The Italian Contribution to the Electron Ion Collider

P. Antonioli

INFN-Bologna

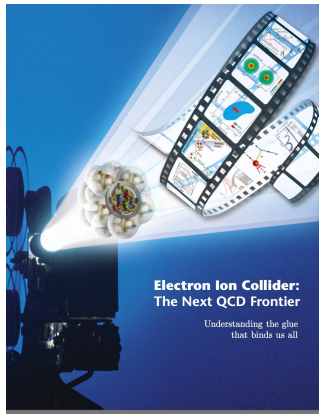
Why this talk?

- We are in Italy ;-)
- We will have Giornate Nazionali since this afternoon (an introduction)
- If you are not from Italy (or you are not working currently with INFN) is however good thinking about "your future": how your country community is contributing/will contribute to the EIC?
- We want to grow a new "EIC generation" → know your "space"
- **How I can/want to contribute?**

CAVEAT: some information here are "old" on purpose: last updates on R&D during "Giornate Nazionali"
CAVEAT: I take advantage of nice ePIC presentation made by Silvia Dalla Torre on Tuesday

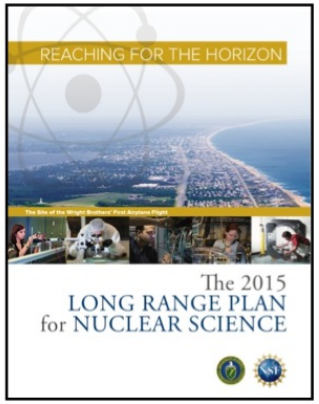
A long story is becoming reality

https://www.bnl.gov/eic/



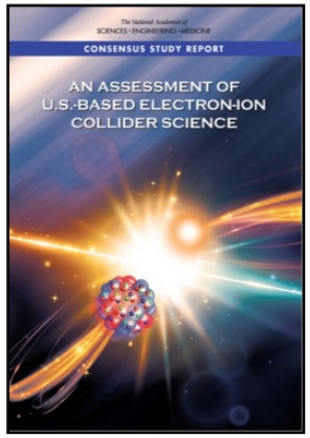
2012 White paper

The Electron-Ion Collider: the next QCD frontier



2015 NP LRP

"We recommend a high-energy high-luminosity polarized EIC as the highest priority for new facility construction following the completion of FRIB."



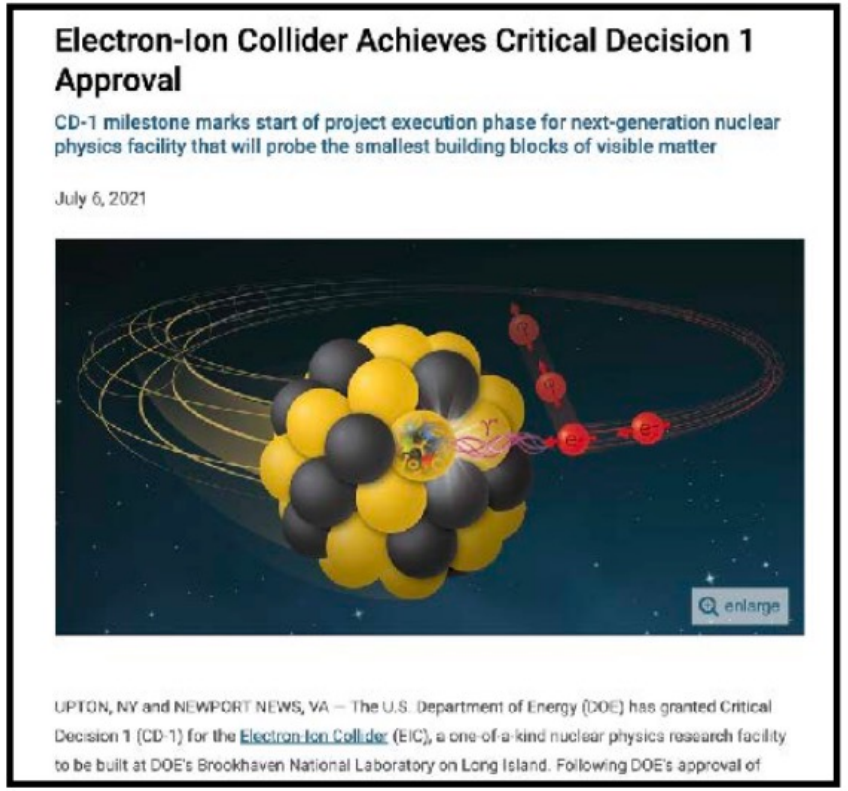
2018 National Academy Science report

"The committee finds that the science that can be addressed by an EIC is compelling, fundamental and timely."

A long story is becoming reality

https://www.bnl.gov/eic/

Dec 2019/Jan 2020
CD-0 ("mission need") status achieved
BNL site selection



Electron-Ion Collider Achieves Critical Decision 1 Approval

CD-1 milestone marks start of project execution phase for next-generation nuclear physics facility that will probe the smallest building blocks of visible matter

July 6, 2021

enlarge

UPTON, NY and NEWPORT NEWS, VA — The U.S. Department of Energy (DOE) has granted Critical Decision 1 (CD-1) for the Electron-Ion Collider (EIC), a one-of-a-kind nuclear physics research facility to be built at DOE's Brookhaven National Laboratory on Long Island. Following DOE's approval of

Jun 2021
Following CDR presented, CD-1 passed

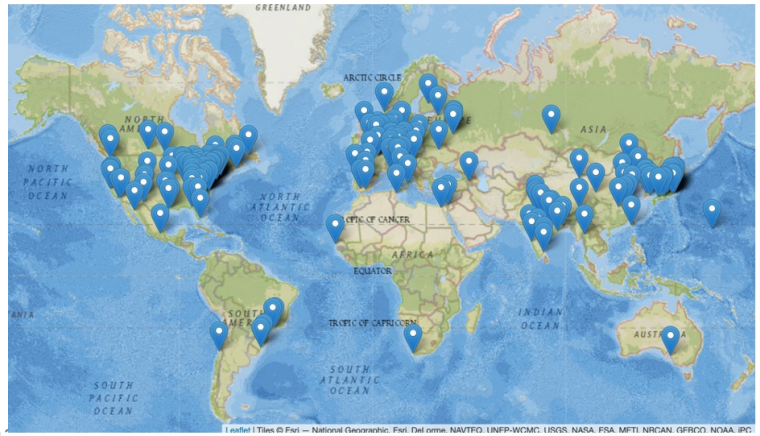
A little bit of (Italian) history

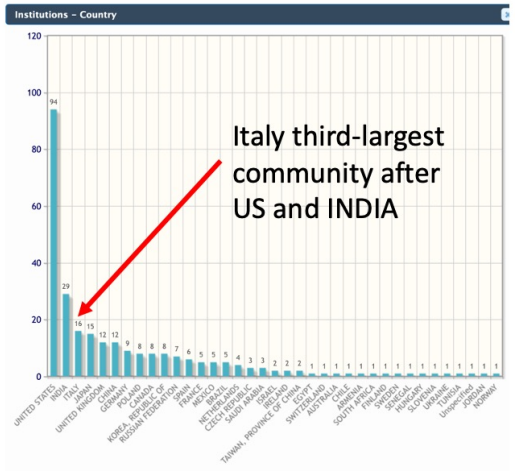
Italian groups first interested to EIC physics are from HERA diaspora (HERMES in particular), from COMPASS (DIS @ CERN SPS program), from JLab ("hadron physics") and from a strong theoretically community (Pavia, Perugia, Cagliari, ...)

Some Italian groups participated to early R&D efforts for EIC (funding from DoE) and EIC User Group acted as the first "engine" to coalesce groups...

Intermezzo 1: the EIC User Group https://www.eicug.org

- community based initiative started in 2016
- 271 institutions, 1386 members (both experimentalists [856], theorists [355], accelerator scientists [160])
- It has its own structure/charter → current steering committee vice-chair M. Radici (INFN-PV)
- before moving to "collaboration-mode" one of the real engines of the project!





Marco is now EICUG chair

2016 Nuclear Physics INFN community meeting

Opportunità future per la fisica adronica negli USA *Patrizia Rossi*

Aula Bruno Touschek, Laboratori Nazionali di Frascati 17:40 - 18:10

Patrizia is Associate Director at JLab

https://agenda.infn.it/event/10586/contributions/3969/attachments/2968/3258/Rossi_INFN2016.pptx

- One of the first presentations to the largest INFN community
- Check the slides!

A little bit of (Italian) history (II)

2017

https://agenda.infn.it/event/12368/?ovw=True

Giornata sulle opportunità del progetto Electron-Ion Collider (EIC)

17 January 2017
Museo di S.Agostino
Europe/Rome timezone

Enter your search term

- Overview
- Timetable
- Registration
- Come arrivare al Museo Sant'Agostino
- Dove mangiare
- Participant List

La realizzazione di un Electron-Ion Collider (EIC) è stata inclusa nelle raccomandazioni de *Range Plan for Nuclear Science* del Nuclear Science Advisory Committee ("Recommendation III: We recommend a high-energy high-luminosity polarized EIC as priority for new facility construction following the completion of FRIB").
Questo riconoscimento rappresenta un importante passo nel processo di definizione de successivo finanziamento da parte del governo USA (DOE - Nuclear Physics) del futuro ac della strumentazione necessaria.
La possibilita' di studiare nuove distribuzioni partoniche sensibili ai gradi di libertà t nucleoni e nei nuclei in un ampio intervallo di $x_{Bjorken}$ e Q^2, con un esperimento di alta pre luminosità con accesso ai gradi di libertà di spin rappresenta una formidabile sfida ed u opportunità per la completa comprensione della QCD. I temi allo sttudio, spaziano dalla

	Welcome/Intro	*Guido Maria Urciuoli et al.*	
	Sala Conferenze, Museo di S.Agostino	10:30 - 10:45	
	La fisica di EIC	*Dr Alberto Accardi*	
11:00	*Sala Conferenze, Museo di S.Agostino*	10:45 - 11:30	
	Gli acceleratori per EIC	*Dr Fulvia Pilat*	
	Sala Conferenze, Museo di S.Agostino	11:30 - 12:00	
12:00	**L'opzione JLEIC - EIC@JLab**	*Evaristo Cisbani*	
	Sala Conferenze, Museo di S.Agostino	12:00 - 12:30	
	L'opzione eRHIC - EIC@Brookhaven	*Silvia Dalla Torre*	
	Sala Conferenze, Museo di S.Agostino	12:30 - 13:00	

Silvia is now ePIC deputy spokesperson

	Opportunita per i gruppi italiani	*Marco Contalbrigo*	
	Sala Conferenze, Museo di S.Agostino	14:30 - 15:00	
15:00	**EIC Status and Realization Road Map: A Users Perspective**	*Prof. Abhay Deshpande*	
	Sala Conferenze, Museo di S.Agostino	15:00 - 15:15	

Marco is now dRICH sub-system leader

(Note: Google is unable to find a photo of Marco, apparently)

EICUG meeting in Italy…

"INFN consider EIC an important opportunity for the hadronic physics community and encourage partnerships and collaborations with the other Institutions involved in the project''

