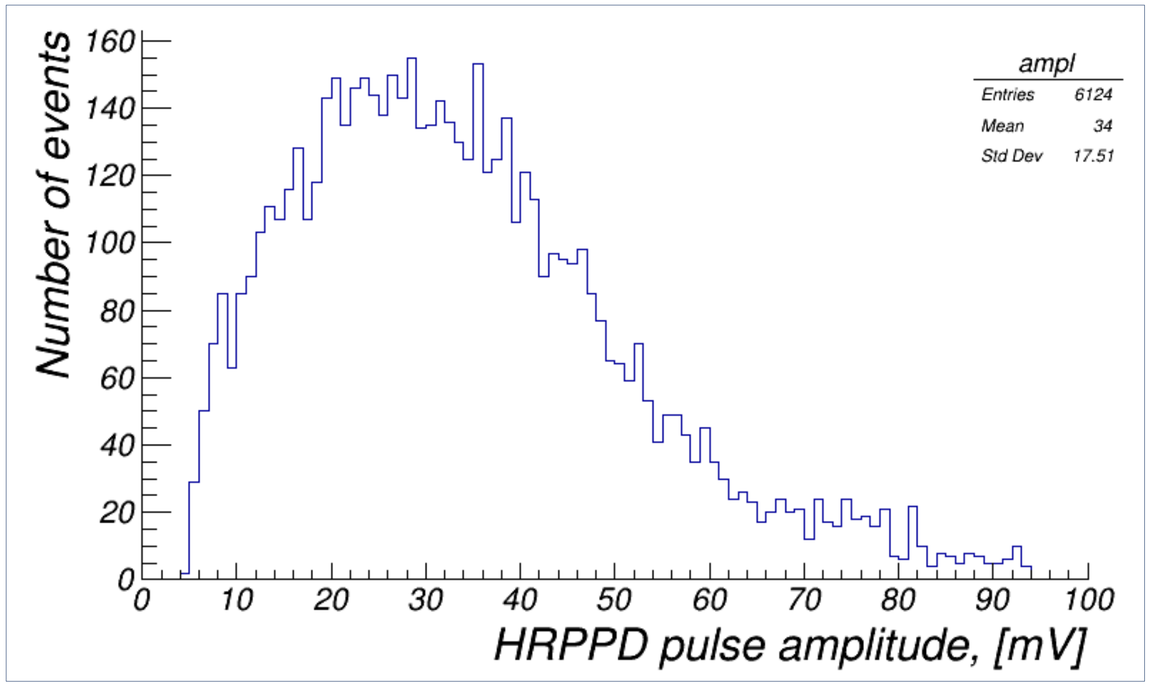


Make use of a very low intensity 4th harmonic @ 390 nm

Single Photon Timing Resolution Using Elmo Laser

- Laser beam focused on a single HRPPD pad center; intensity tuned down to ~95%; empty events
- HRPPD signal used for triggering (5 mV effective threshold)
  - increase data taking efficiency
- Signal waveform data taken with a Tektronix MSO66B scope (50 GS/s, 8 GHz ABW)
  - Leading edge fits [10% .. 90%] performed offline; $\Delta t = t_{HRPPD} - t_{FastPD}$ is a plotted quantity





HRPPD 15: bias voltage 775 V, photocathode voltage 100 V (gain ~$1.5*10^6$)

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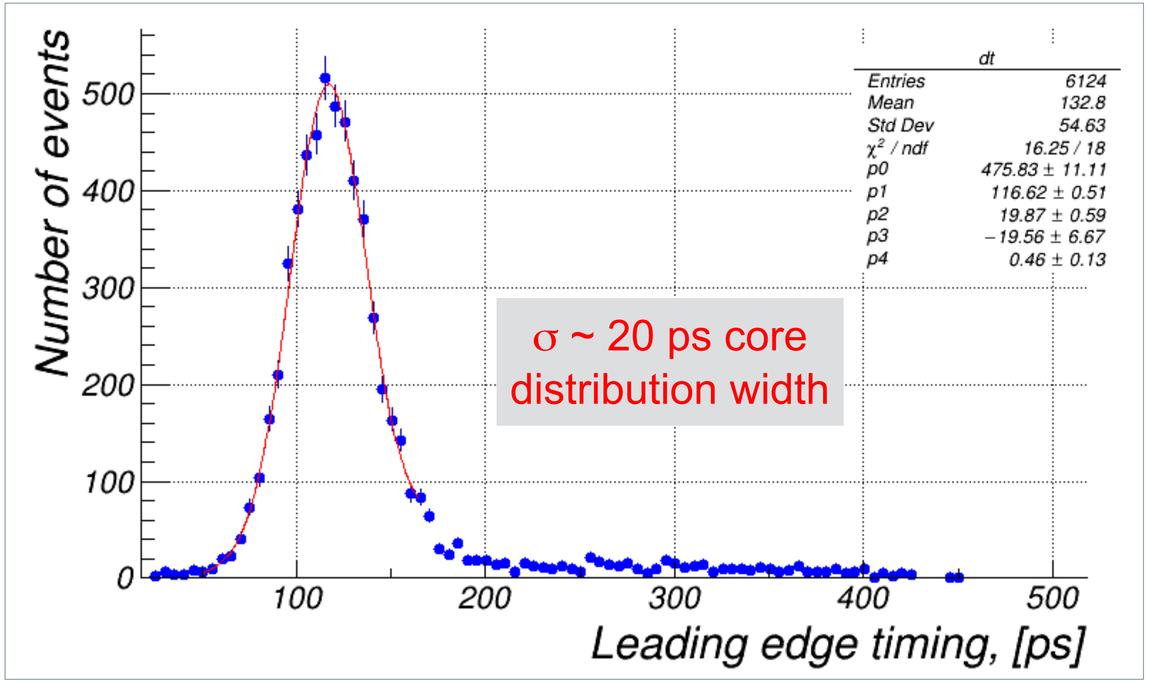
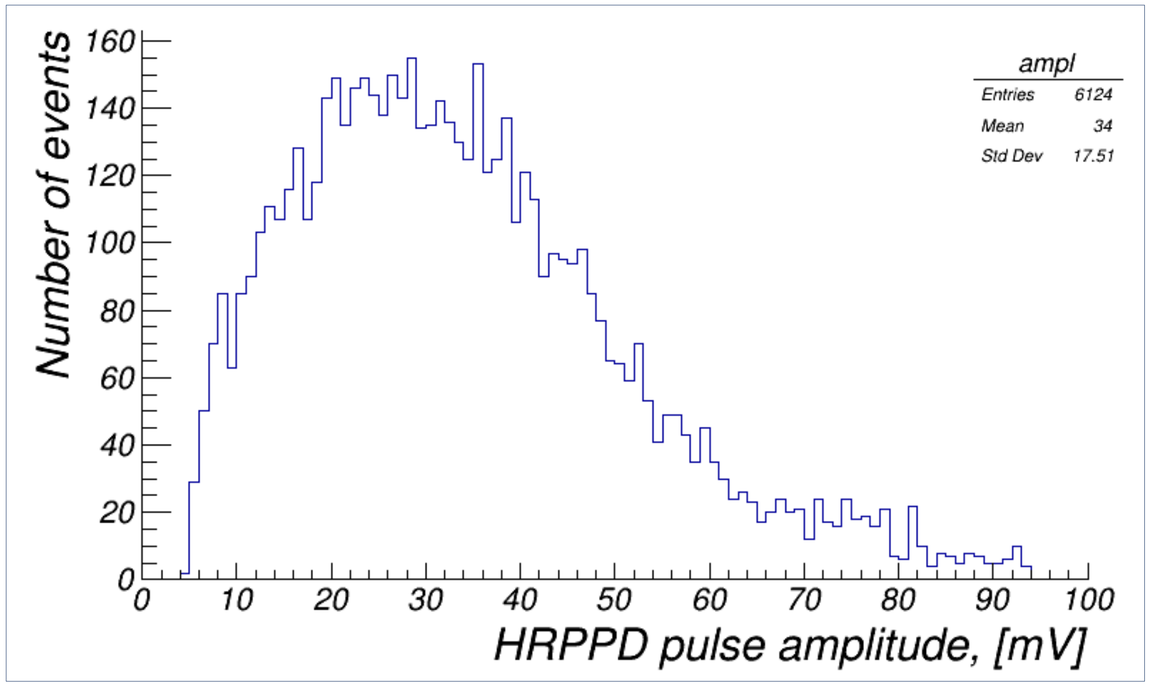
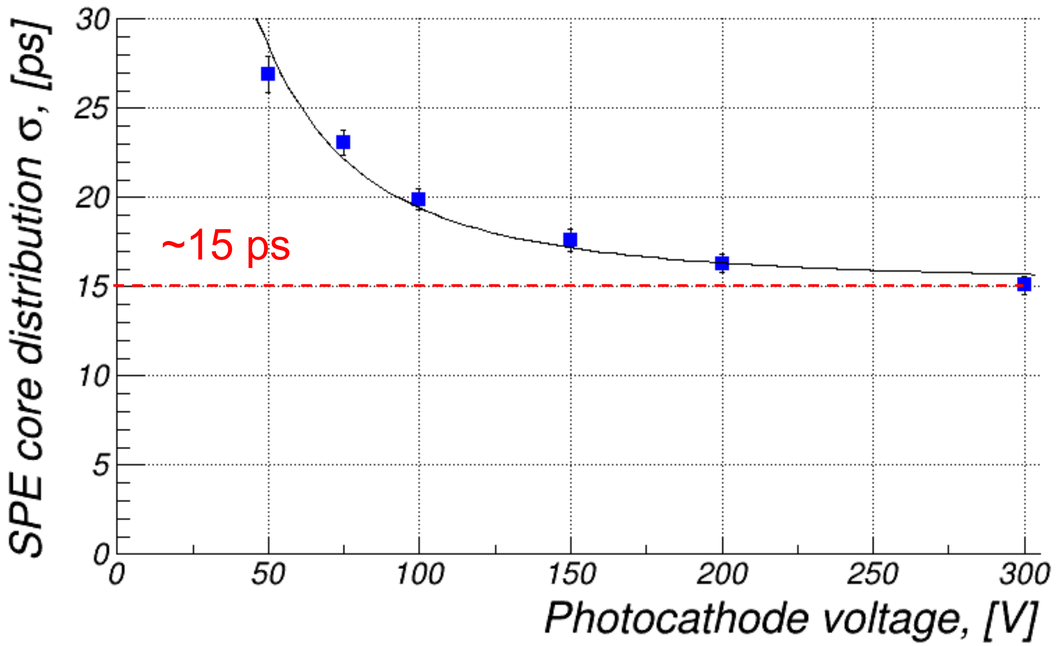




