PRECISE TIMING WITH A MICRO PATTERN GASEOUS DETECTOR PROPOSAL # 3

- Klaus Dehmelt

- EIC-related Generic R&D Proposal Review Meeting
- November 16, 2022

Stony Brook University | The State University of New York

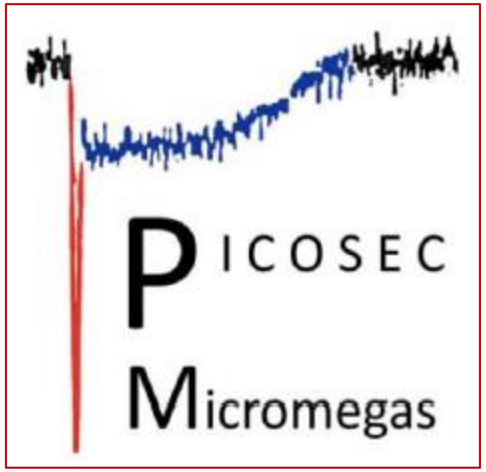
Center for Frontiers in Nuclear Science

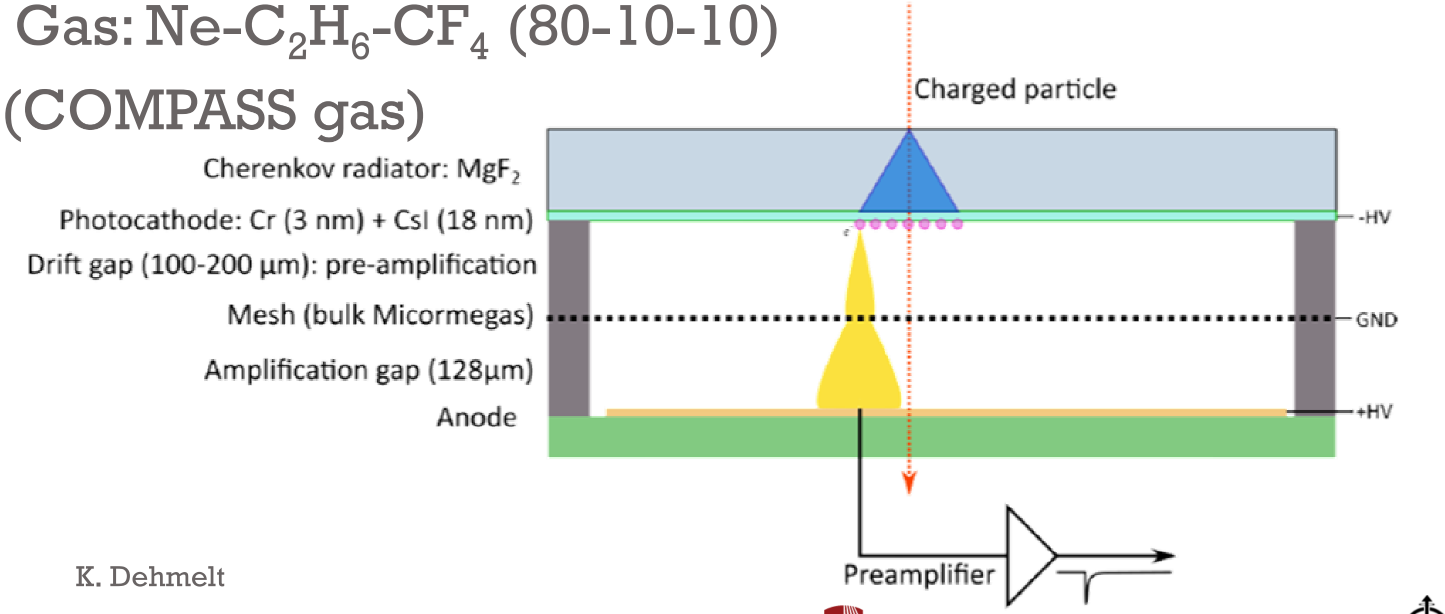
THE PICOSEC – HOW IT STARTED

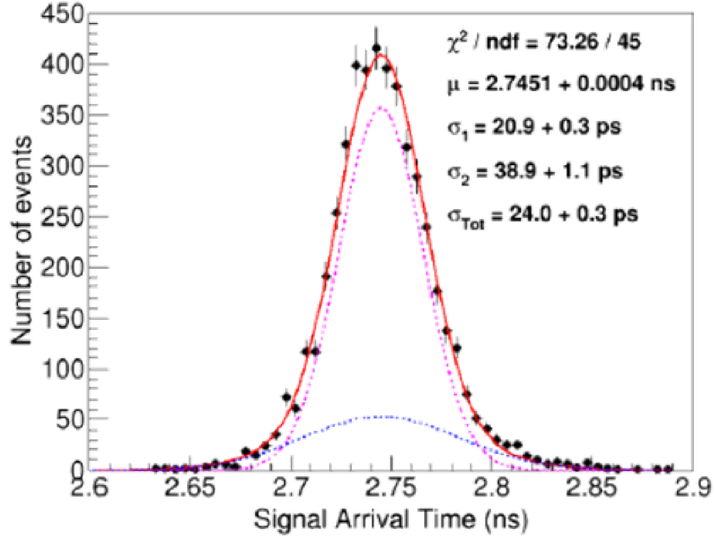
- HL-LHC → identify pile-up induced background
  - Bunch crossing at HL-LHC with $\sigma_z \sim 5$ cm $\Rightarrow \sigma_t \sim 170$ ps
  - Detector with time resolution of ~ 20 ps needed → reduce background
- Hermetic timing coverage requires large area coverage
- MPGD → MicroMegas presently the best candidate
- Use the fastest signal generator → Cherenkov radiation