E. Nappi,
then INFN vicepresident

Groups coalesced in a formal proposal of an INFN initiative to explore EIC opportunities in May 2018
EIC_NET initiative approved by INFN Nuclear Physics committee in September 2018
EIC_NET started operations beginning of January 2019

and INFN "EIC_NET" initiative

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RIUNIONE EIC-INFN, Roma, 10 Maggio 2018

Riunione della Comunita' INFN interessata a EIC

S. Dalla Torre

gruppi e FTE per il 2019 e apertura sigle

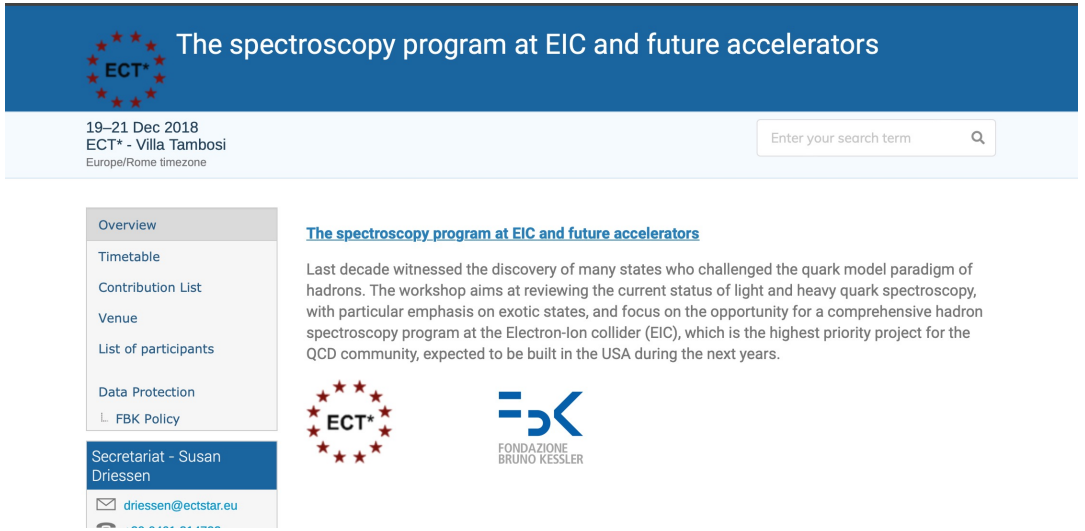
- Al momento, dichiarazioni di interesse da 11 gruppi:

1. BARI
2. BOLOGNA
3. CATANIA
4. FERRARA
5. GENOVA
6. LNF
7. ROMA 1
8. ROMA TOR VERGATA
9. SANITA'
10. TORINO
11. TRIESTE

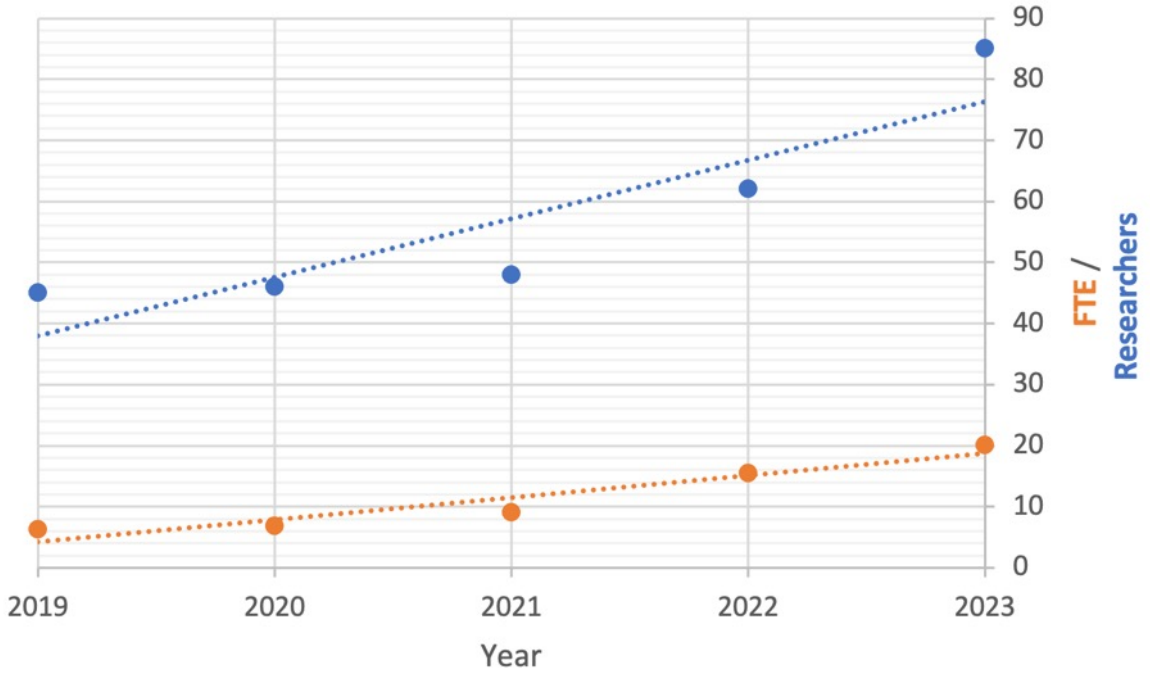
Prospettive FTE ?

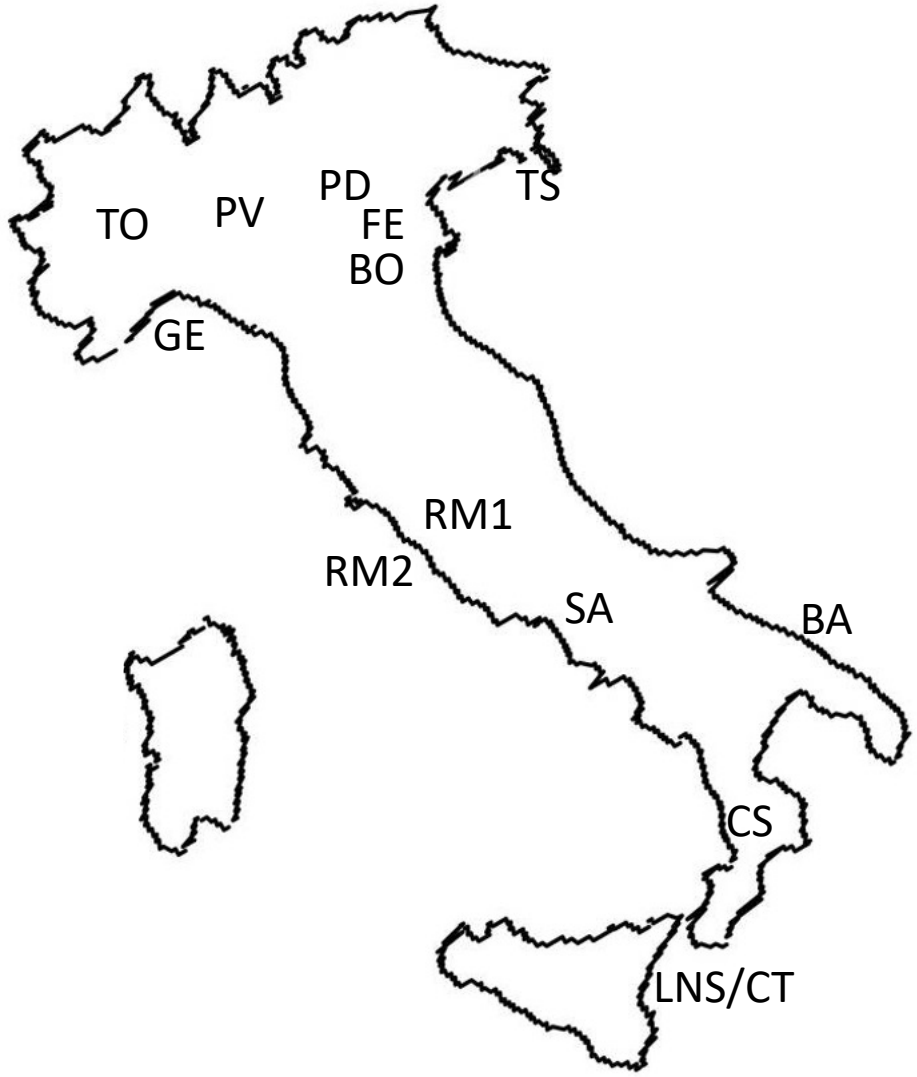
Roma, 10 maggio 2018 S. Dalla Torre 7

https://indico.ectstar.eu/event/29/timetable/?view=standard



EIC_NET status: a growing community





A growing community with different background:
COMPASS, JLAB/CLAS12, ALICE, ATLAS, CMS, STAR, DARK SIDE, ...

Giornata nazionale EIC_NET 2019

Giornata nazionale EIC_NET 2020

3–4 Dec 2020
Online by Laboratori Nazionali di Frascati LNF
Europe/Rome timezone

Enter your search term

Giornata nazionale EIC_NET 2021

20–21 Dec 2021
Torino

Giornata nazionale EIC_NET 2022

30 June 2022 to 1 July 2022
Catania

Enter your search term

https://agenda.infn.it/category/1561/

from this year first RRB meeting (April 2023)

International Interest & In-Kind - Updated

Entity	Interest and Important Facts
NSF	NSF-MSRI pre-proposal submitted by 10 US universities – aims at full scope of backward EM calorimetry (eECal). Armenia, Czech, France/IN2P3 as unfunded contributors. Invited to submit proposal.
Armenia	Contributions, mainly labor to eECal and many EM calorimetry and particle id detectors component tests.
Canada	EIC included in 2022 Canadian Subatomic Physics Long-Range Plan; Interested in Compton Polarimetry, Electromagnetic Calorimetry and Software
China	Forward EM Calorimeter
Czech	Working with funding agency; Interested in eECal (PbWO4 crystals and glass) and Silicon
France/IRFU	Interested in SC magnet design, electronics and MPGD/tracking. Saclay/IRFU provided 30% design work for magnet as in-kind, contributions to 60% and ongoing 90% design.
France/IN2P3	International contribution to backward EM calorimetry (including in-kind design) and to readout electronics (e.g., ASICs for AC-LGAD detectors and Calorimetry). IRFU & IN2P3 discussing together for higher-level contributions.
India	Consortium is working with Funding agency; Interested in detector software (non-project scientific contribution), contributions to DAQ/slow controls, and PID – ToF as hardware (investigating Forward AC-LGAD to make links with Si plants)
Italy/INFN	Working with INFN since a while; Aims at major scope of forward particle identification detector (dRICH), at (part of) the Si/MAPS tracker scope, and at photo-sensor contributions. Further investigating possible interest in EIC detector magnet scope.
Israel	B0 Detectors (Si tracking and PbWO4)
Japan	Interested in a US-Japan agreement; Aims at full scope of Zero-Degree Calorimeter in collaboration with Taiwan/Korea. Pursuit of full scope of barrel AC-LGAD detector as EIC-Asia consortium. Contribution to DAQ/streaming. Possible aerogel.
Korea	Fiber-based EM calorimetry (barrel and/or hadronic ZDC), Small work package for barrel AC-LGAD as part of EIC-Asia consortium (includes also Japan,Taiwan), collaboration on Si tracking detector (backward Si disks), Si-based hadronic calorimetry for ZDC.
Poland	Actively working with ministry/funding agency; Interested in detectors along the beam line (luminosity detector, Roman Pots)
Taiwan	Pursuit of full scope of barrel AC-LGAD as part of EIC-Asia consortium. LYSO-based EM calorimeter for ZDC, Also optical readout/fiber. Possible later interest in PCBs. Computing.
UK	STFC seed funding for UK detector R&D (3M£). Interest in Si/MAPS tracker, polarimetry and detectors along the beams (Low-Q2/TimePix). Follow-up grant request for 5-7 years submitted early 2023 (includes accelerator part).