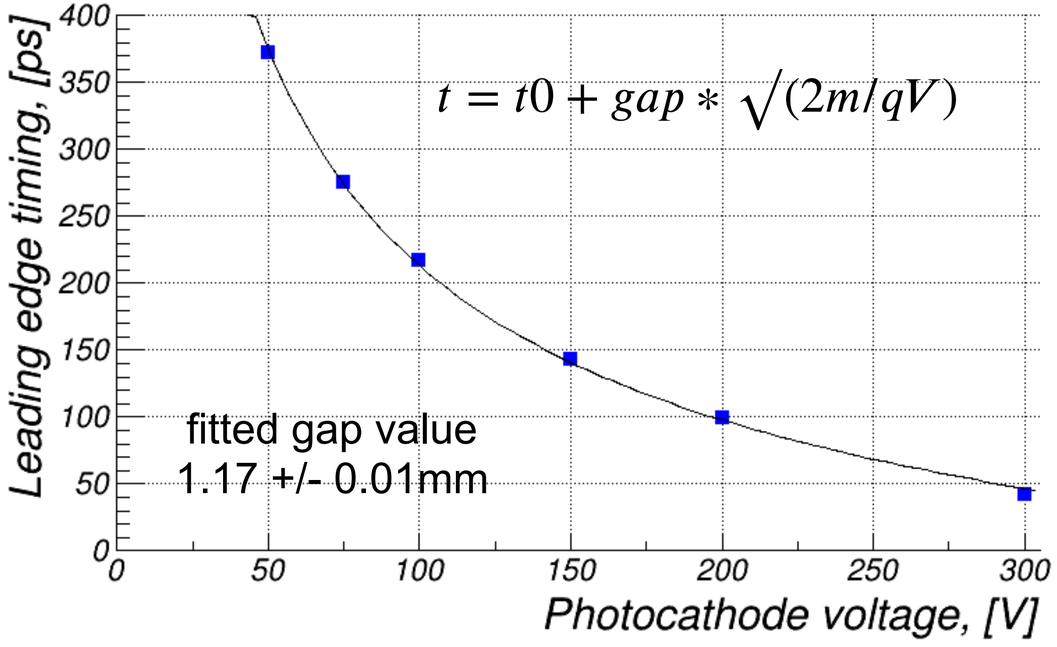
HRPPD 15: bias voltage 775 V, photocathode voltage 100 V (gain ~$1.5*10^6$)

Single Photon Timing Resolution Using Elmo Laser

- SPE timing resolution is below 20 ps for nominal HRPPD 15 HV settings (bias 775 V, PC 200 V)
- A scale cross-check: primary electron drift time decreases with PC voltage as expected
- Nominal PC->MCP#1 gap is 1.1 mm per design [compare to a fit value of ~1.2 mm]



Single photon timing resolution



Primary electron drift time PC->MCP#1

Directors Review for CD-3B

SC4 – Detector Systems

- **Comments**
- Simulations were added upon request. They provided more confidence regarding the performance of the detector. It would be beneficial having an extended report capturing the full (global) performance of the detector available before CD-2 (e.g., in the TDR).
- New, very large area silicon detectors carry risks (e.g., Astropix) associated with scalability and availability of technology.
- A plan for bake-out of the beampipe was presented with no obvious show-stopper. Further optimization is being pursued and additional testing is beneficial.
- Expertise and personnel in control of specific critical steps (e.g., chip design verification) is critical and often a limiting factor and has to be taken into account in the schedule.
- Dependence on possibly 'oversubscribed' laboratories for board production of the MPGDs (e.g., CERN) is a risk. It may be mitigated with early procurement.
- New avenues to manufacture AC-LGAD may require several iterations and backup options should remain open.
- Given the balance of NRECs versus wafers costs, additional procurement of ASIC wafers and fabrications (iterations) is encouraged.
- Steel for the endcap are based on one estimate. A second estimate was significantly higher. Additional evaluations of the cost, after further estimates come in, may be needed.
- Results of the first engineering test article of HRPPDs are promising. A second engineering run is encouraged to mitigate risk.

Electron-Ion Collider

EIC CD-3B Director's Review, October 22-24, 2024 Presenter First Initial, Last Name 47

- Project will fund a second ER for the HRPPDs
- Not incremental but more "final" (pre-production) version that should addresses all issues discovered so far

pfRICH is well on its way to become the first RICH detector deploying LAPPDs/HRPPDs in a collider detector

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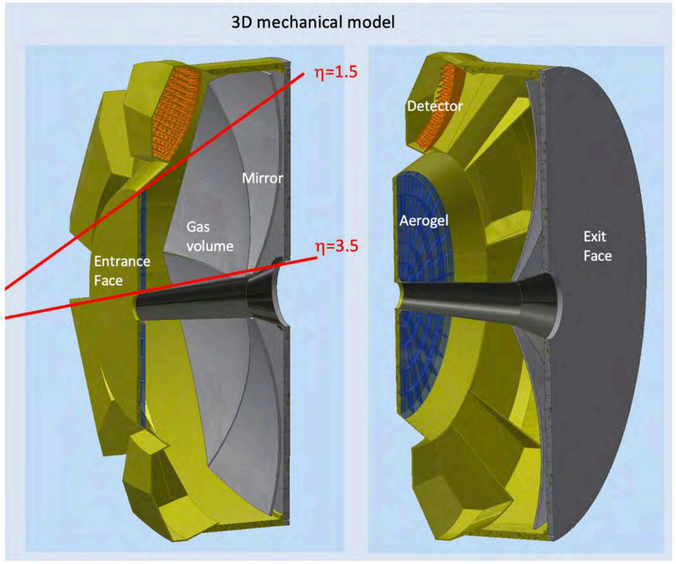
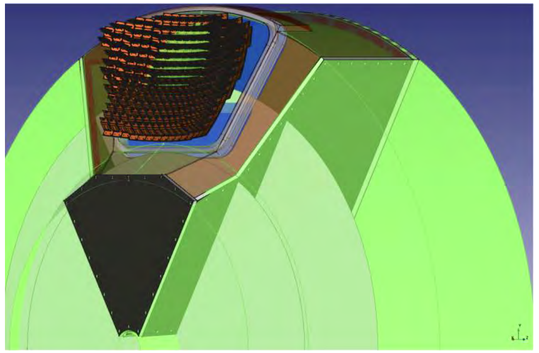
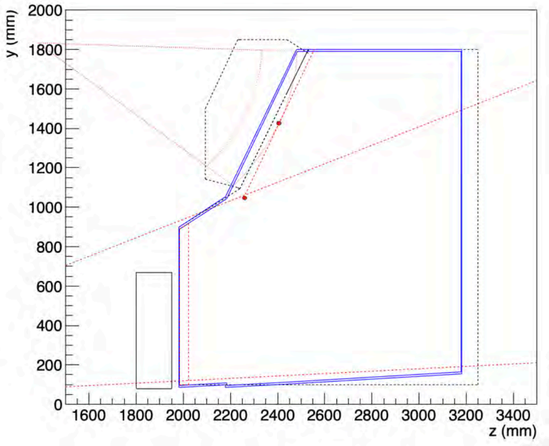
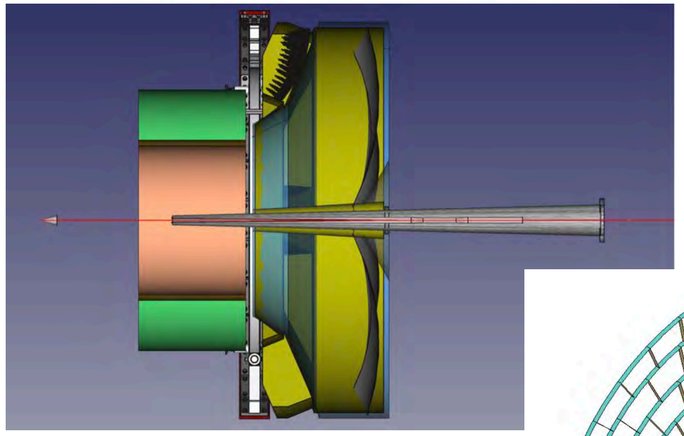
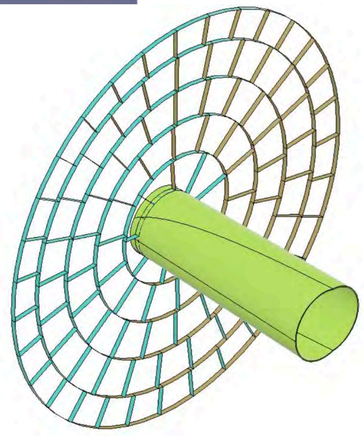
dRICH Mechanics