- We will make use of a demonstrated concept
- Possible alternative MPGD: μRWell

THE PICOSEC – CONCEPT

- Fastest signal generator
  - Let charged particle traverse high n_r-medium
  - "Instantaneous" generation of Cherenkov photons
  - Convert photons to electrons → at identical z-position (ideally)
  - Amplify electrons after extremely short trip → anode readout
  - Gas: $Ne\text{-}C_2H_6\text{-}CF_4$ (80-10-10) (COMPASS gas)







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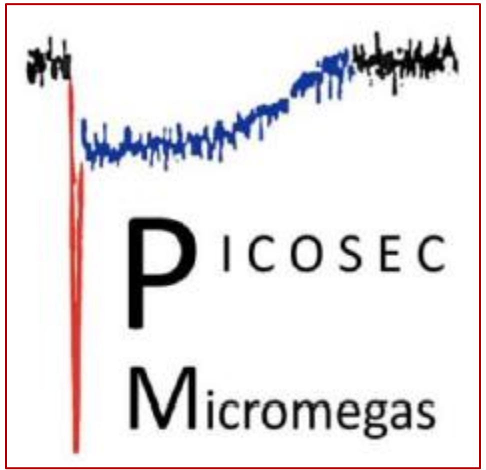

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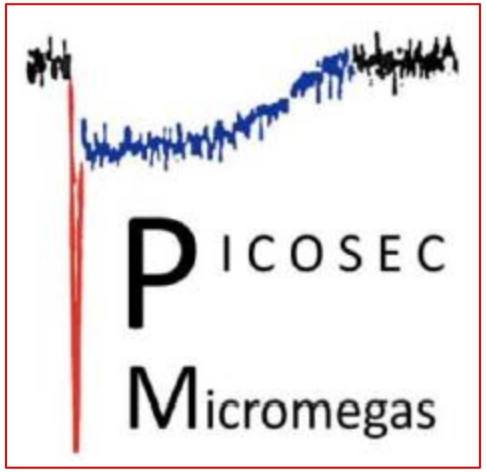

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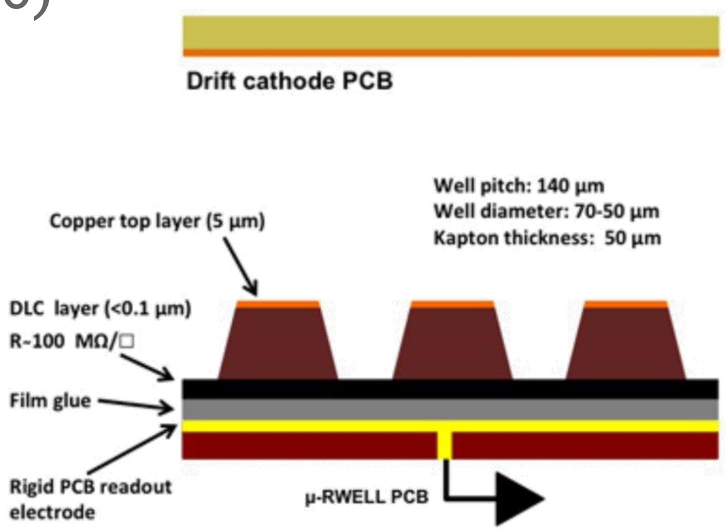
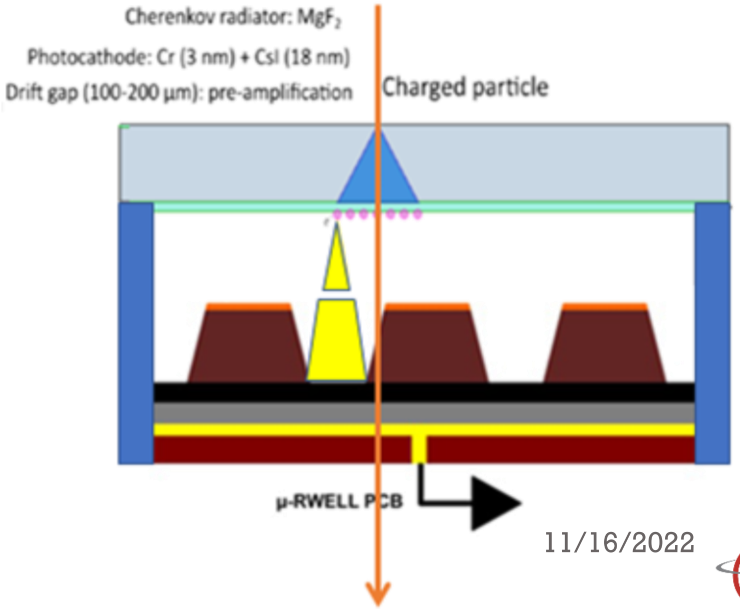
  - Possible alternative
    - Replace MM with μRWell