20

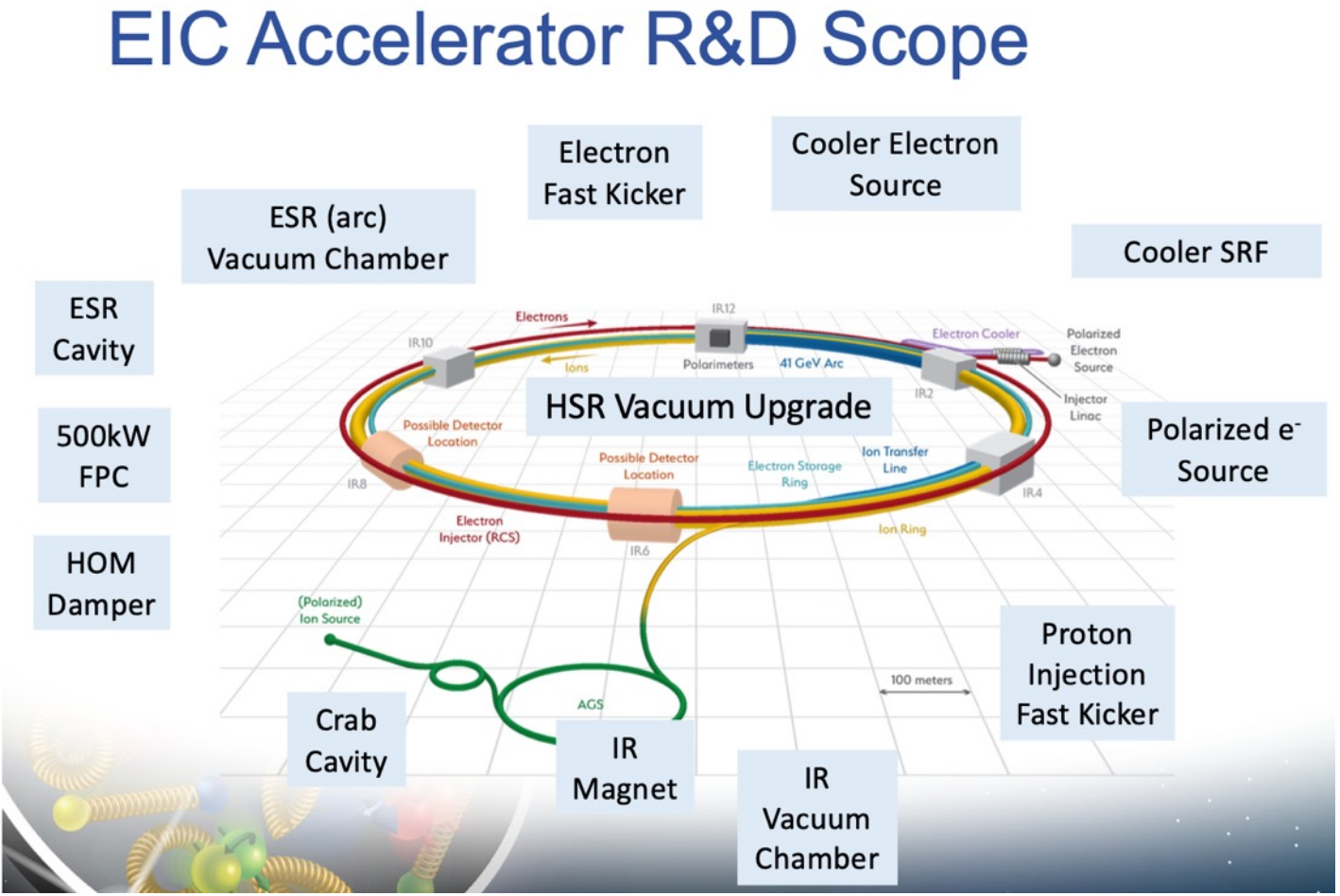
RRB = Resource Review Board → meeting of funding agencies representatives of different countries

Not only the detector: the accelerator

Many developments in critical R&D for accelerator design

T. Satogata@EICUG meeting – July2022

https://indico.bnl.gov/event/15342/contributions/64650/attachments/42380/70993/2022-07-26-EICUG-Satogata-AcceleratorDesign.pdf



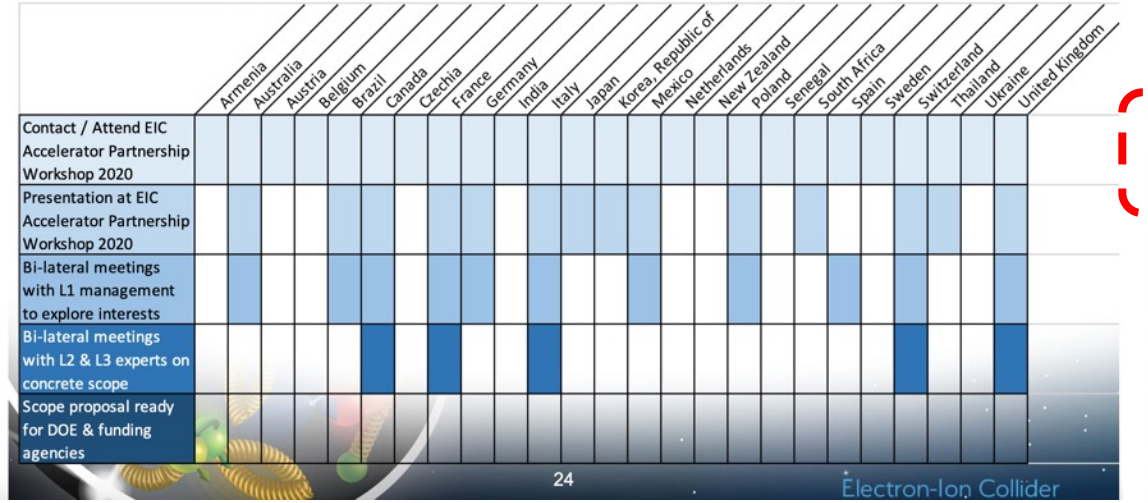
- design consolidation of different components needed
- no show stoppers
- R&D needed in different areas but not critical
- HSR Vacuum upgrade needed due to higher current and shorter bunch length:
  - resistive-wall impedance
  - e-cloud buildup

Solution identify in copper-clad (to reduce resistivity) and aC (amorphous Carbon) thin film to reduce secondary electron yield

EIC accelerator: international contributions (& INFN)

International Engagement - Accelerator

- Active engagement ramped up last summer through meetings with DOE and funding agency reps, Accelerator Workshops, and dialogue with potential partners
- Collaborations contributing to both design and hardware that cover a broad range of WBS items are in development
- Bi-lateral meetings now expand from EIC L1 management to L2 & L3 EIC experts for detailed technical discussion of possible in-kind scope
  - Examples: **Crab Cavity** system information exchange meeting w/UK and Canada, meetings w/INFN-Accelerator collaboration on **HSR vac. system**, w/CERN on **ESR vac. sys.**, etc.



"INFN acceleratori" involvement!

T. Satogata@EICUG meeting

Potential Accelerator Contributions

- Italy, INFN
  - HSR vacuum chamber inserts

High level readiness of technical status
Possibly, first case for use of seed funds

- Canada, TRIUMF
  - SC Crab Cavity system
  - Pulsed systems

High level readiness of technical status

- UK, ASTEC & Cockcroft Inst.
  - ERL components
- France, IJCLab
  - SHC ERL diagnostics
- France, CEA Saclay
  - IR SC magnets
  - SC spin rotators
- CERN, Switzerland
  - ESR SC cryomodules joint design
  - ESR high current elements joint design
- Japan, KEK
  - ESR collimation system

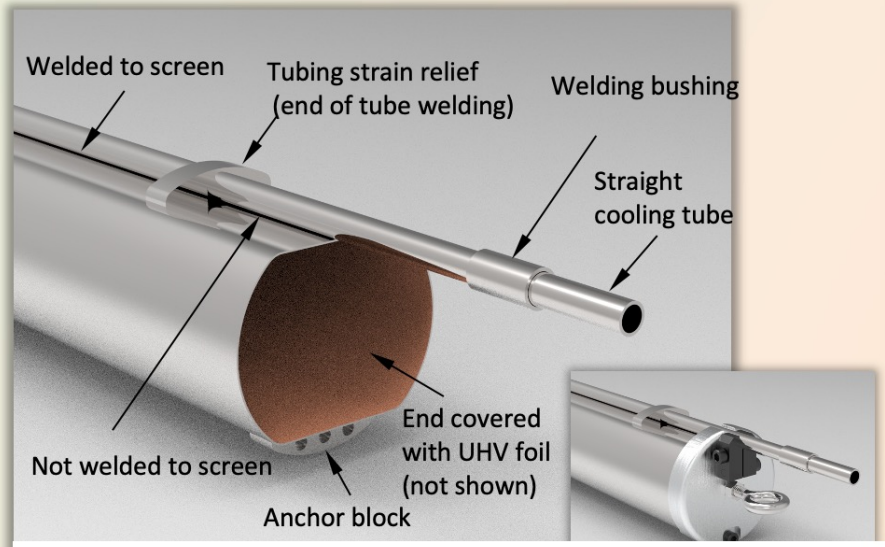
Project is developing possibility of "Seed" funds for EIC international collaboration that can enable early start of EIC accelerator design efforts in partner countries

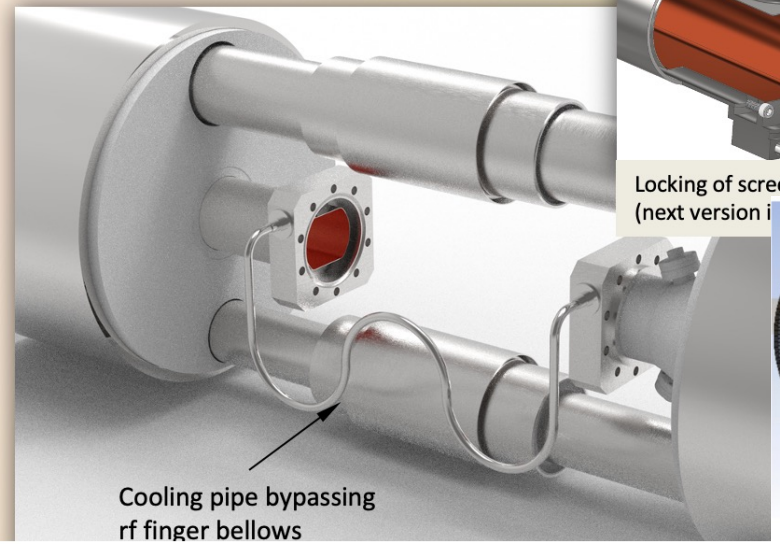
- Recent & tentative:
- Israel, SARAF
  - RF power amplifiers, collimators, controls
- Sweden, Uppsala Uni.
  - SSPA