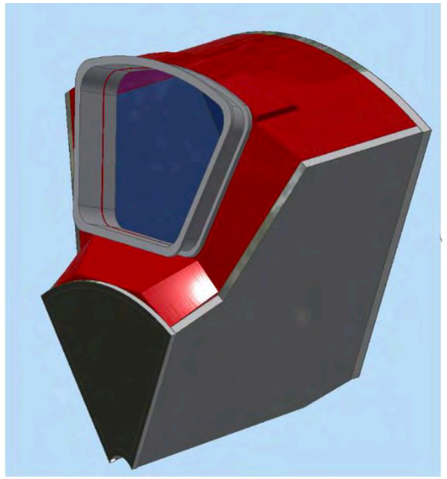


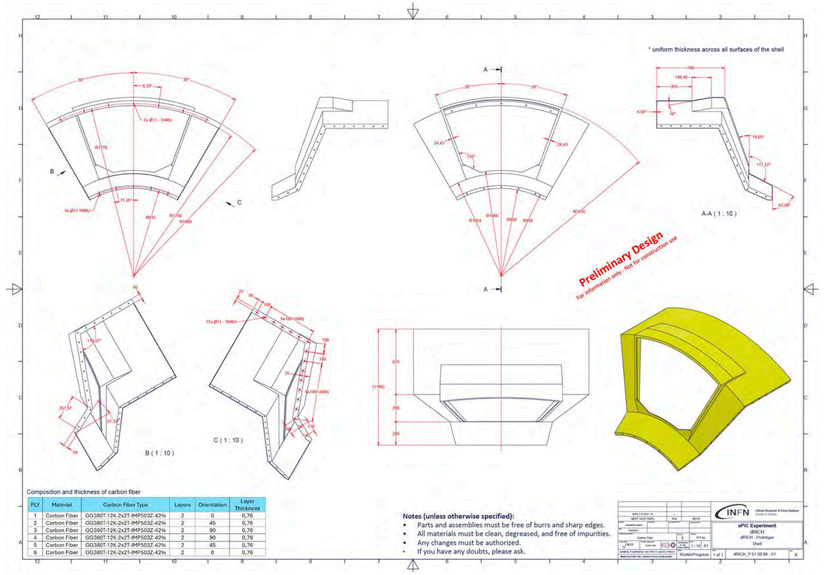






Carbon Fiber Reinforced Polymer (CFRP) Layer composition

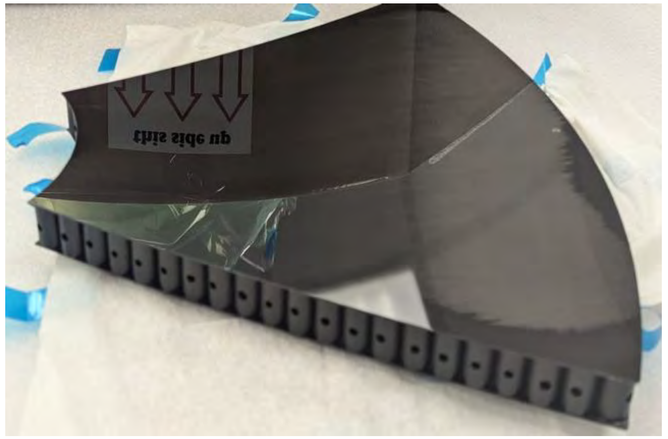


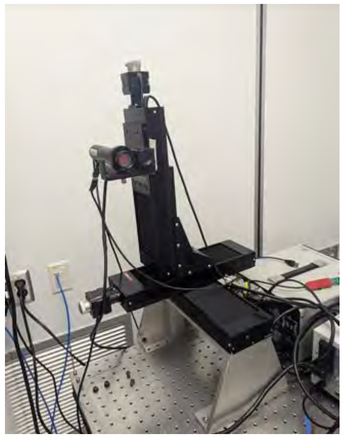


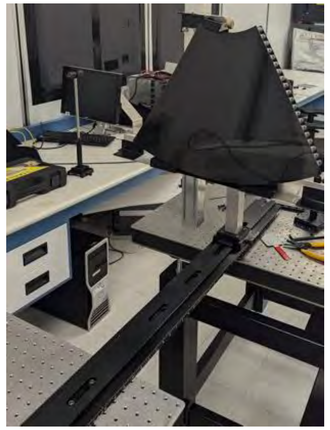
- Bridging mechanical and simulation model for a new geometry release
- Entering the details of the mechanical model moving towards the executive design of the real-scale prototype

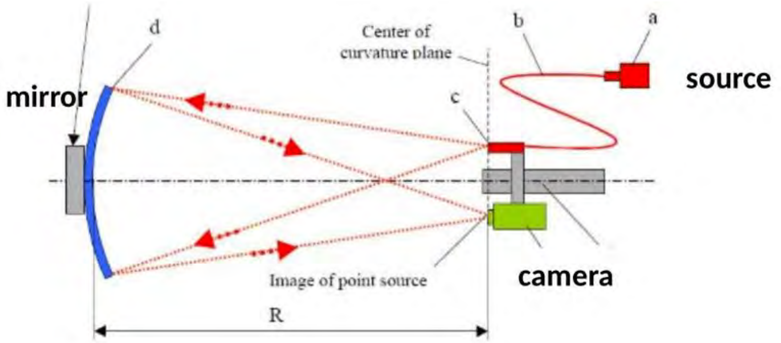
Mirrors

- Characterizing the medium-size (~30 cm side) demonstrator CFRP substrate before coating