TESTBEAM @ CERN (2021)

Beam tests: time resolution for MIPs

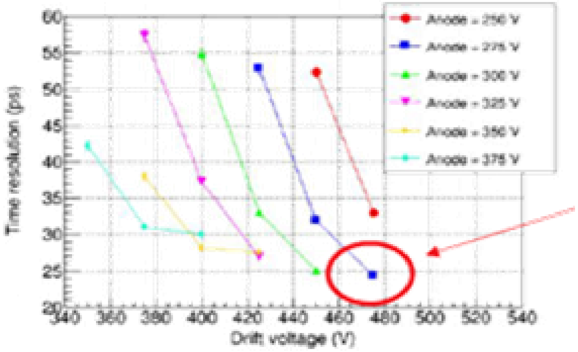
MgF2 radiator 3 mm thick
18 nm CsI on 5.5 nm Cr
Bulk MicroMegas
"COMPASS gas"

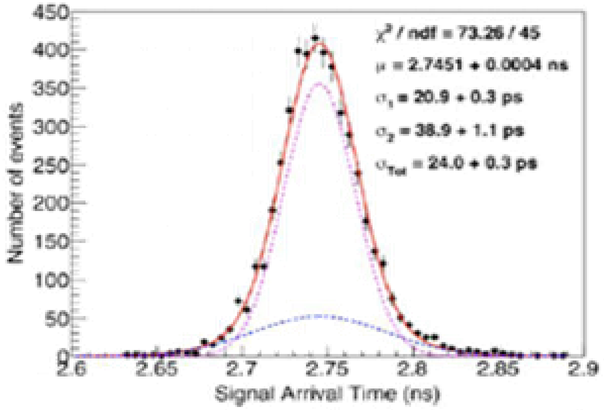
Optimum operation point: V_{drift}/V_{anode}: -475V/+275V

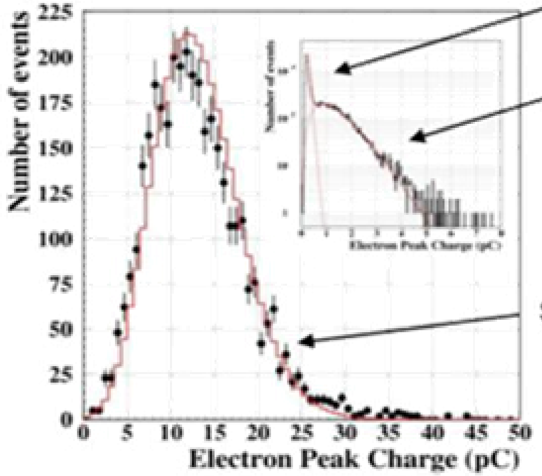
Best result: **24 ± 0.3 ps**

$N_{p.e.}$ = **10.1 ± 0.7**

Mean number of p.e. per muon produced in the CsI photocathode





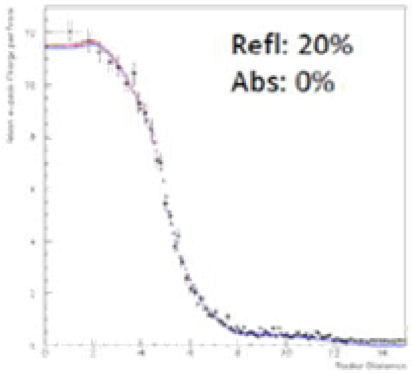


Noise component

Signal for single p.e from UV-lamp tests: "Polya" (Gamma distribution)

Signal of MIPs

Convolution of Poisson, geometrical acceptance function and single p.e. response (Polya)



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PROSPECTS

Robustness

More robust photocathode

Picosec baseline cathode is CsI:

Pro

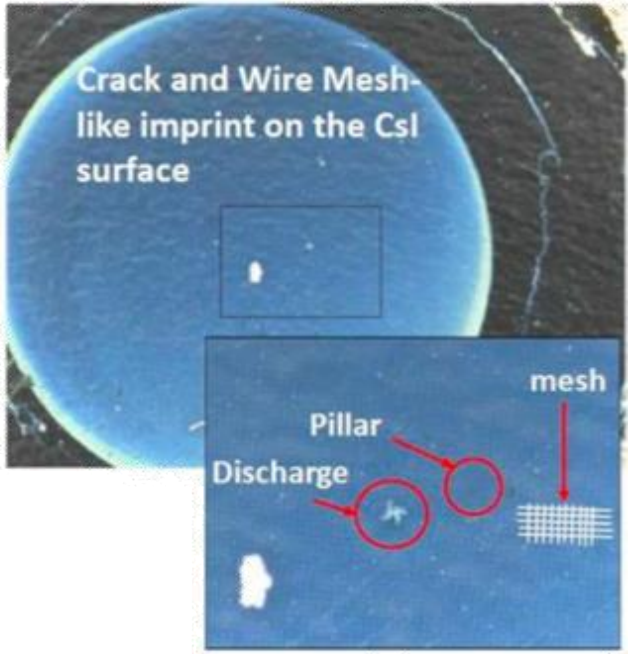
- high quantum efficency (10 p.e/μ) -> better time resolution

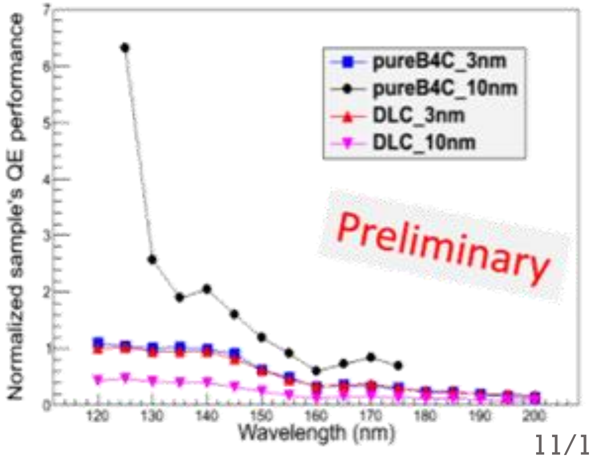
Cons

- poor robustness agains IBF and discharges,
- difficult to handle and store due to the sensitivity to humidity

Research for alternative photocathodes/protection layers

- Metallic photocathodes
  - 20 nm Cr -> 0.66 p.e/μ, time resolution 189 ps
  - 6 nm Al -> 1.69 p.e/μ, time resolution 71 ps
  - 10 nm Al (on 5 mm MgF_2) -> 2.2 p.e/μ, time resolution 57 ps
- DLC
  - 2.5 nm -> 3.7 p.e/μ (550V/275V, 40 ps)
  - 5 nm -> 3.7 p.e/μ
  - 7.5 nm -> 2.2 p.e/μ
  - 10 nm ->1.7 p.e/μ
- B4C
  - Shows better QE than DLC. with UV light test in the lab.





https://indico.cern.ch/event/757322/contributions/3387110/attachments/1839691/3015624/MPGD2019_WangXu_f.pdf

Sohl, Lukas. *Development of PICOSEC-Micromegas for fast timing in high rate environments*. Diss. Université Paris-Saclay, 2020.

Summary

- PICOSEC: detector concept with large potential
  - Simple construction
  - Affordable
  - Excellent timing performance
  - Can be used as fast photo-detector
  - Electronics to be verified
  - Has large room for improvements
  - PICOSEC Collaboration highly competent and enthusiastic