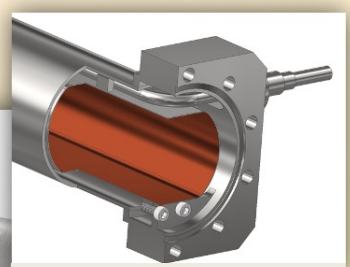
Some more details

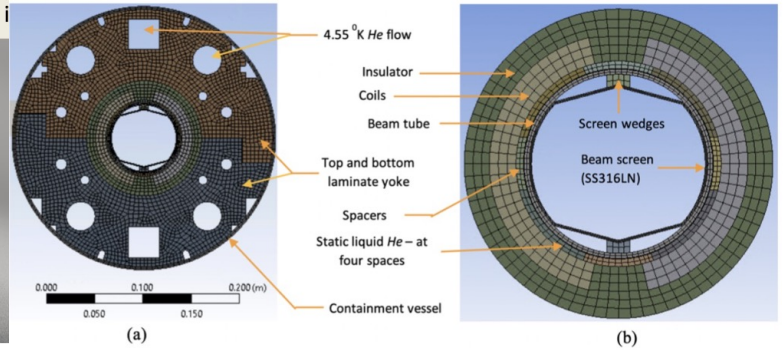
A. Gallo: EIC-INFN collaboration opportunities

- Alternative: Actively-cooled aC/Cu/SS screen. Amorphous carbon coated (~100 nm) copper-clad stainless steel (75 um / 0.5 mm) screen **with dedicated 4-20 K He cooling system**
  - *Advantages:* removes risks associated to quench limit, cryocoolers.
  - *Concerns:* leak tightness, vibrations of cooling pipes; requires cutting beam pipes coming out from cold mass (labor, dust, alignment)
  - Main difference w.r.t. LHC version: **single cooling pipe**







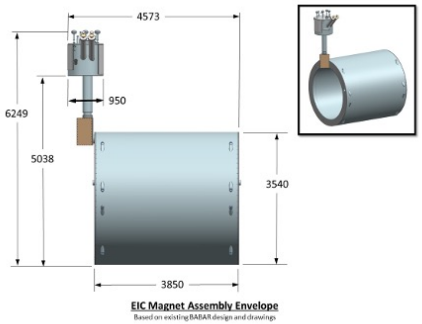


Working towards **comparison of cost, labor, schedule** between baseline solution and alternative solution

Workshop Nazionale INFN Acceleratori, Milano April 7-8 2022 27

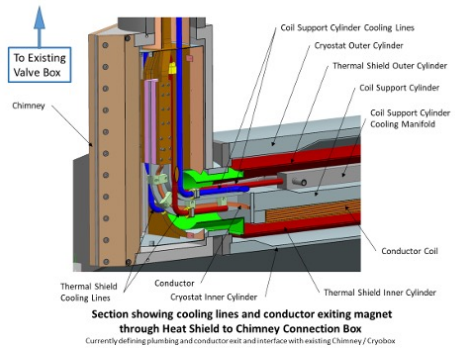
- SEY Characterization of coated surfaces at **LNF**
- Development of a system ("turn-on key") for SEY measurements to be performed on site at BNL

Not only the detector: the magnet ?



EIC Detector Solenoidal Magnet - MARCO

Joint CEA-Saclay-JLab-BNL effort



- Magnet status:

CD-1 Approval	June 2021
3T Detector solenoid preliminary design report	December 2021
Incremental (30%) Design and Safety Review	February 2022
DPAP closeout report – led to reduced field (< 3 T)	March 2022
Contract for 60% Design Review	April 2022
60% design team formation and kick off meeting	May 3, 2022
Mid-Project Progress meeting (@BNL, hybrid meeting)	June 28, 2022
Point design adjusted to stretch goal of 2 T (operation at 1.7 T)	August 10, 2022
60% Design and safety Review	October 18, 2022
90% Design contract in place	December 2022
Found qualified vendor willing to make conductor	January 2023
RFI out	March 2023
Sample Conductor contract	March/April 2023

- Magnet planning:

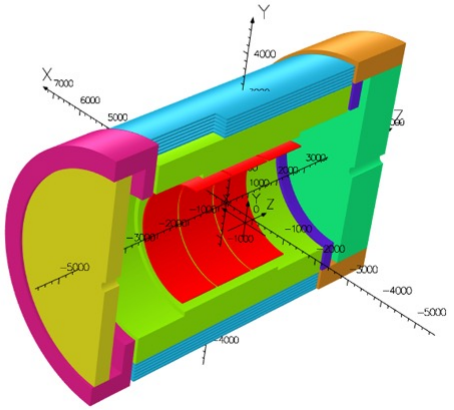
Progress meeting (@JLab, hybrid meeting)	April 18, 2023
90% Design completion	September 2023
(90% design completion is 100% - final design - for “Vendor Design-Build” procurement).	
Final Design Review (FDR)	Week of October 2-6 2023

→ **Magnet is ready for procurement at CD-3A date (expected January 2024)**

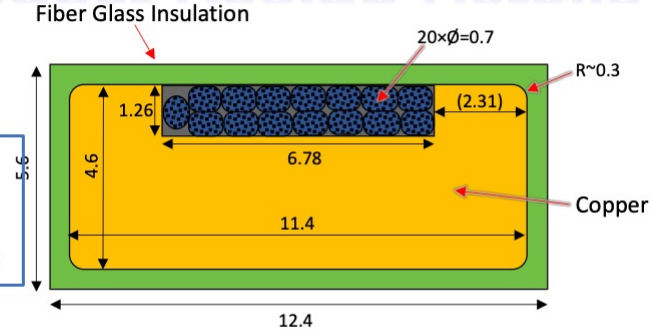
7

Not only the detector: the magnet ?

MARCO Magnet Design Details



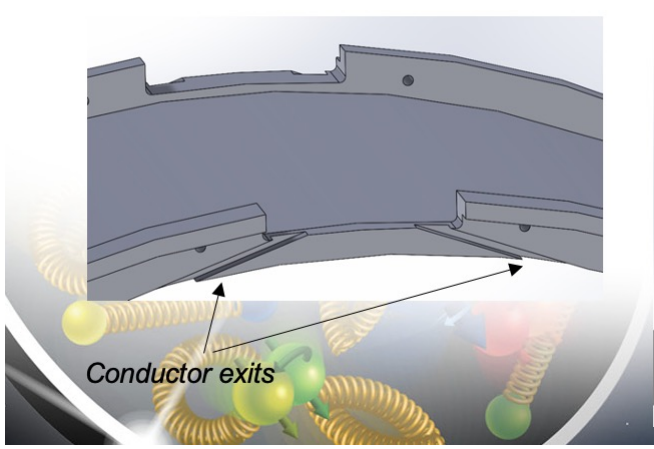
Coil is divided in 3 modules with 557 Turns each. This is done mainly to accommodate possible conductor length.

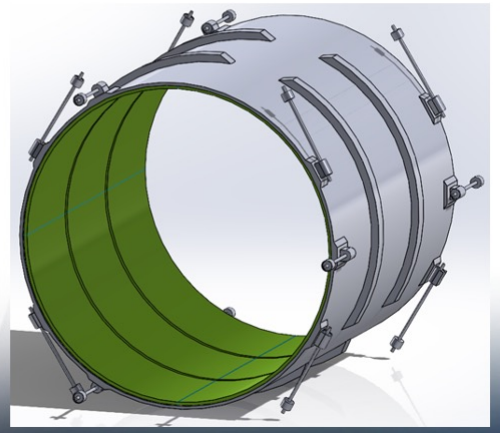


Conductor is based on CEA-Saclay experience as used for previous magnets

Conductor Dimensions are in mm

B_0	1.5 T	1.7 T	2.0 T	Units	
Current	2900	3296	3924	A	
B_{peak}	1.925	2.187	2.602	T	
Temp. margin	3.1	2.9	2.5	K	> 1.5 K
Load line margin	60.6	55.3	46.8	%	
$I / Ic(T_m, B_{peak})$	17.3	21.3	28.8	%	<30 %





The two most important design parameters are conservative: large temperature margin and large critical current margin

Mechanical analysis Ongoing

Potential involvement of an Italian excellence: ASG semiconductors

ASG SUPERCONDUCTORS

MAIN APP

ASG has sup
magnet for t

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ASG is currently manufacturing 4 of the 6 Poloidal Field Coils in Cadarache, as their diameter exceeds 24m. Currently the last PF coil is being completed.

HEP AND NUCLEAR FUSION

ASG
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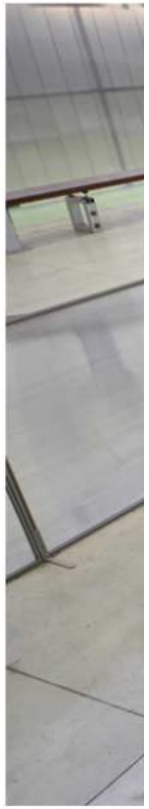
ASG is currently collaborating w
high field magnets for LHC High
"D2" and to the Future Circular Co



ASG has entered a framework contract for the recurrent supply of compact superconducting-cryogen free magnets for IBA's synchro-cyclotron for hadrontherapy. Such systems are now operating since more than a decade with guaranteed uptime.

What are doing INFN groups?

dRICH

FE TS LNF (RM1)

optics mechanics

radiators

aerogel

FE BA

pressurized Argon vs C_2F_6

FE LNS + BNL/JLab

photosensors

BO FE CS-SA-CT

SiPM

ALCOR

TO

LAPPD

GE TS

DAQ for dRICH

PV CS TO

SiTracker

BA TS PD

MAPS 65 nm technology

streaming readout

GE RM2

El. cal. @JLAB + TRIDAS

TS BA LNS SA + Duke + NISER

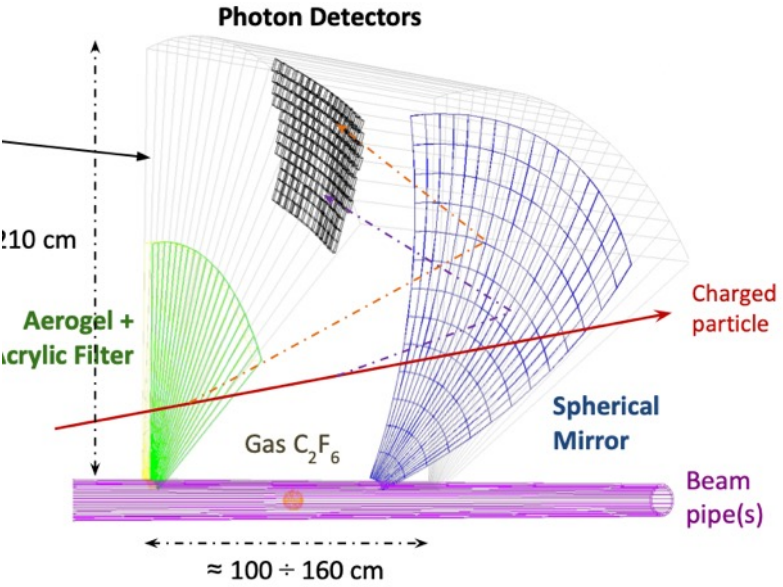
Simulation & computing

TS CT CS BA

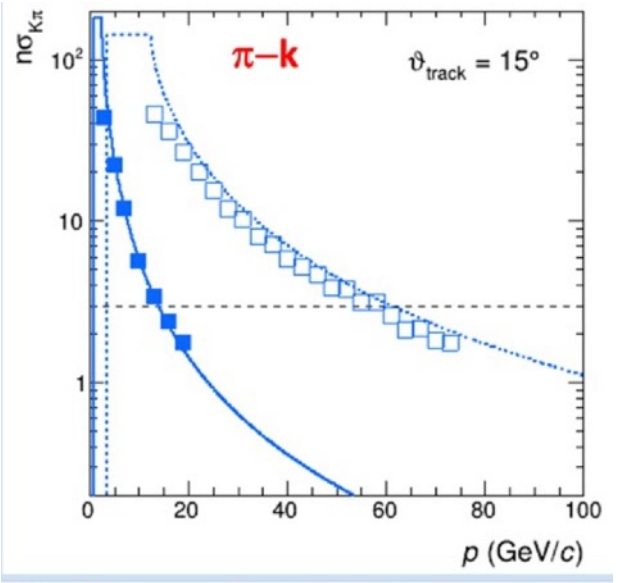
Physics (SIDIS, Exclusive tagging, diffractive, hadron spectroscopy and hadronization, ...)