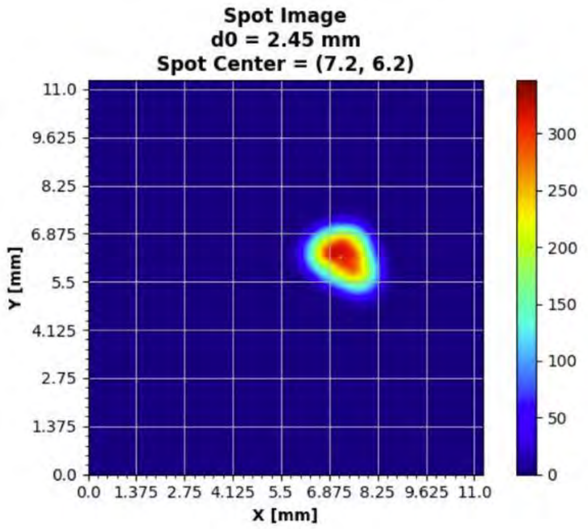


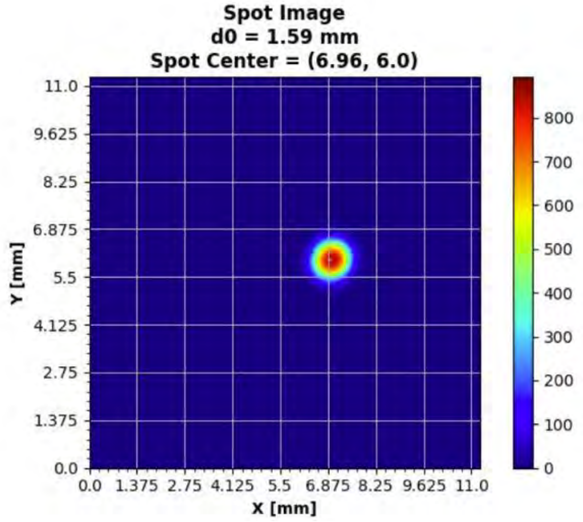


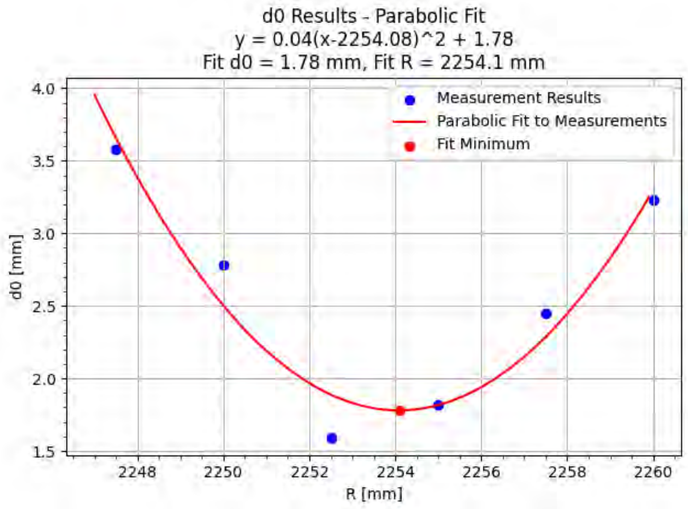




✓ D0 < 2.5 mm ✓ R = 2200 +/- 1%

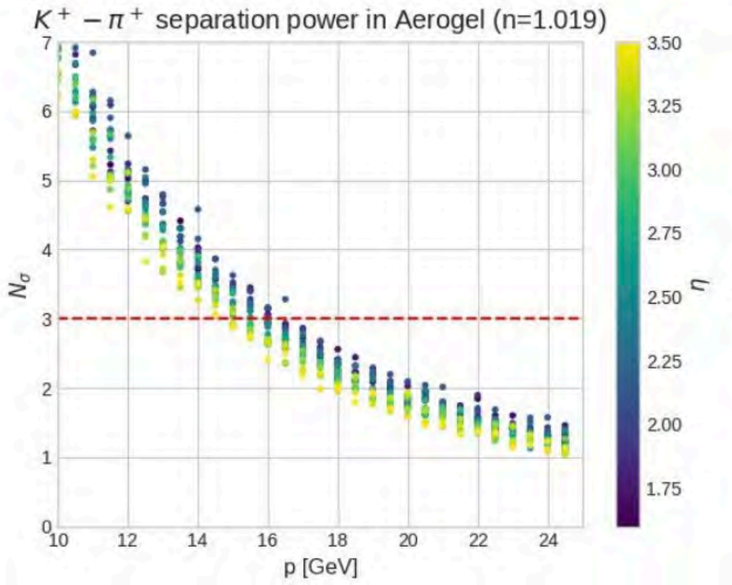


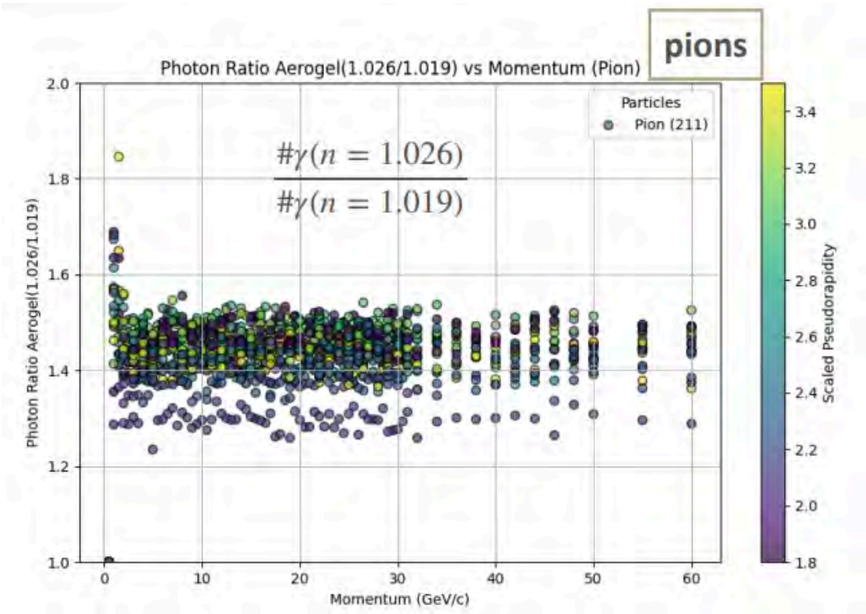


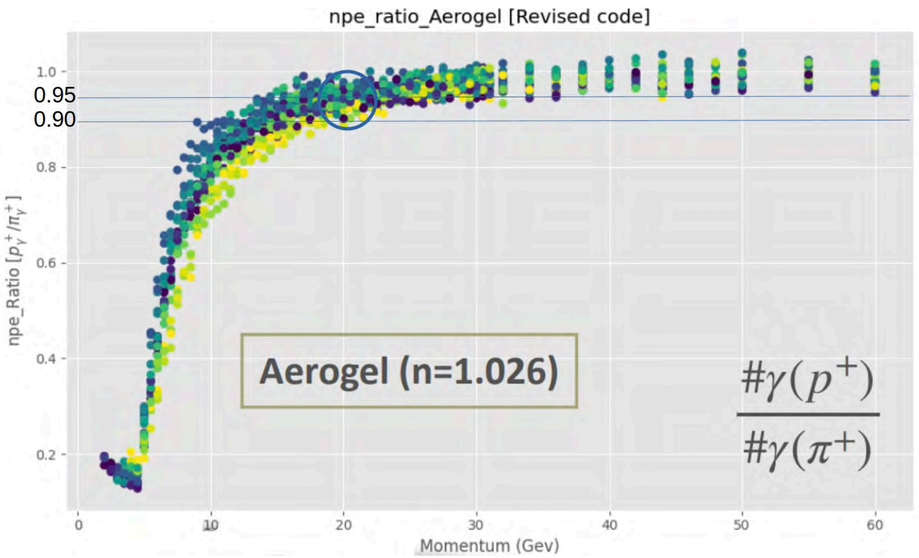


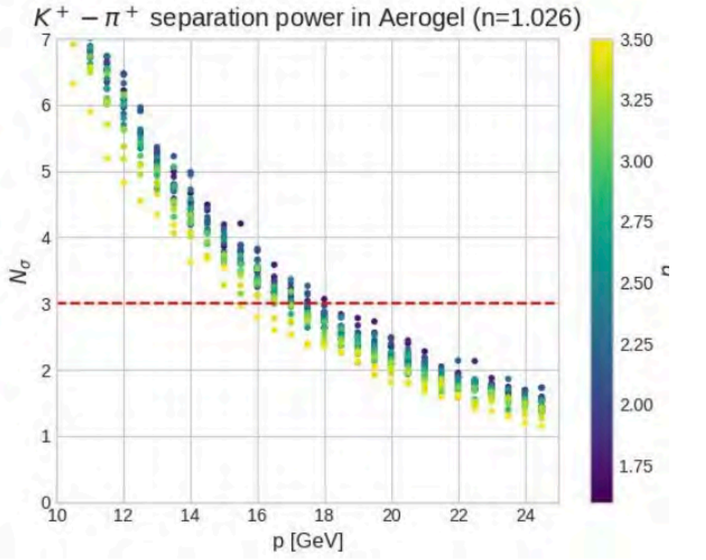
Aerogel: Simulations ⇆ Hardware

- T. Boasso suggested aerogel 1.026 performs better than 1.019
  - Large data set studies validated such observations
- Almost 2 GeV improvement. No noise added so far (will be checked).
- n=1.026 has at higher photon count, ~ 50%
- New studies of Photon ratio of pions and protons follows expectations
  - way to cross-check the simulation and beam test results.









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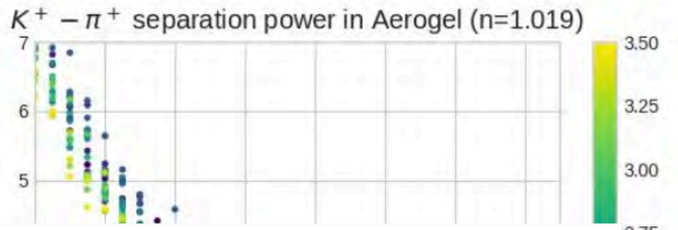
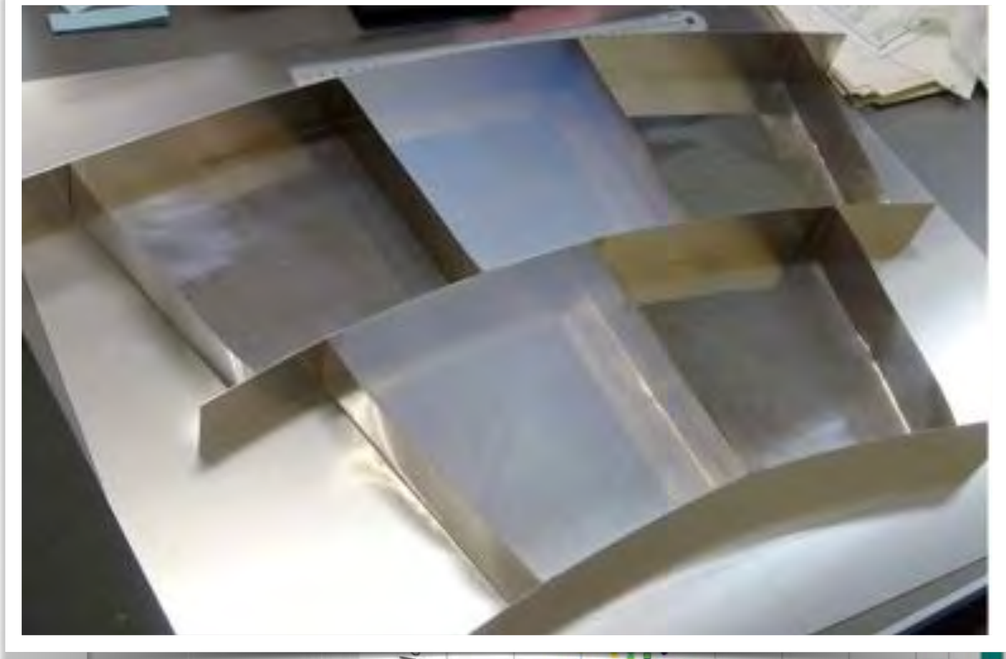
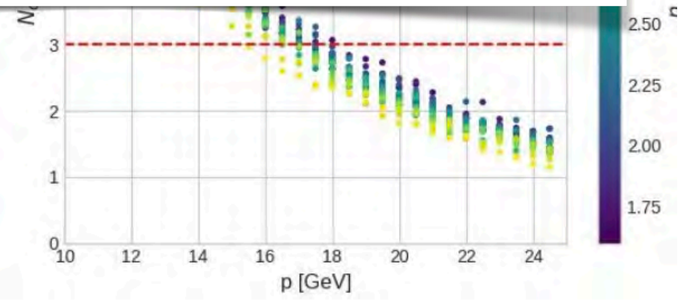
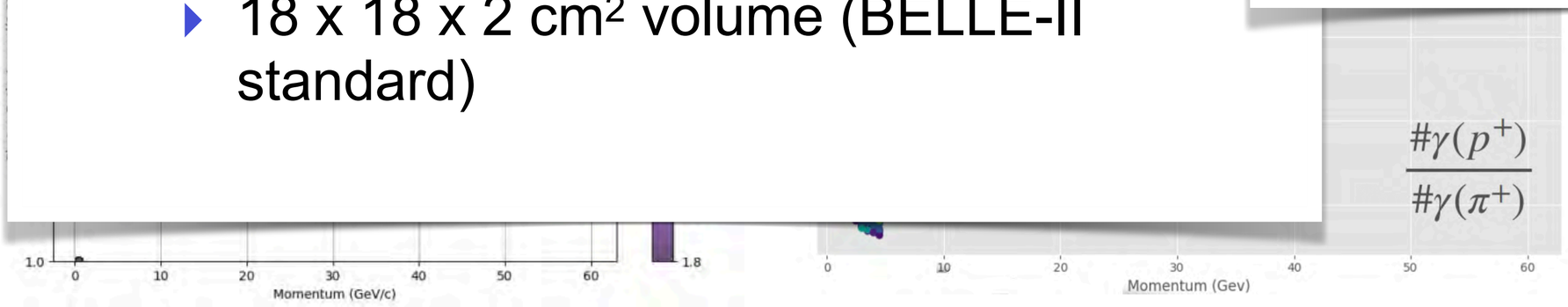