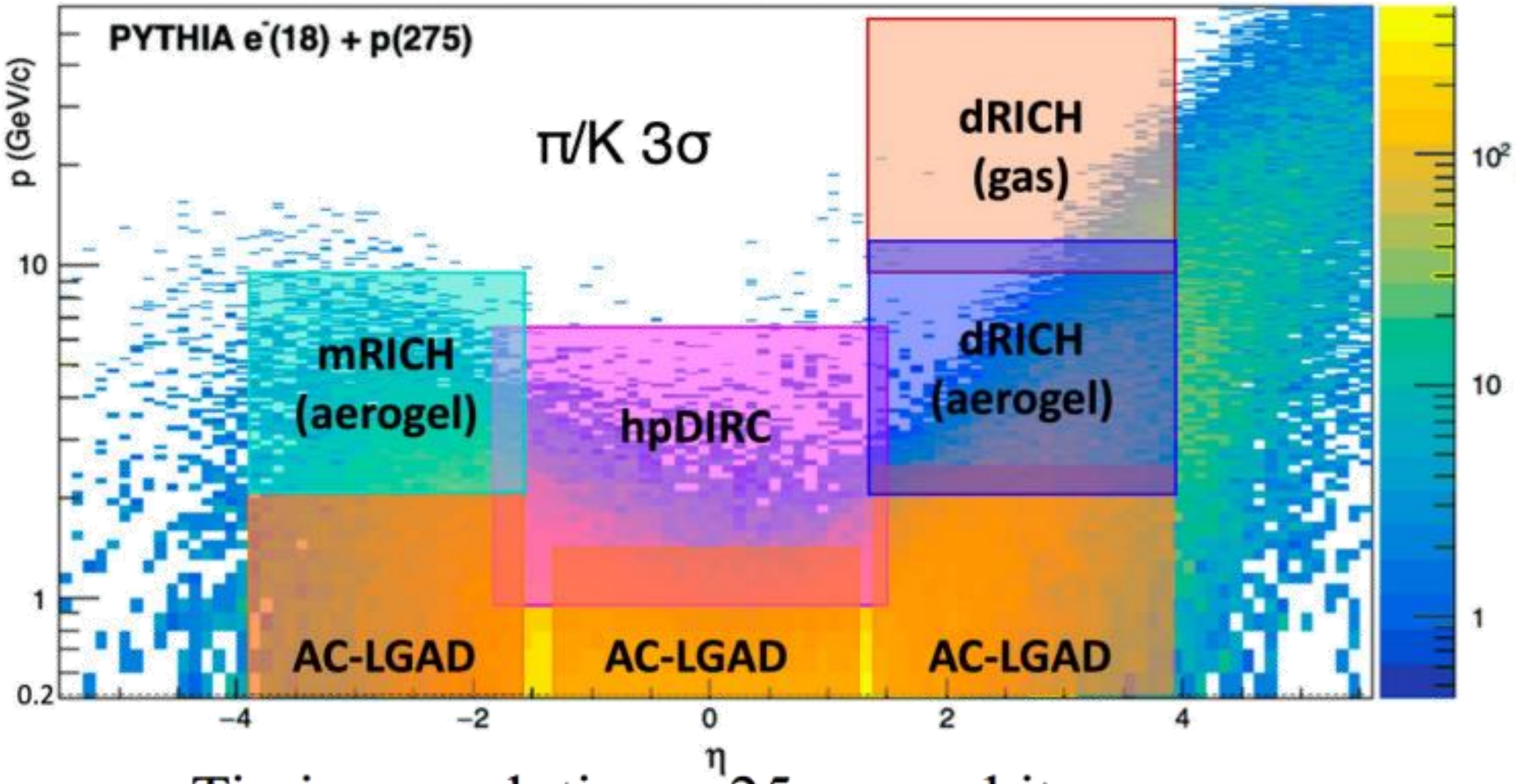
QUESTIONNAIRE

- EICGENR&D2022_03: Precise Timing with a Micro Pattern Gaseous Detector
  1. Please elaborate on the role and potential advantages of using a PICOSEC detector for the EIC. Based on reasonable assumptions about the radiator/photocathode/gas gain structure, how would this technology compare to LGADs for use as an EIC TOF detector in terms of multiple scattering, heat generation, and services?
  2. Please show a diagram of where the PICOSEC detector would be placed in the experiment.
  3. Describe in detail the proposed scope of work for Year 1.
  4. What generic R&D and achieved milestones would be sufficient to establish that this technology is a viable candidate for an EIC TOF detector? (Further refinements in the radiator, photocathode, and gas gain structures are inherently open ended, but a final configuration could be established using project R&D.)
  5. Regarding labor: Can you detail the %FTE participation by other collaborators? Which part of the project could be accomplished without funding for a PhD student?

POTENTIAL ADVANTAGE OF PICOSEC IN EIC

- Timing resolution $\sigma_t \sim 20ps$
- Possibly track point usage
- Large area coverage
- Could be mounted on existing infrastructure
- Costs
- …

POSSIBLE COMPARISON TO LGAD



- Timing resolution: ~25 ps per hit ✓
- Position resolution: ~30 μm with 500 μm pitch ✗
- Material budget: ~7.5% X0 ✓
- Total area: ~ 15 m^2 ✓