Toward detector definition and optimization, simulation capacity will be key: a big working space for all our groups

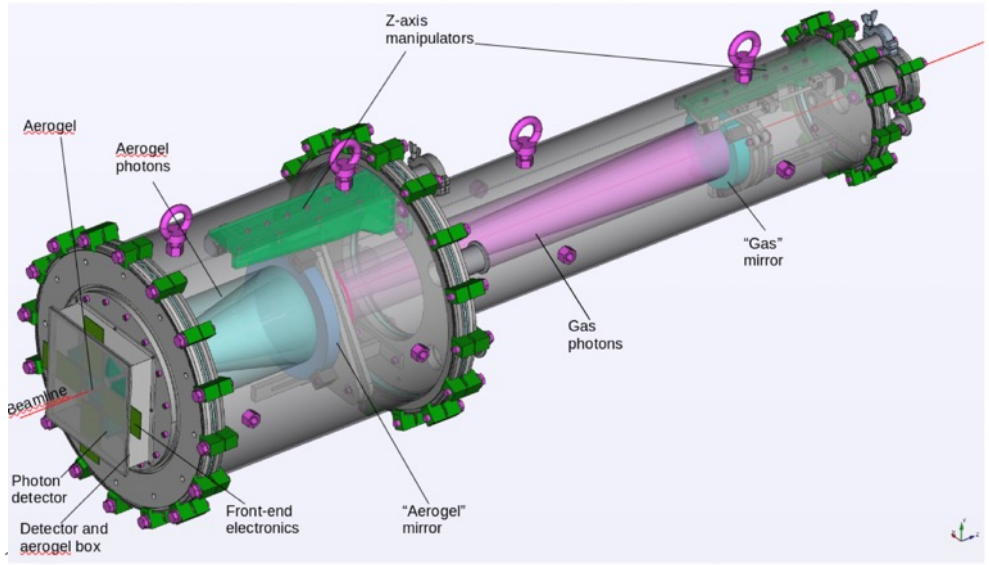
dRICH R&D: the idea and the main prototype

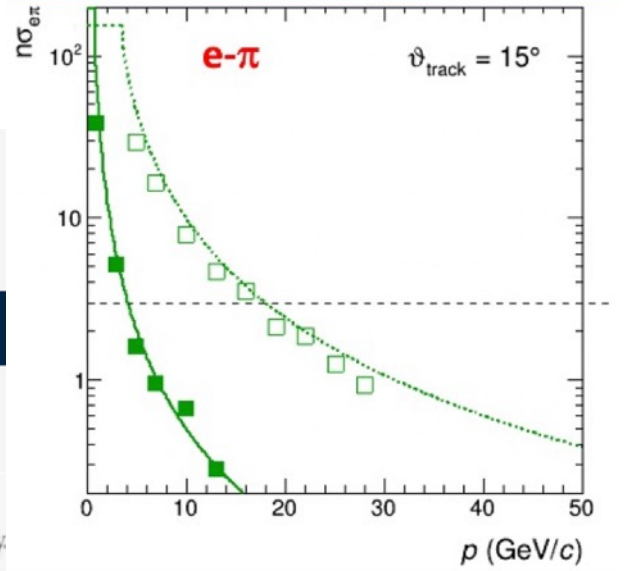


- hadron identification crucial for SIDIS
- radiators: Aerogel (n=1.02)/ Gas (n=1.008)
- 3 m^2 area, 3x3 mm^2 pixel
- SiPM (LAPPD) option for photosensors



dRICH "prototype" to study performance

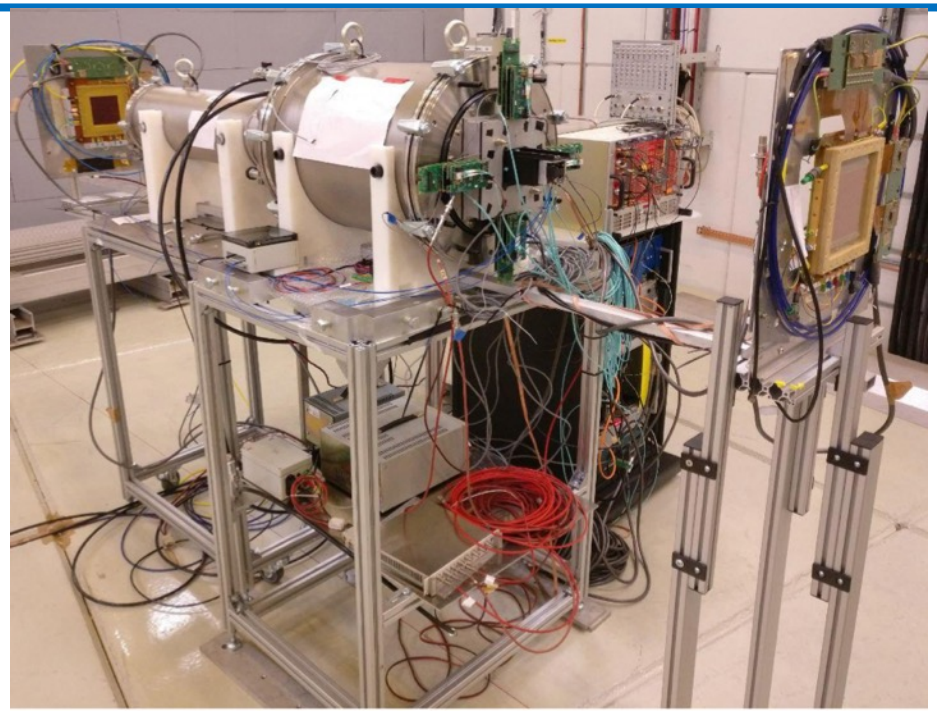


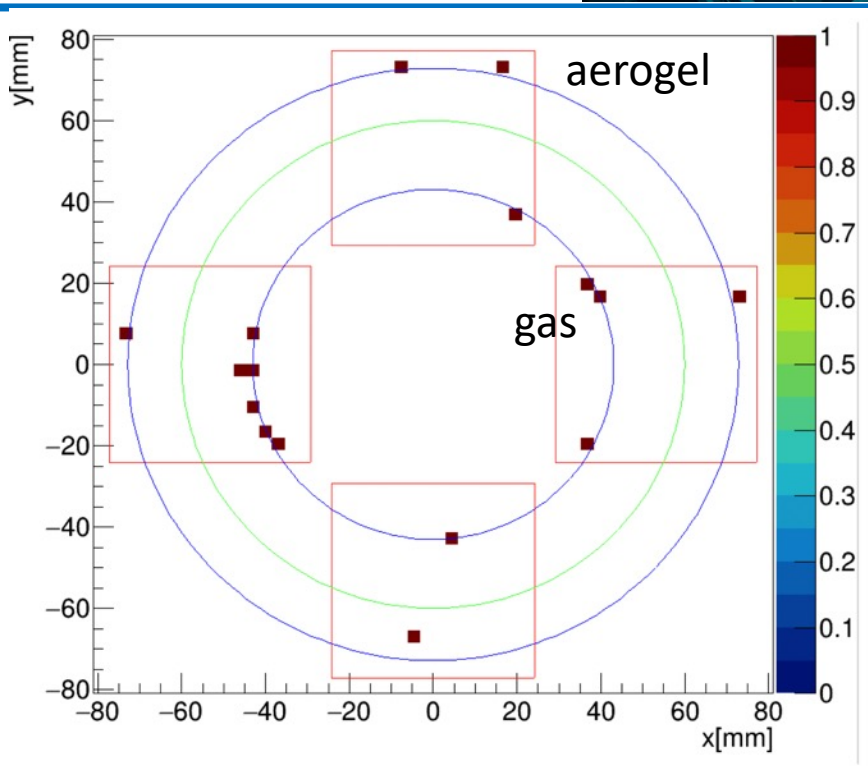


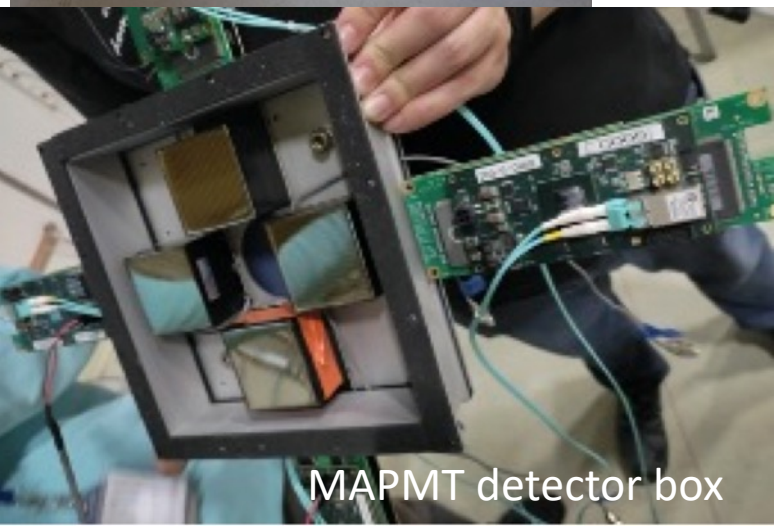
Building dRICH Collaboration
one of the 2023 tasks