- Characterizing n=1.026 and awaiting real-scale demonstrators
- Next step: move to real dimensions & specs
  - ePIC quality specs: clarity, absorption, planarity, dimension tolerance, …
  - Squared and water-jet cutting shaped
  - 15 x 15 x 3 cm^2 volume
  - 18 x 18 x 2 cm^2 volume (BELLE-II standard)

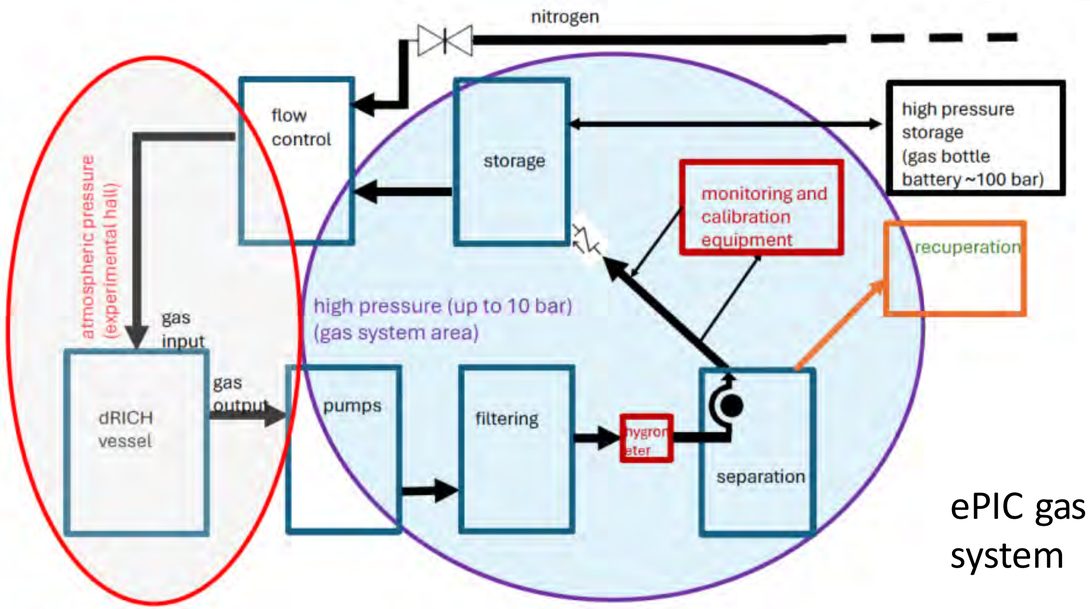






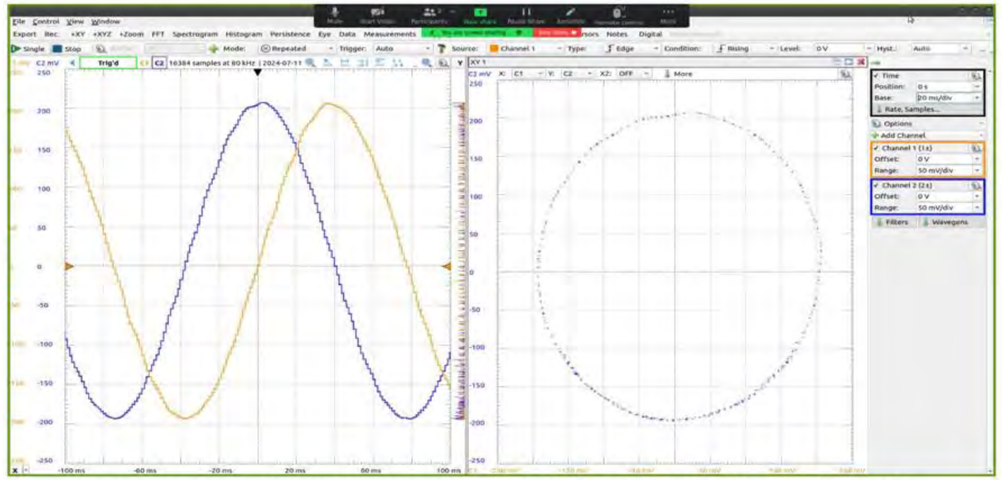
$$\frac{\#\gamma(p^+)}{\#\gamma(\pi^+)}$$

Gas System



ePIC gas system

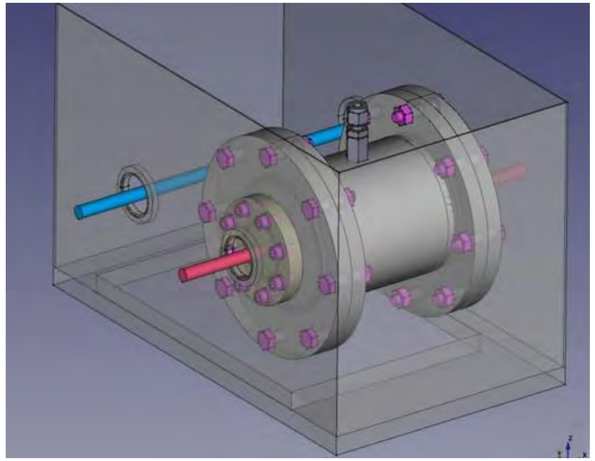
Jamin interferometer for precise n detrmination



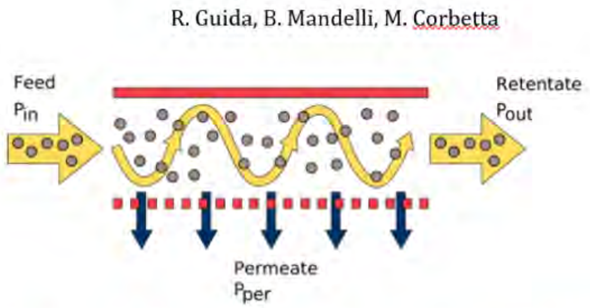
Un periodo (360°) corrisponde a 1 ppm di variazione dell'indice di rifrazione
La risoluzione consente la misura di variazioni di n inferiori a 10 ppb

Studying Purging and online Monitoring

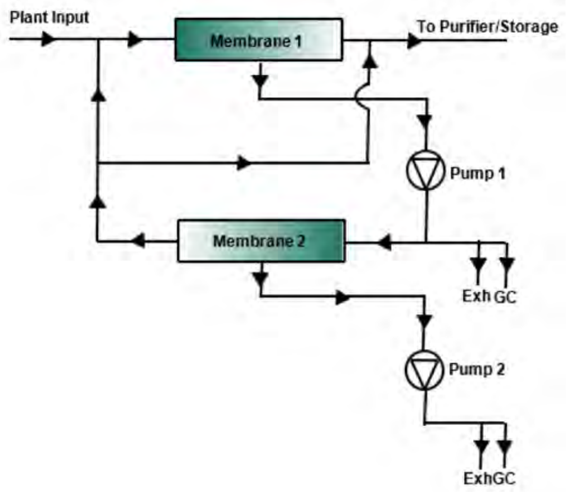
High-pressure vessel for light transmission measurements