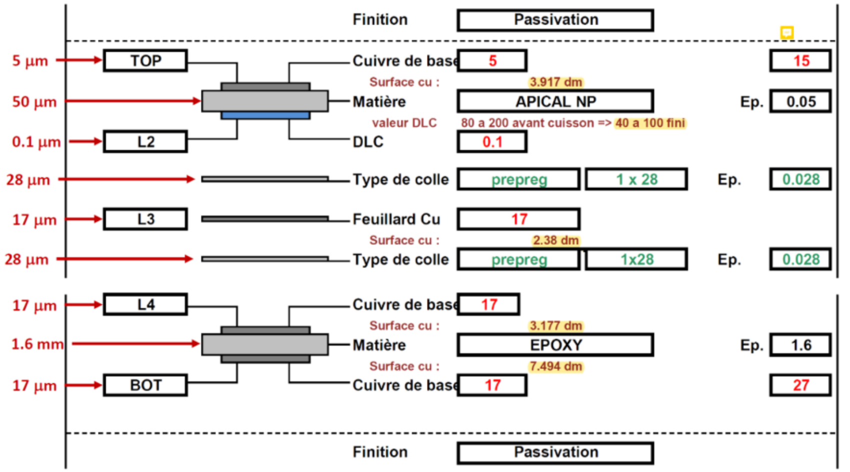
Zhenyu Ye, Det1 Gen. Mtg. 060922 2

MULTIPLE SCATTERING/HEAT GENERATION/SERVICES

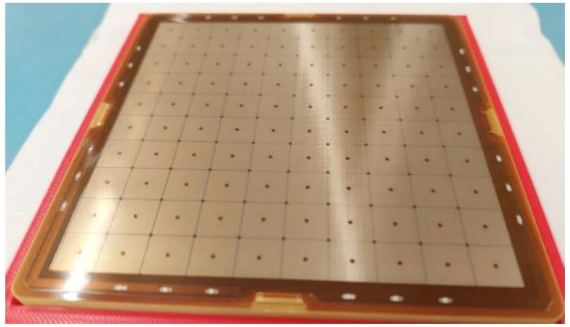
- Radiation length: X/X_0 of $\mathcal{O}(5\%)$ → material is 75% driven by radiator
- Heat generation: 78 mW/ch with electronics under development → 780 W/m^2
- Services: gas supply and power supply