Duke UNIVERSITY
NISER
Georgia State University
Stony Brook University

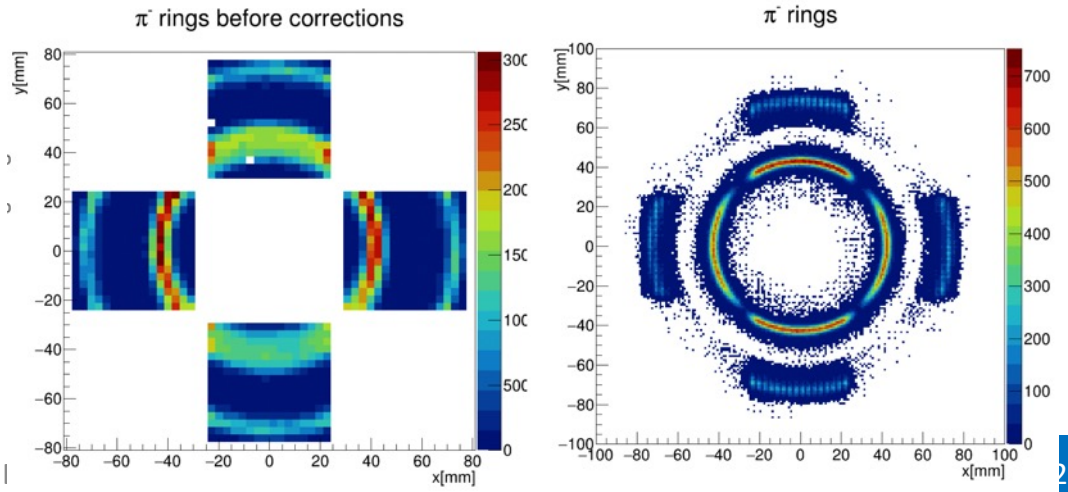
dRICH prototype 2021 @ test beams



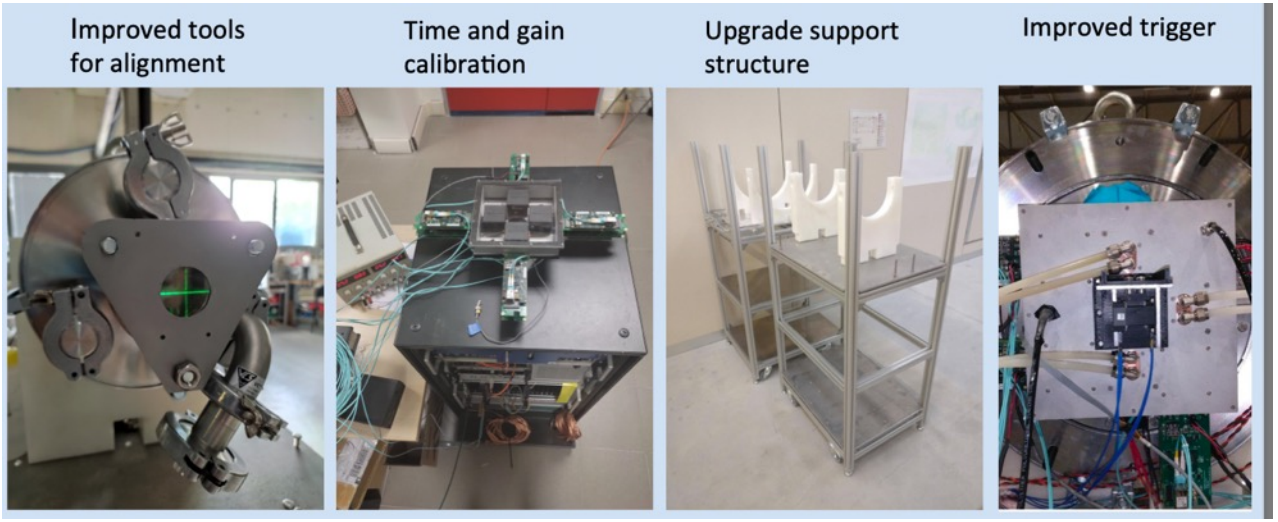




- Tracking with GEM
- Preliminary results on σ_θ resolution with aerogel and gas



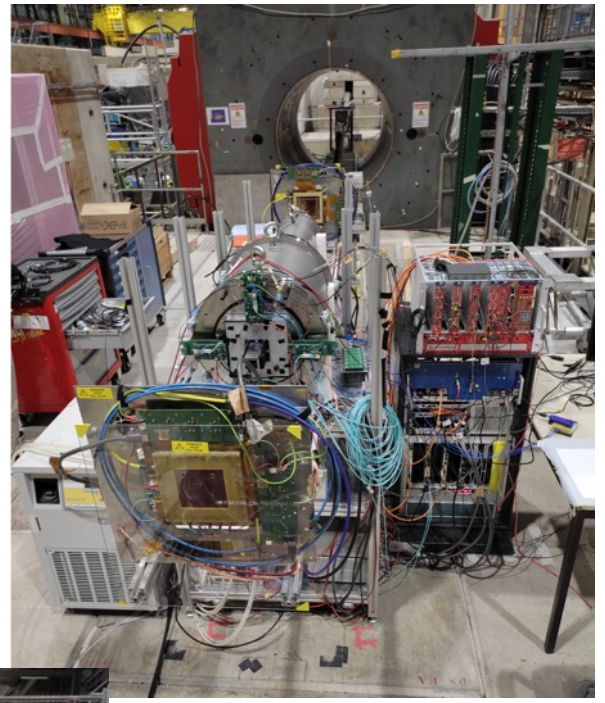
dRICH 2022 test beam campaign

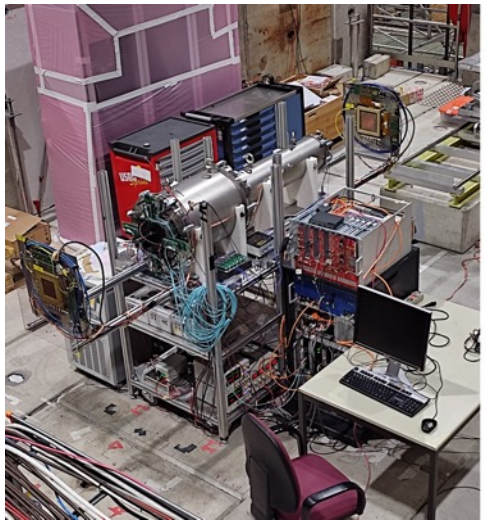


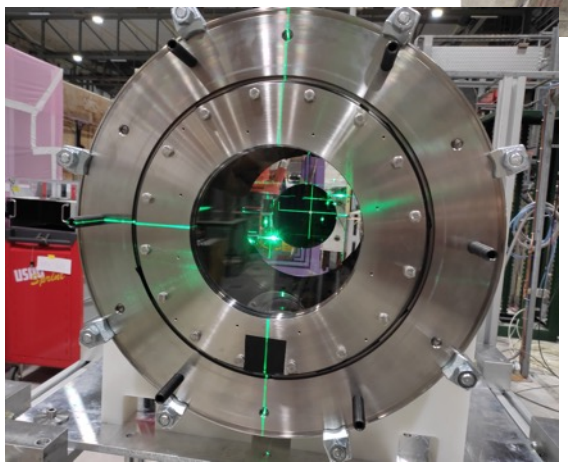
→ direct comparison between MAPMT and SiPM readout
→ Finalize resolution studies (in better controlled beam conditions)

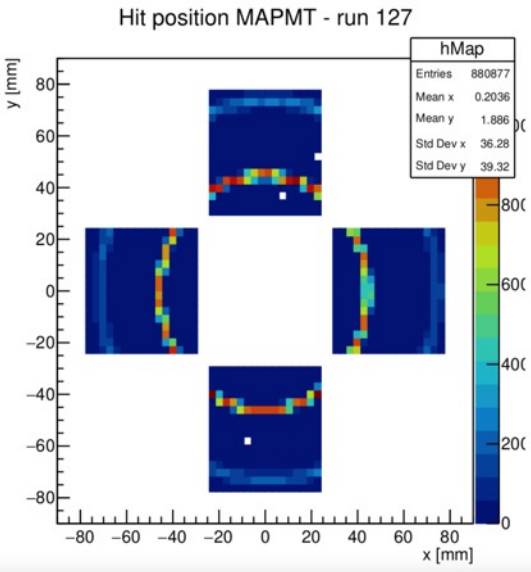
FE

Test @SPS and PS



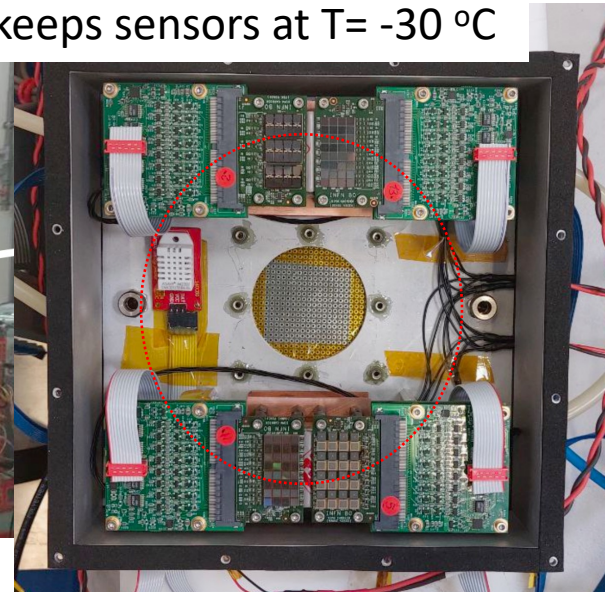






Bringing irradiated sensors on a dRICH (prototype)