Gas separation via membranes



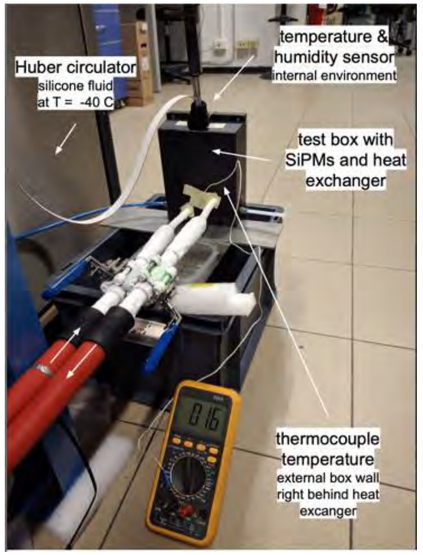
https://edms.cern.ch/document/2816490/1

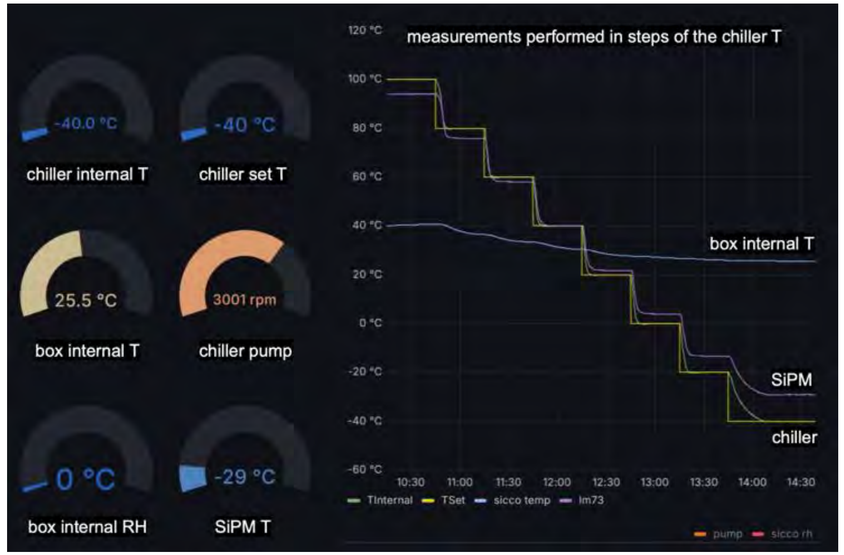


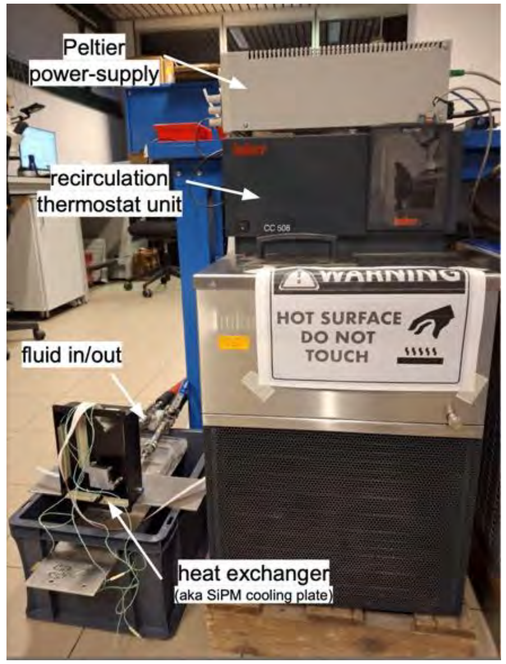
Thermodynamics of SiPM Sensors

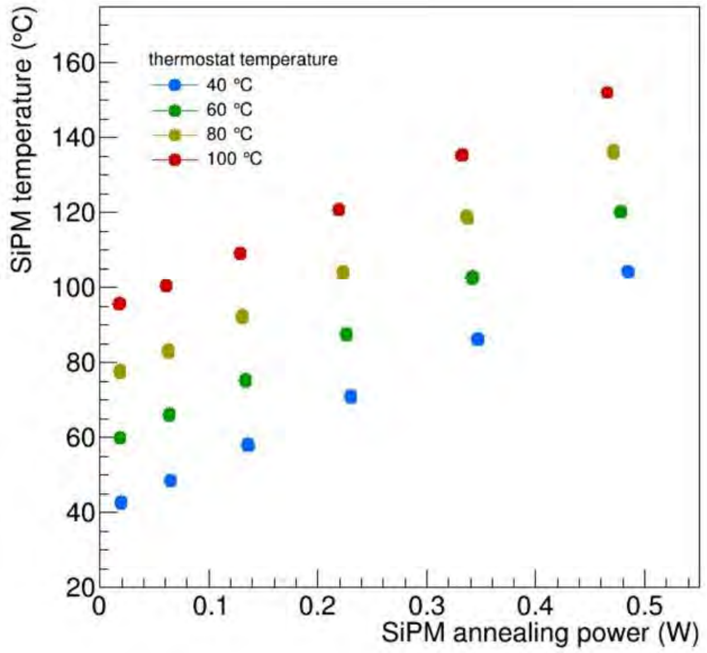
Performing systematic cooling and annealing tests

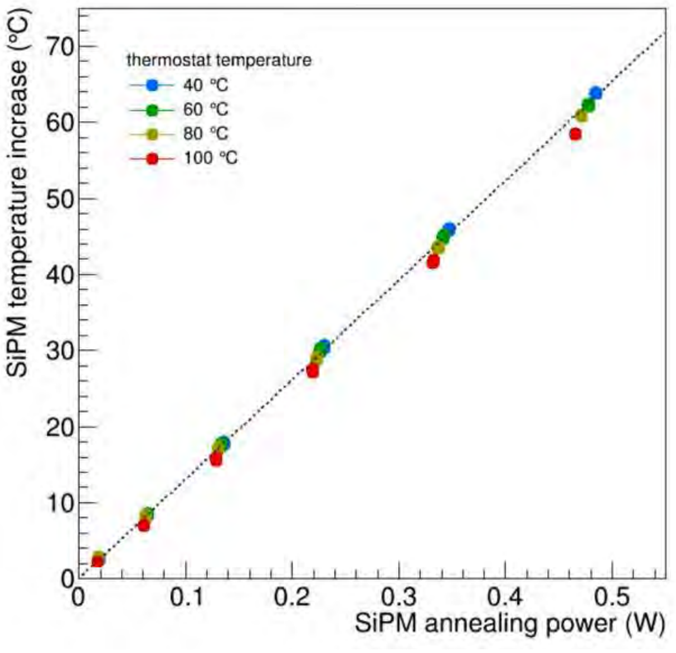
instrumental to optimize protocols, study insulation and safety