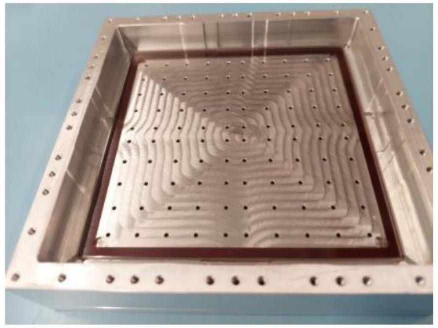
µRWell

Radiator



Micromegas



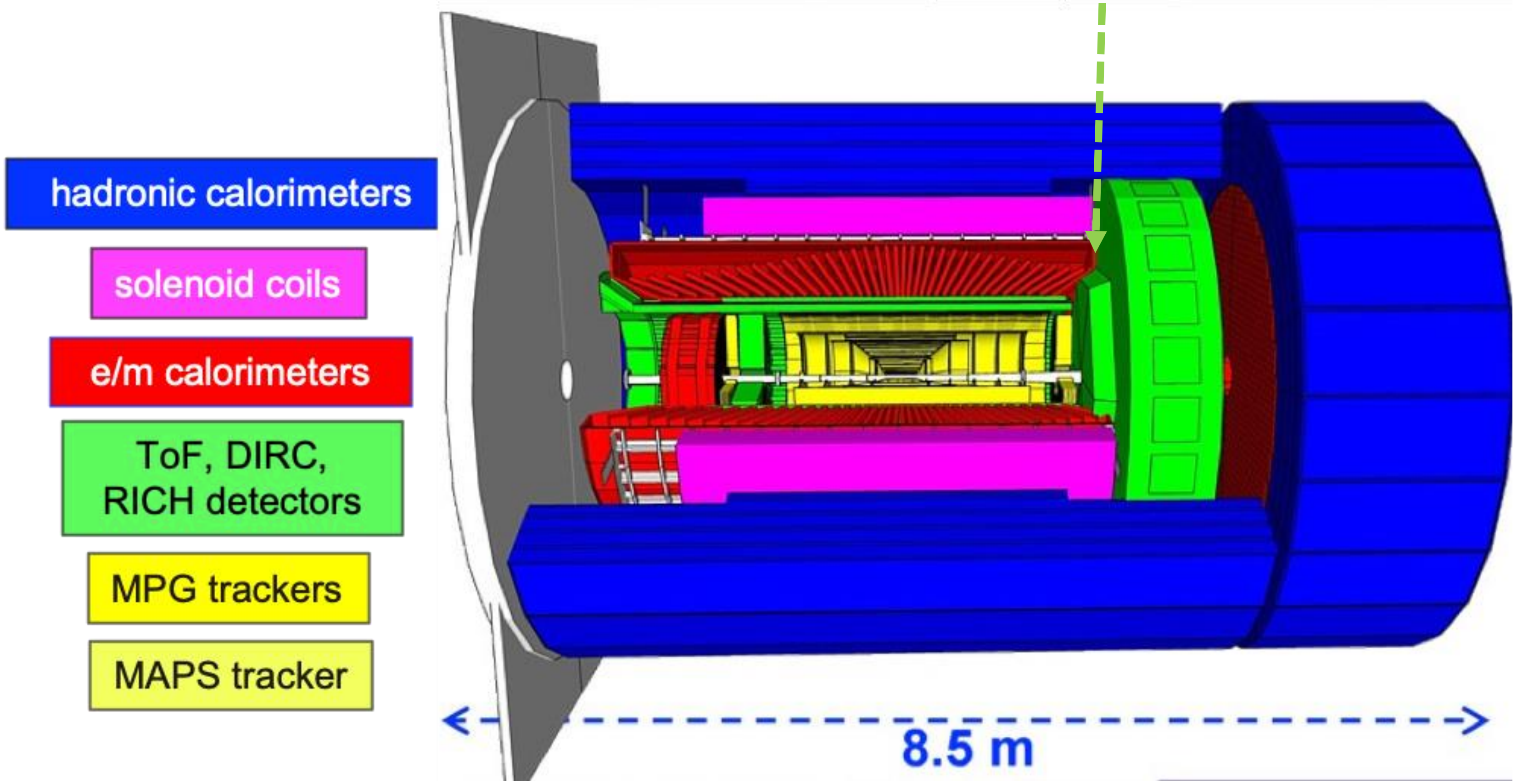


Outer board + Micromegas + Housing +MgF_2

PLACEMENT IN EIC DETECTOR

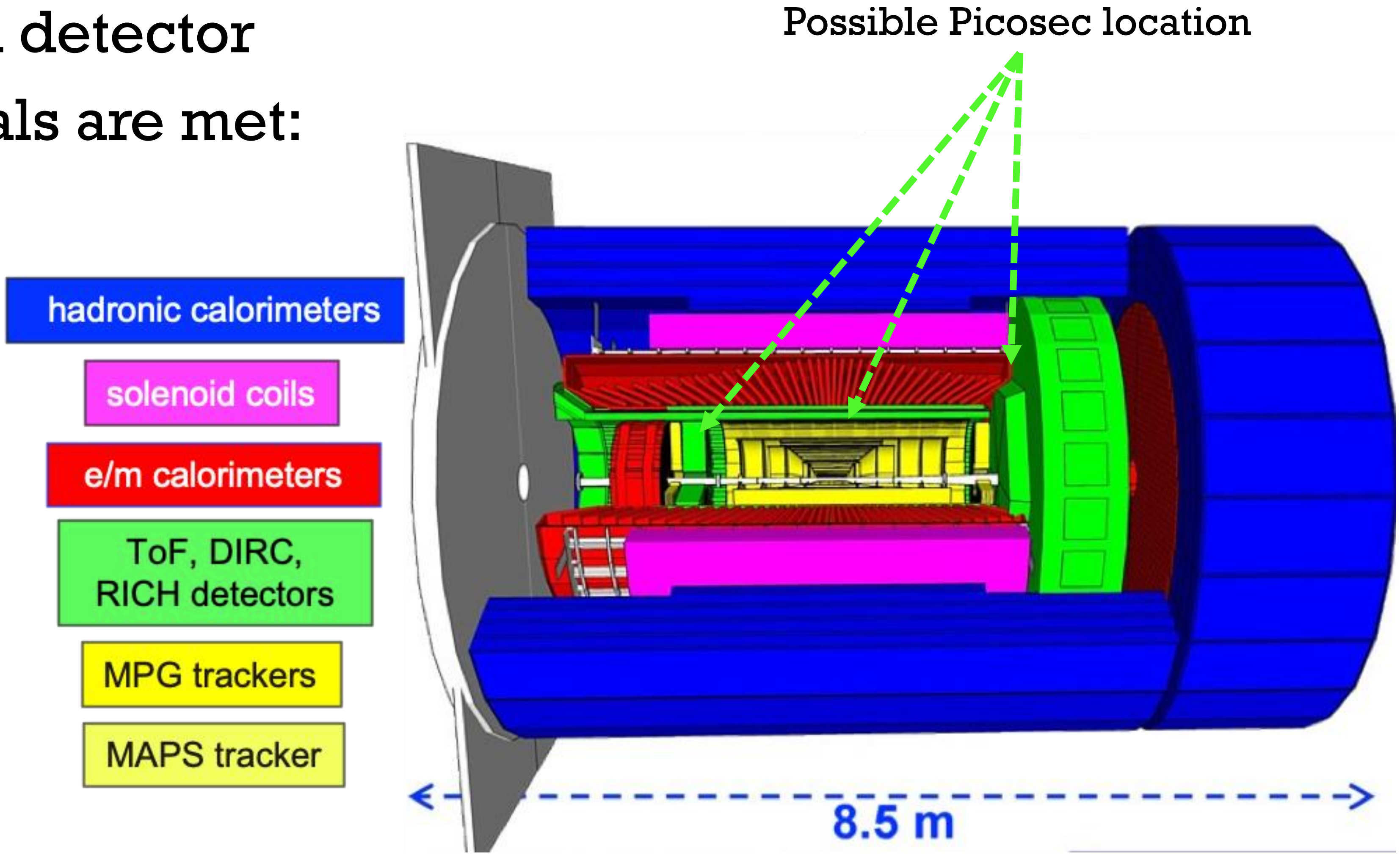
- For instance, EPIC:

Possible Picosec location



PLACEMENT IN EIC DETECTOR

- Second IR detector
  if R&D goals are met:



PROPOSED SCOPE YEAR 1

- Familiarize with MM-Picosec
  - Get detector in operating conditions and compare with GDD-FT device
- Establish mechanical stability
  - Investigate and develop mechanical structure with minimal material impact
- Explore readout electronics
  - Investigate and demonstrate feasibility of readout electronics
- Laboratory testing with light source
  - Verify photon-yield
  - Investigate performance
  - Verify timing resolution
- Testbeam at CERN

GENERIC R&D AND MILESTONES

- Generic R&D
  - Investigate electronics performance with MM-Picosec
  - Improve stability with minimum material supply
  - Investigate large area readout performance
  - Replace MM with μRWell, verify performance (2^{nd} + years)
- Possibly achieving milestones with
  - Demonstrate electronics performance
  - Demonstrate stability improvement
  - Demonstrate large area readout capability
- Possibly achieving milestones with further refinements
  - Verify improved photon-yield with modified photo-cathode/radiator
  - Similar timing resolution of μRWell compared to MM → $\sigma_t \sim 20$ ps
  - Demonstrate performance equivalent of μRWell compared to MM

%FTE from Collaborators/ No Student Support

- Project needs a person dedicated to topic → Ph.D. student
- Collaborator contributions: consulting, test beam support

Item	Nominal Budget	Year 1	Year 2	Year 3	Total
1	Salary Ph.D. student	$ 61,525	$ 63,201	$ 64,927	$ 189,653
2	Travel costs (Test Beam)	$ 7,975	$ 15,950	$ 15,950	$ 39,875
3	Picosec Amplification Structure	$ 4,080	$ 4,250		$ 8,330
4	Radiator	$ 1,224	$ 1,500		$ 2,724
5	Sapphire window	$ 510			$ 510
6	Aluminum housing	$ 1,020			$ 1,020
7	Outer PCB	$ 1,530	$ 1,530		$ 3,060
8	Preamplifier	$ 4,590			$ 4,590
9	Digitizer SAMPIC 128 CH	$ 12,240			$ 12,240
	Total	$ 94,694	$ 86,431	$ 80,877	$ 262,002

%FTE FROM COLLABORATORS/ NO STUDENT SUPPORT

- Project needs person dedicated to topic → Ph.D. student
- Collaborator contributions: consulting, test beam support
- Budget reduction → personnel cost reduction → significantly project delay

Item	Nominal Budget -20%	Year 1	Year 2	Year 3	Total
1	Salary Ph.D. student	$ 46,144	$ 47,401	$ 48,695	$ 142,240
2	Travel costs (Test Beam)	$ 4,417	$ 14,464	$ 16,007	$ 34,888
3	Picosec Amplification Structure	$ 4,080	$ 4,250		$ 8,330
4	Radiator	$ 1,224	$ 1,500		$ 2,724
5	Sapphire window	$ 510			$ 510
6	Aluminumhousing	$ 1,020			$ 1,020
7	Outer PCB	$ 1,530	$ 1,530		$ 3,060
8	Preamplifier	$ 4,590			$ 4,590
9	Digitizer SAMPIC 128 CH	$ 12,240			$ 12,240
	Total	$ 75,755	$ 69,145	$ 64,702	$ 209,602

%FTE FROM COLLABORATORS/ NO STUDENT SUPPORT

- Project needs person dedicated to topic → Ph.D. student
- Collaborator contributions: consulting, test beam support
- Budget reduction → personnel cost reduction → significantly project delay → project not feasible

Item	Nominal Budget - 40%	Year 1	Year 2	Year 3	Total
1	Salary Ph.D. student	$ 30,763	$ 31,601	$ 32,464	$ 94,827
2	Travel costs (Test Beam)	$ 859	$ 12,978	$ 16,062	$ 29,899
3	Picosec Amplification Structure	$ 4,080	$ 4,250		$ 8,330
4	Radiator	$ 1,224	$ 1,500		$ 2,724
5	Sapphire window	$ 510			$ 510
6	Aluminumhousing	$ 1,020			$ 1,020
7	Outer PCB	$ 1,530	$ 1,530		$ 3,060
8	Preamplifier	$ 4,590			$ 4,590
9	Digitizer SAMPIC 128 CH	$ 12,240			$ 12,240
	Total	$ 56,816	$ 51,859	$ 48,526	$ 157,200

NO STUDENT SUPPORT

Project <u>**unfeasible**</u>