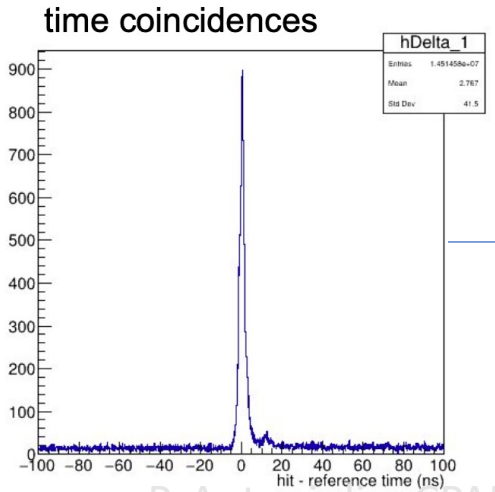
cooling keeps sensors at T= -30 °C



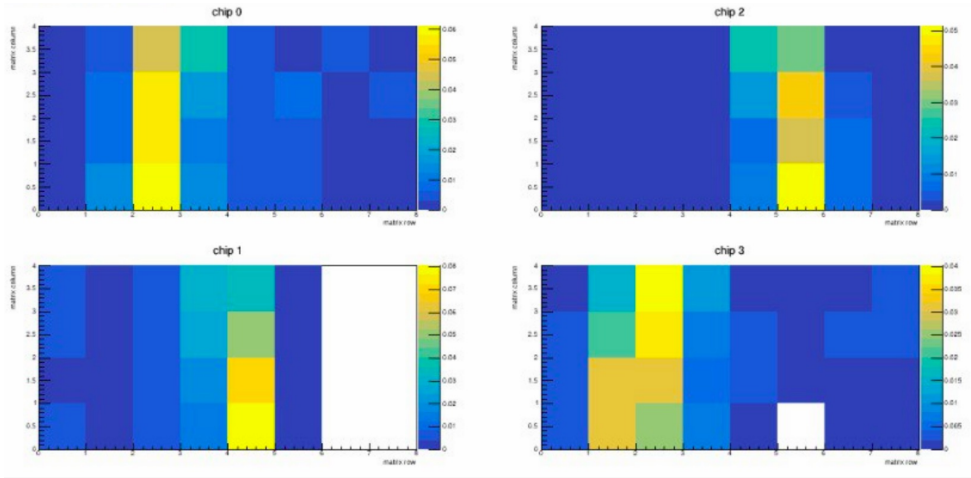
irradiated/**annealed** sensors

timing

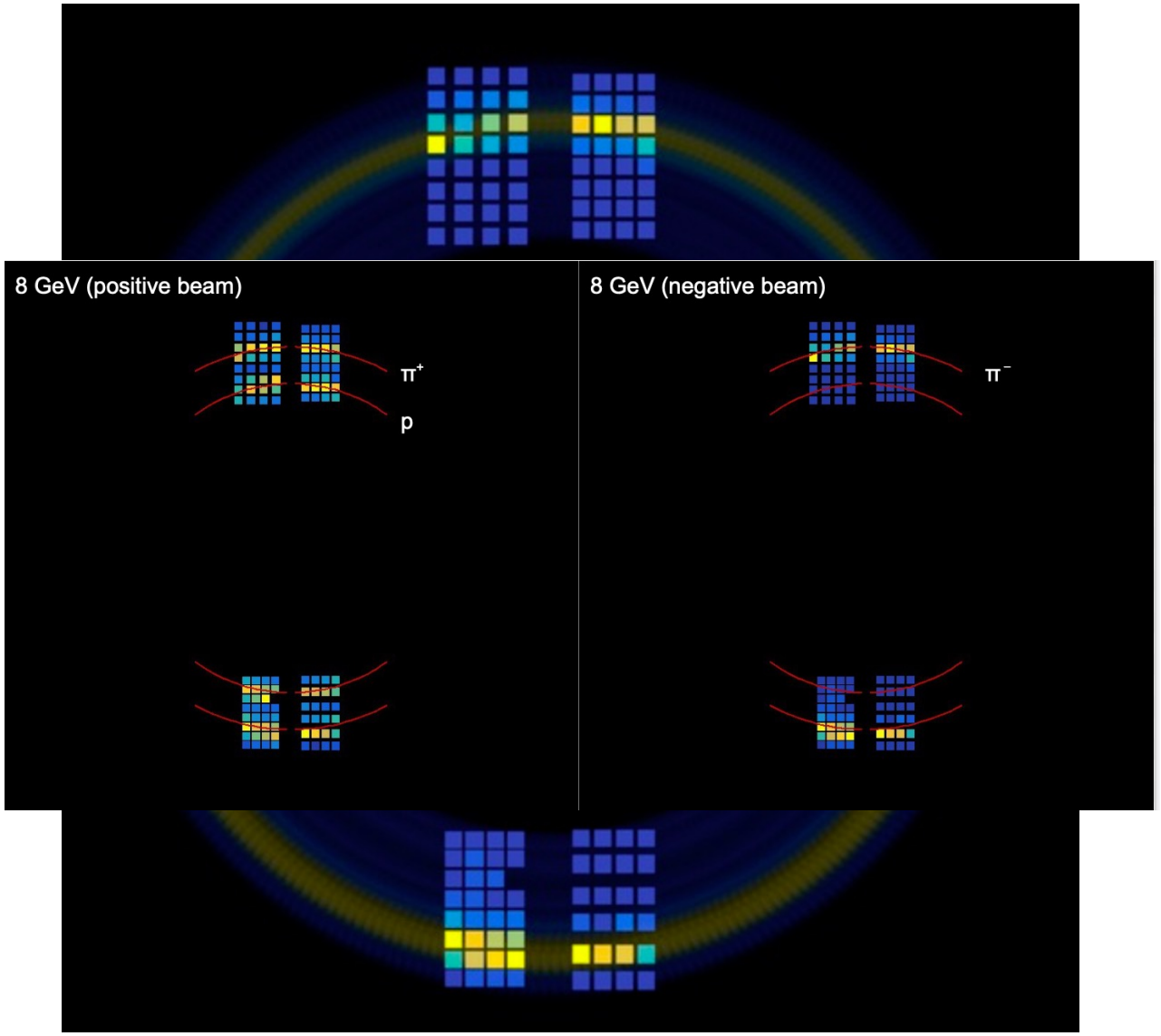
ALCOR streaming readout
time tagger with scintillators



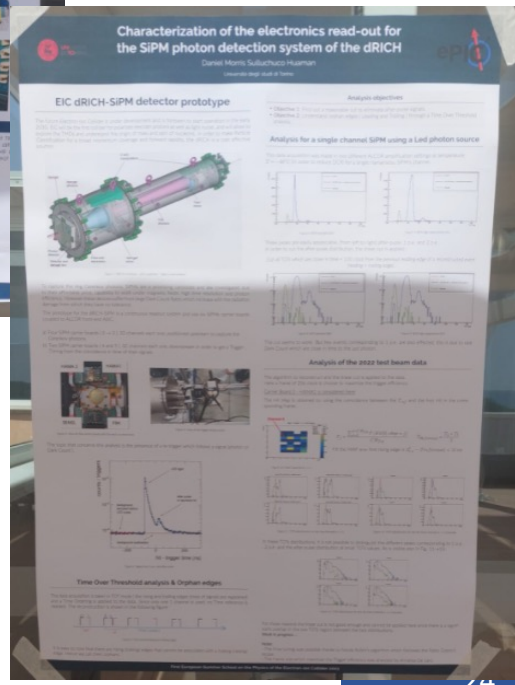
Cherenkov photons visible!



Irradiated sensors on test beam/dRICH prototype

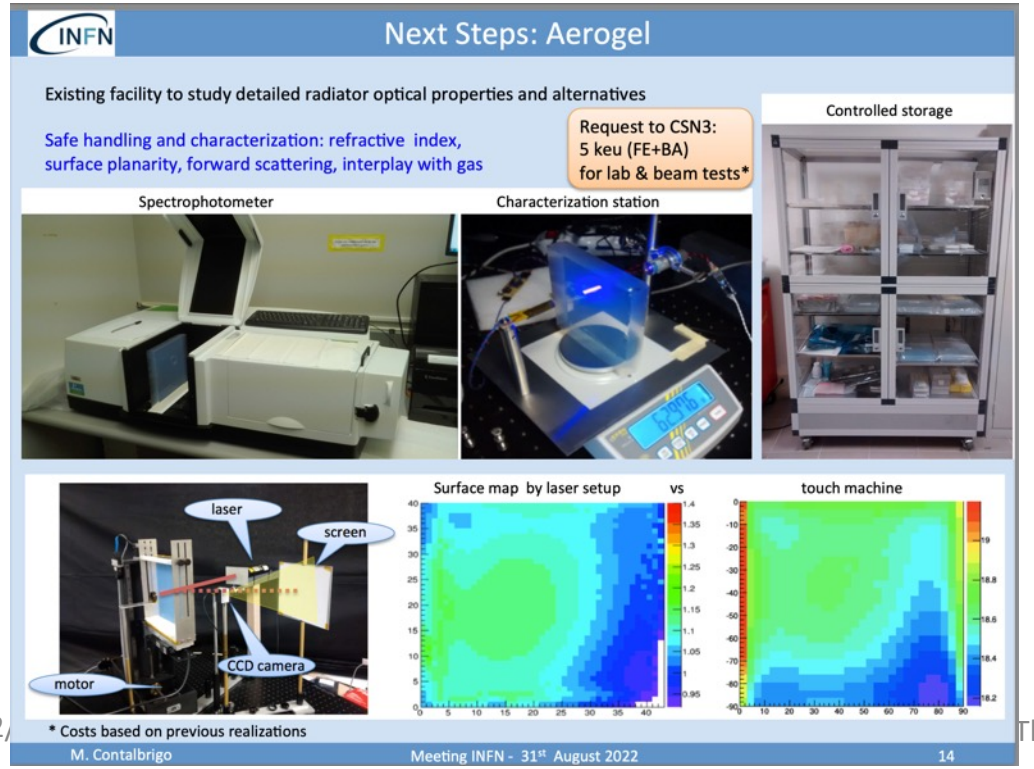


see also Daniel, Luisa and Nicola's posters



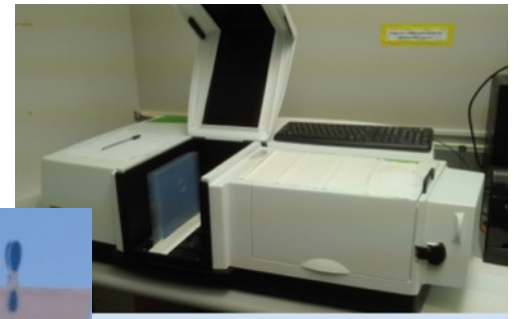
dRICH: the next steps (happening in 2023)

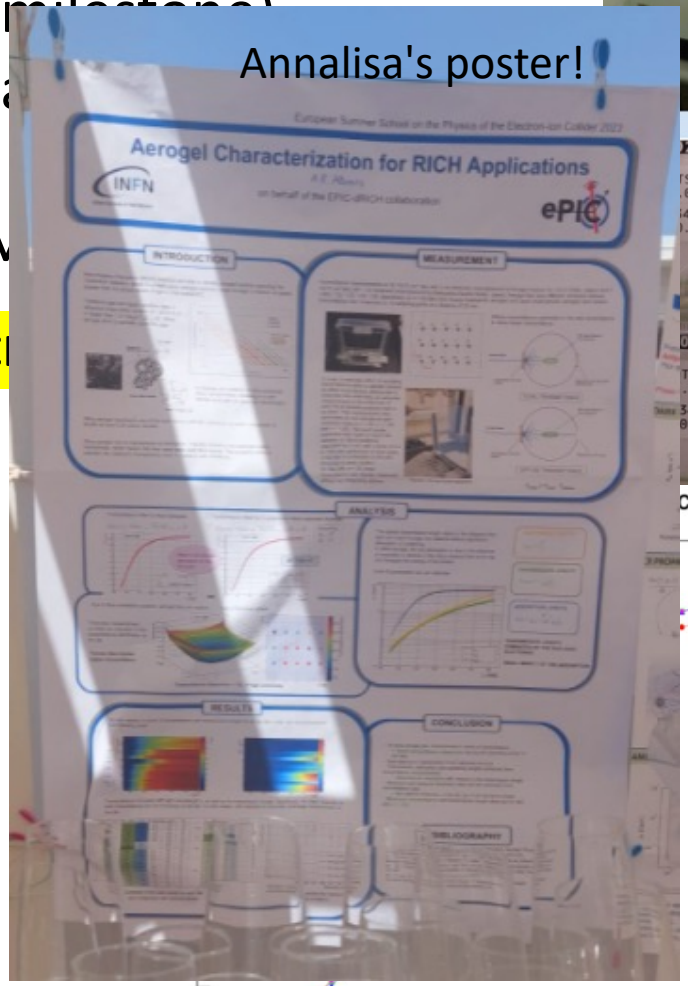
- Assess **Aerogel** producers (Aerogel Factory – Japan and Aspen USA, no longer Budker availability [Russia!])
- Equip dRICH prototype with **SiPM plane** (eRD102 mi
- Explore the **pressurized-Argon option** (as gas repla GPW: 11100!)
- Explore **mirror** options (preferred: carbon fiber CM