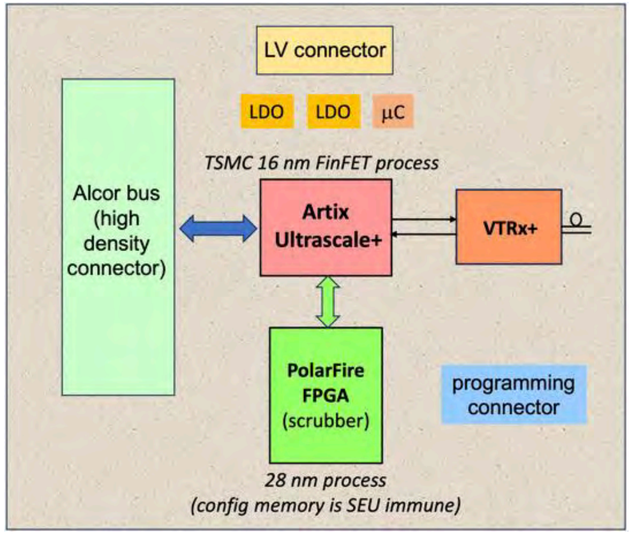


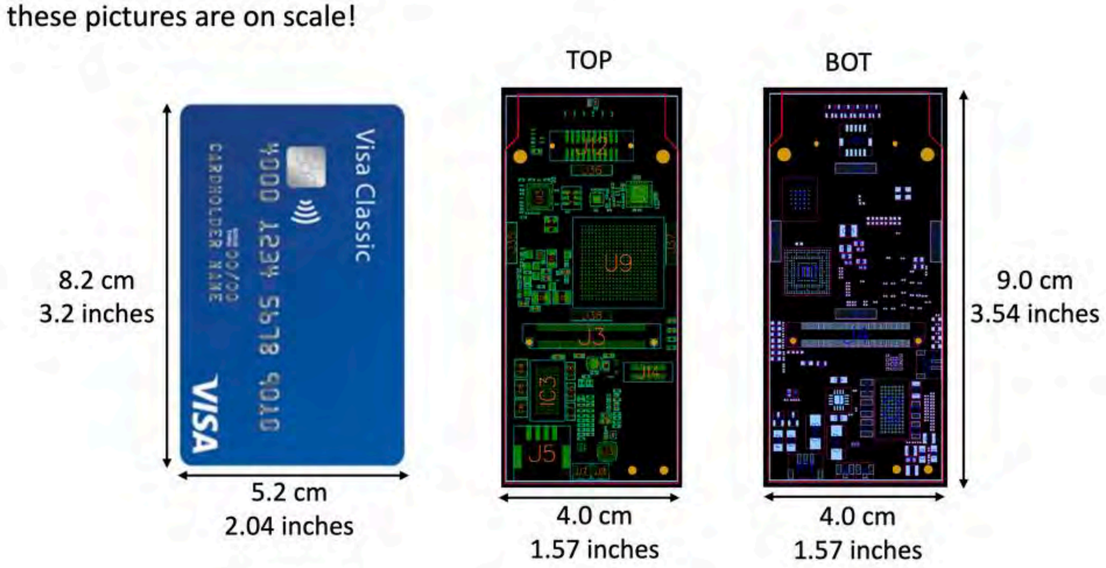


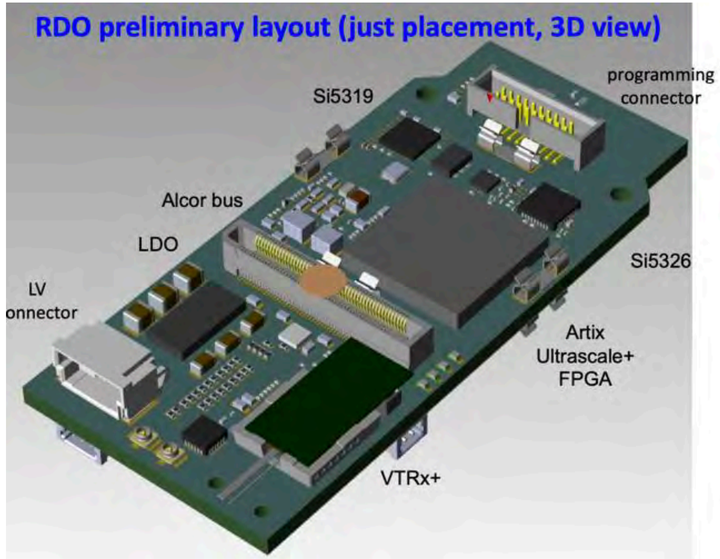


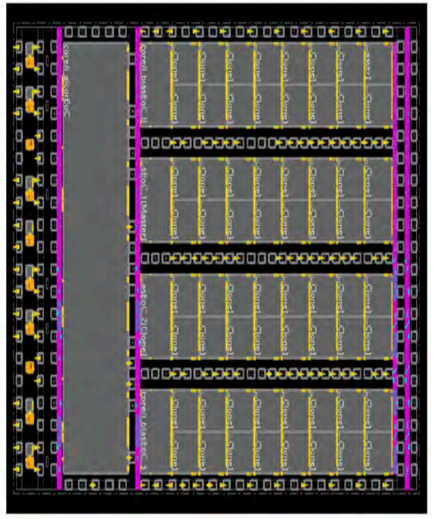
dRICH Electronics and Readout Chip

- Preparing test production of readout electronics in its “final” ePIC layout



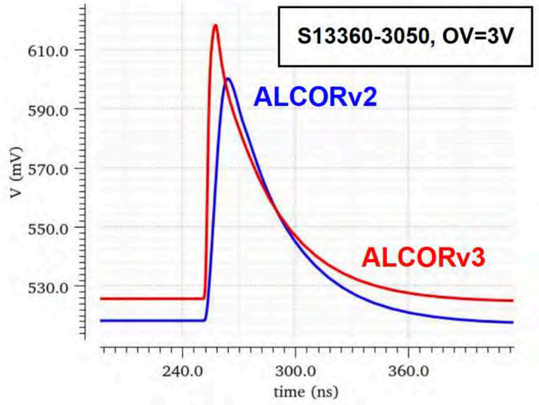


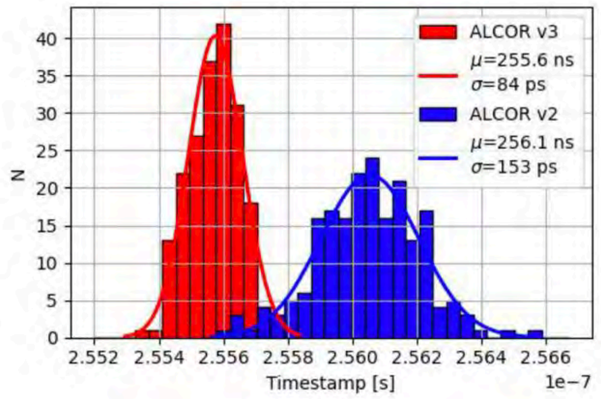




ALCORv64
digitizing chip

- Preparing ALCOR v3 test production - now 64 channels!





Irradiation Tests

Pursuing a new irradiation campaign at large

- **neutron irradiation campaign 2024 (LNL-CN)**
  - irradiation done on 9-11 October
  - several SiPM boards, several fluences
  - also irradiated aerogel, quartz and other optical matetials
- **gamma irradiation campaign 2024 (CERN-GIF)**
  - irradiation done on 14-16 October
  - from 10 to 1 000 rad
- **proton irradiation campaign 2024 (Trento-TIFPA)**
  - will be done on 12-14 December
  - we will also irradiate several pieces of electronics
  - also irradiated aerogel, quartz and other optical materials

Progress on Software and Simulations

- Impressive influx of manpower with groups from India joining
- Simulation team
  - Central University of Karnataka, India (D. Samuel, A. Rajan, N. George)
  - Central University of Haryana, India (R. Kumar, M. Thakur, R. Jangid, Taniya, T. Tanvi, G. Laishram)
  - Ramaiah University of Applied Sciences, India (T. Ghosh, R. Sigh)
  - INFN Trieste (J. Agarwala, C. Chatterjee)
  - INFN Cosenza & University of Calabria (L. Occhiuto)
- New group also provided resources to perform many new simulation - 12h/day allocation for ePIC
  - Substantial use of GPUs
- Simulations and Reconstruction in EICrecon

Progress on Software and Simulations (continued)

Progress on many fronts (too many to discuss here)

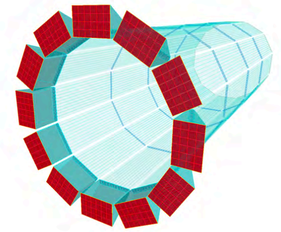
- dRICH separation power in gas and aerogel
  - Gas: Newest geometry, mag. Field; pi/K up to 50 GeV 3-sigma for most of highest eta values.
  - Aerogel: n = 1.026 studies
  - New finer LUT and contours are under preparation, <14-16 GeV> for e/π separation in gas
- Study of effect of chromatic distortions in single photon resolution
- Impact of pixelization on single photon resolution
- New plots fro preTDR in preparation
- Update of IRT reconstruction on its way
- Discussion with pfRICH on joint software efforts

hp*DIRC*

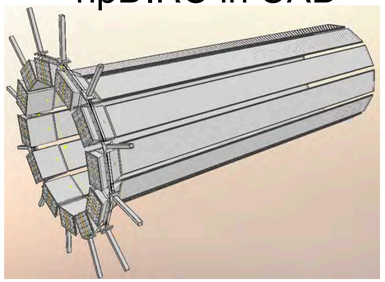
Recent Activities

- hpDIRC prototype in Cosmic Ray Telescope (CRT):
  - Current work is focussed on DAQs integration
- Ongoing hpDIRC studies in simulation:
  - Key studies still in stand-alone software
  - Soon will have expert hpDIRC DSC member taking over simulation in ePIC stack
  - Working on mechanical design details
- Mechanical Design and Integration:
  - Progressing with details of bar boxes and readout boxes
- Validation of the BaBar DIRC bar reuse:
  - Disassembly and QA at JLab in advanced stage
  - Decision on reuse of bars still expected by Q1-Q2/2025

hpDIRC in Geant4

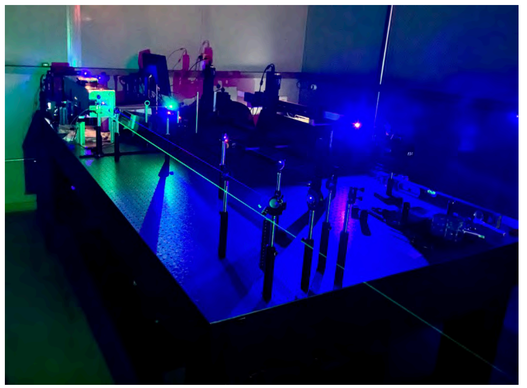


hpDIRC in CAD



Prototype at SBU's CRT

Disassembly setup at JLab



QA lab at JLab

Babar Bar Box Disassembly

- Bar box is open!
- Visual inspection confirms no damages during transport
- Aluminum covers removed except of bottom (next to be removed)
- Glue joints between bars will be decoupled using heat guns
- Optical quality of bars after disassembly will be evaluated in QA DIRC lab, located next to disassembly tent

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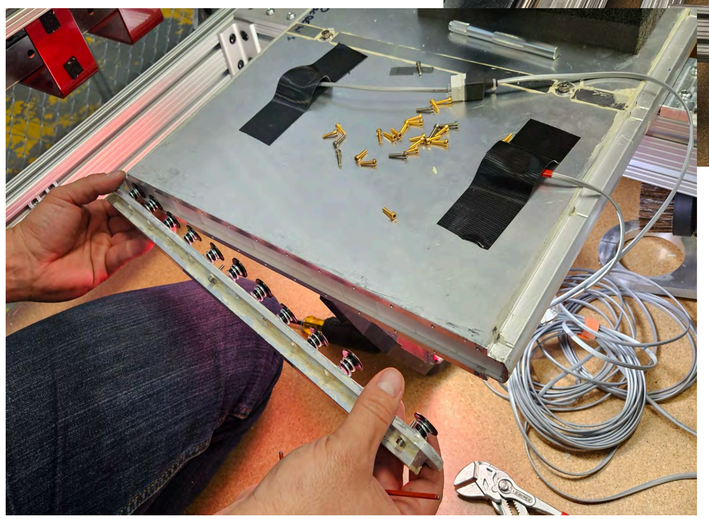

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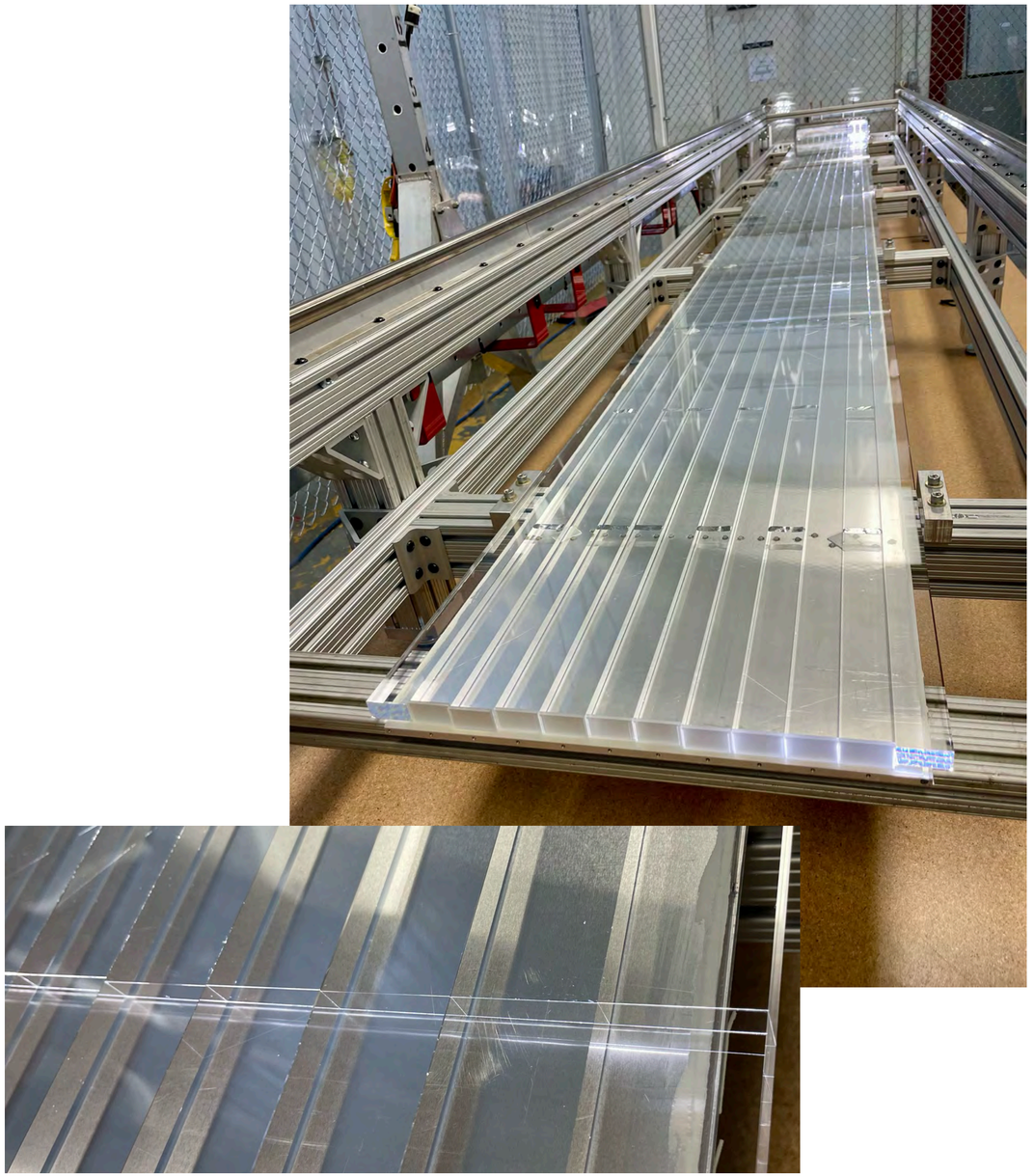

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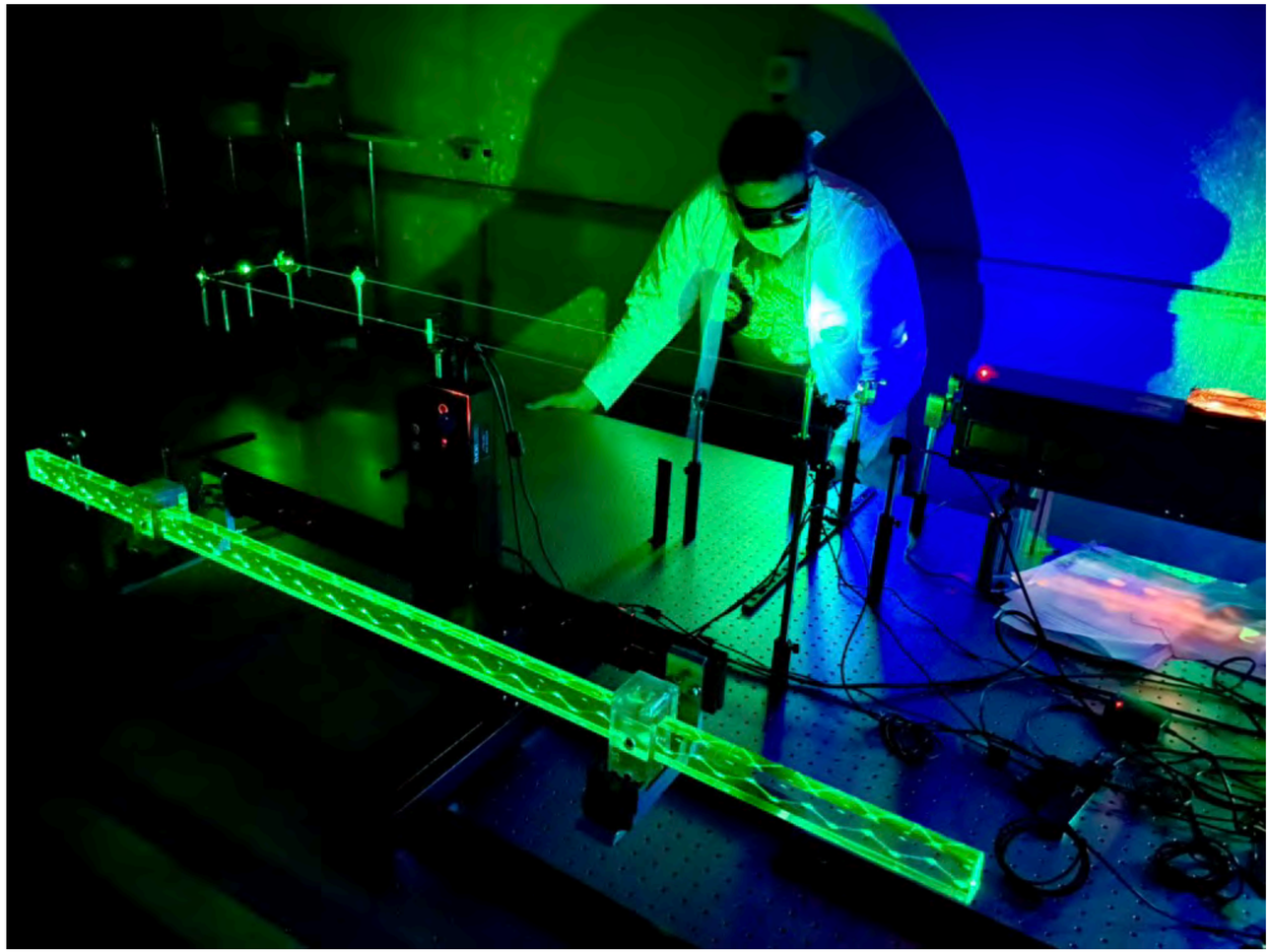

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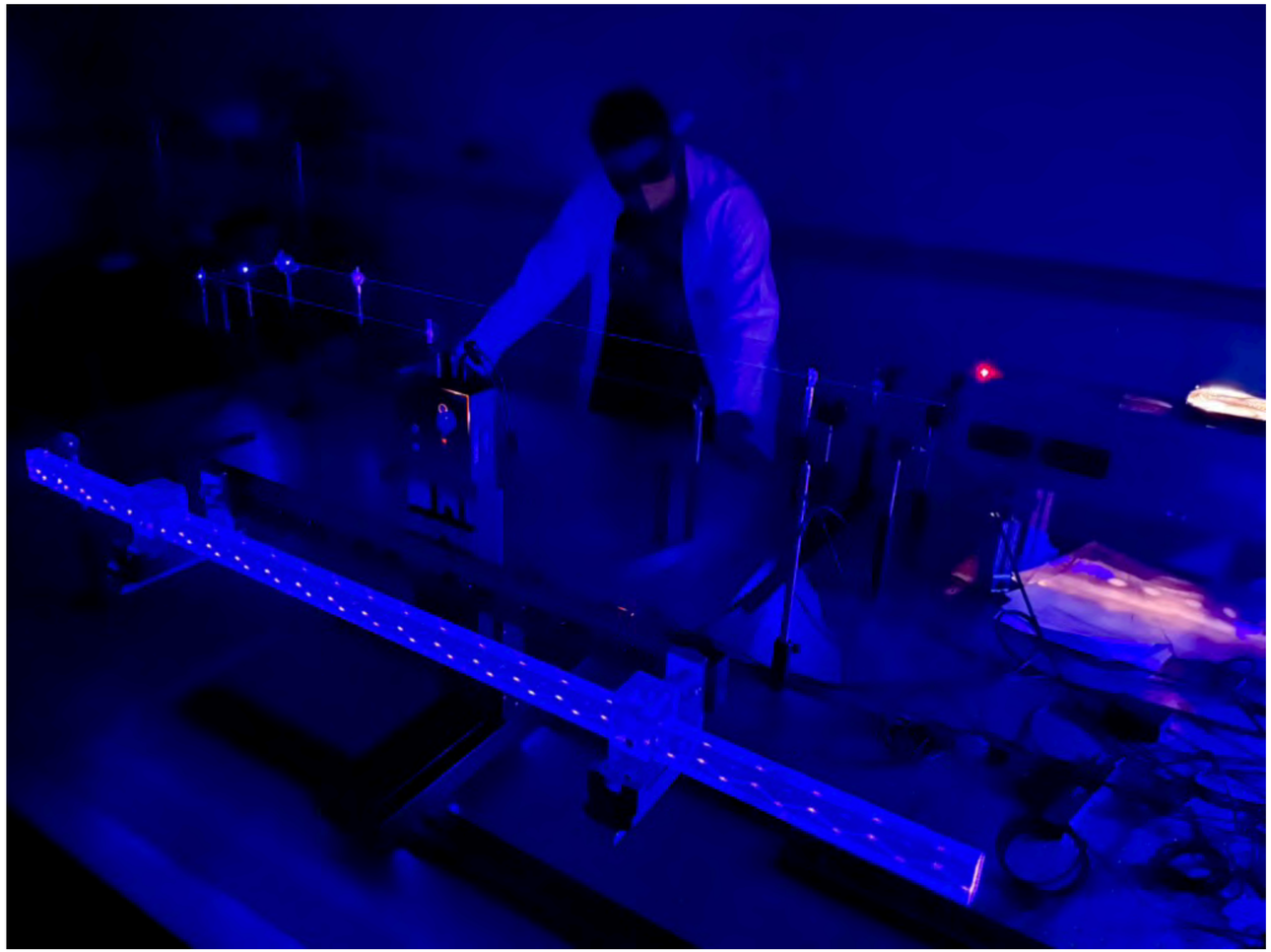

Babar Bar Box Disassembly

So far things look promising … we know more on Q1/Q2 2025

Instead of a Summary of the Summary …