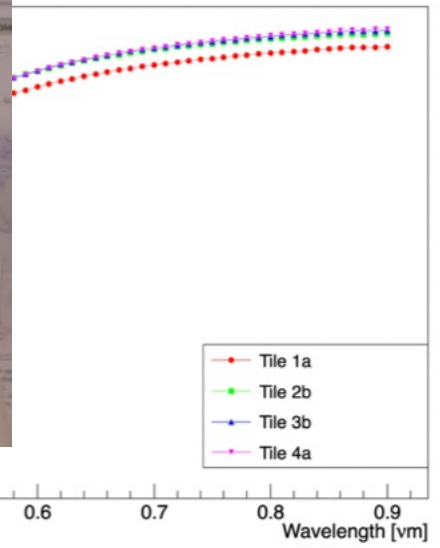
Synergy with ALICE

FE BA

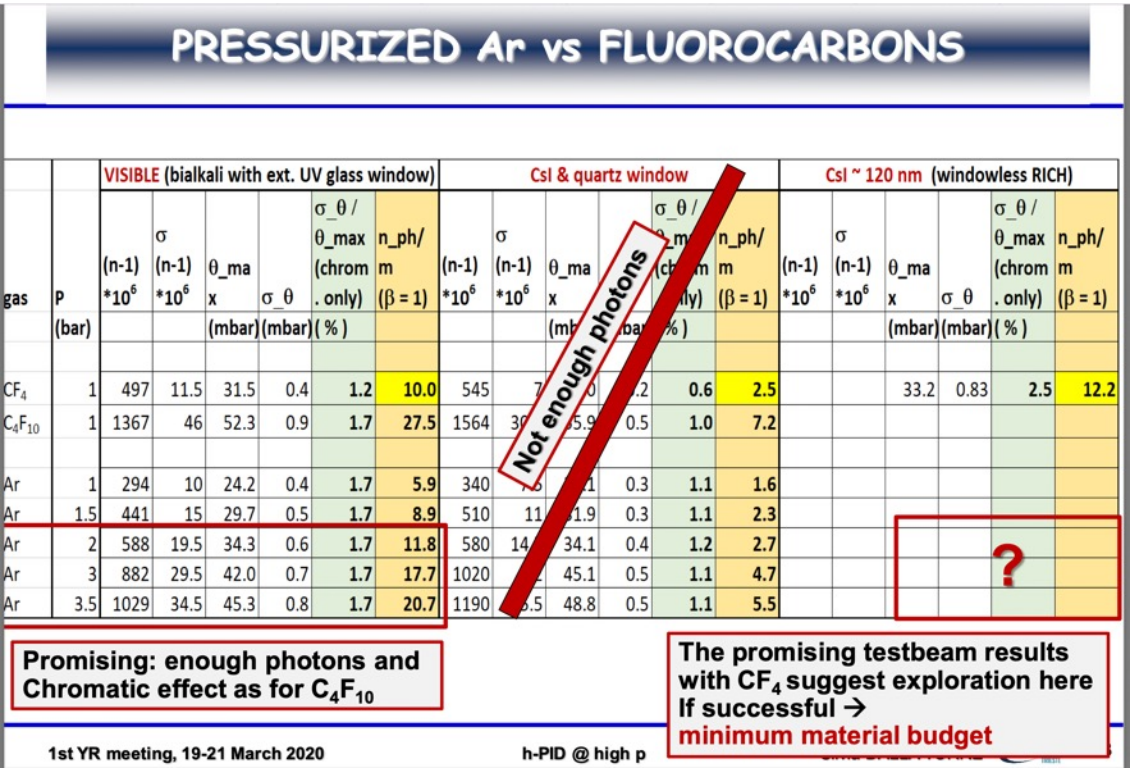




ce of all tiles



Pressurized-Ar vessel



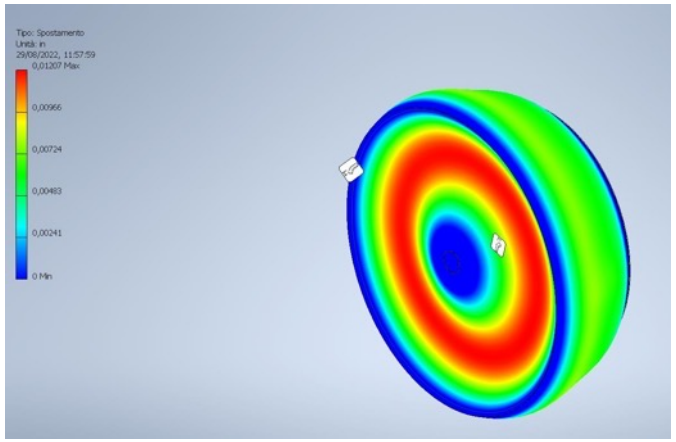
Original idea discussed by S. Dalla Torre at first YR meeting (March 2020)
https://indico.bnl.gov/event/7449/contributions/35912/attachments/27095/41303/DallaTorre_RICH_high-p_March2020_Temple.pdf

Increase Ar pressure to increase number of photons

Identified material (DuPont® Nomex® 410) in carbon – fiber + honeycomb

First prototype to evaluate FME: to be delivered now

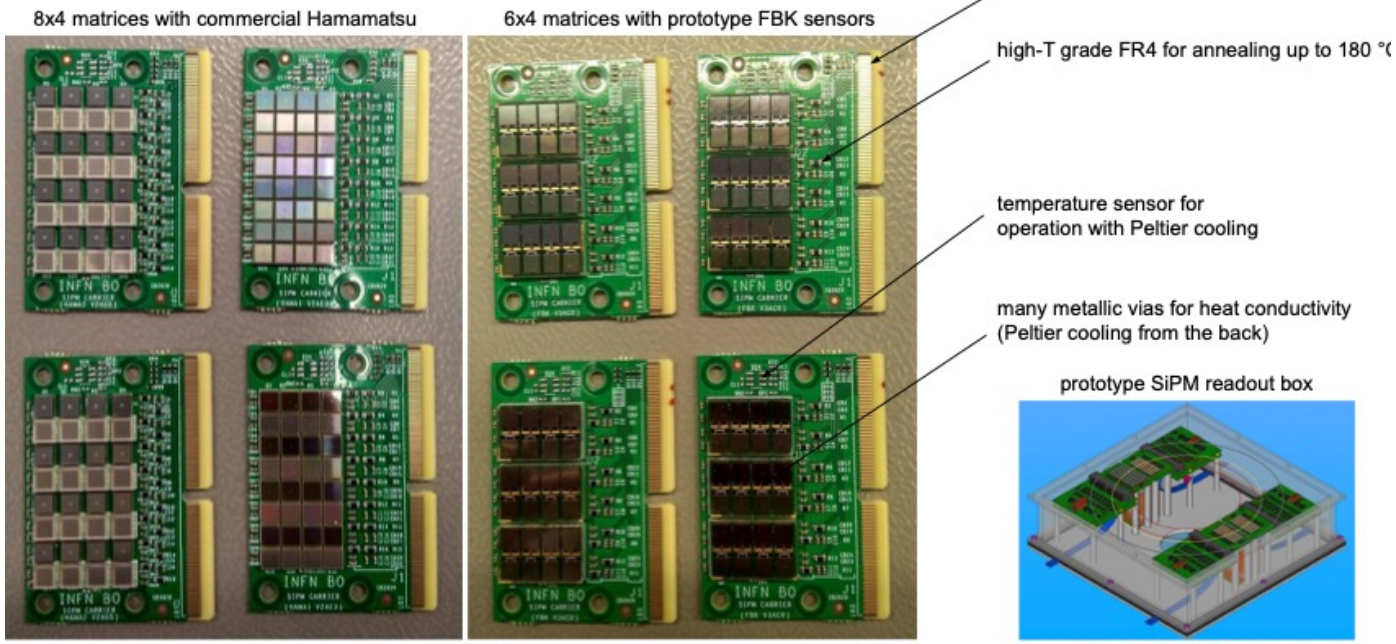
A sector protoype?



FE / LNS + BNL/Jlab

SiPM: radiation tolerance studies and FEE

SiPM custom carrier boards



withstand irradiation, high-T annealing and low-T operation in form-factor usable in beam tests

BO FE CS SA CT

Readout via ALCOR (candidate ASIC for SiPM readout)

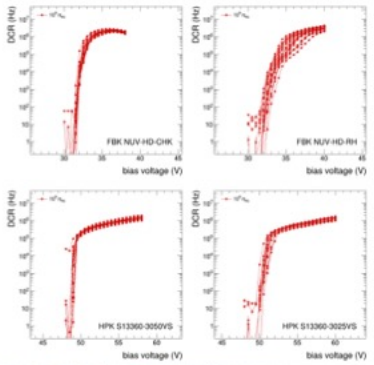
ALCOR v2:
- Just delivered to us
- Will be used in 2023

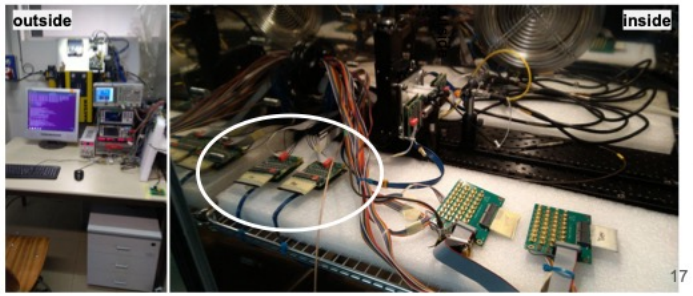
TO

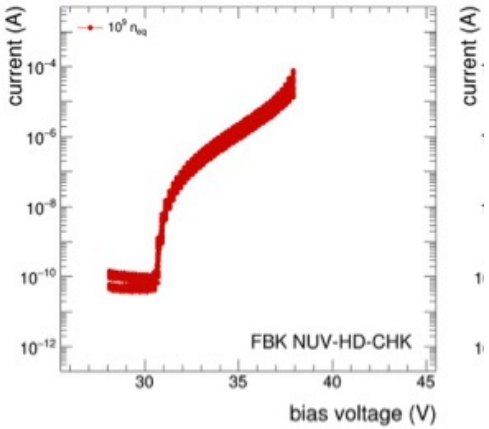
Setup for SiPM characterization

DCR measurements

- **climatic chamber**
  low-temperature operation
  all reported measurements at T = -30 °C
- **2x ALCOR-based front-end chain**
  automatic measurement of 2x SiPM boards (64 channels)
- **FPGA (Xilinx) readout**





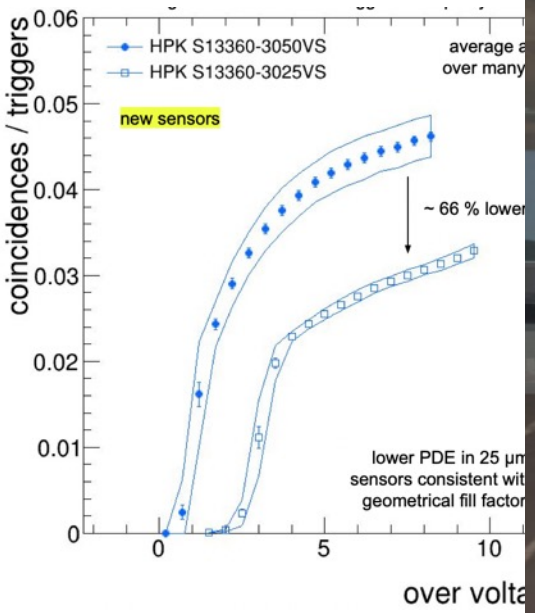


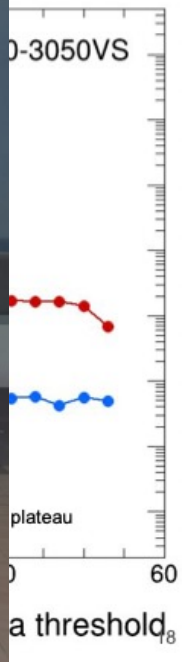
BO FE CS SA CT

- DCR
- I-V
- Pseudo-efficiency (with LED): integrated coincdence/triggers as proxy

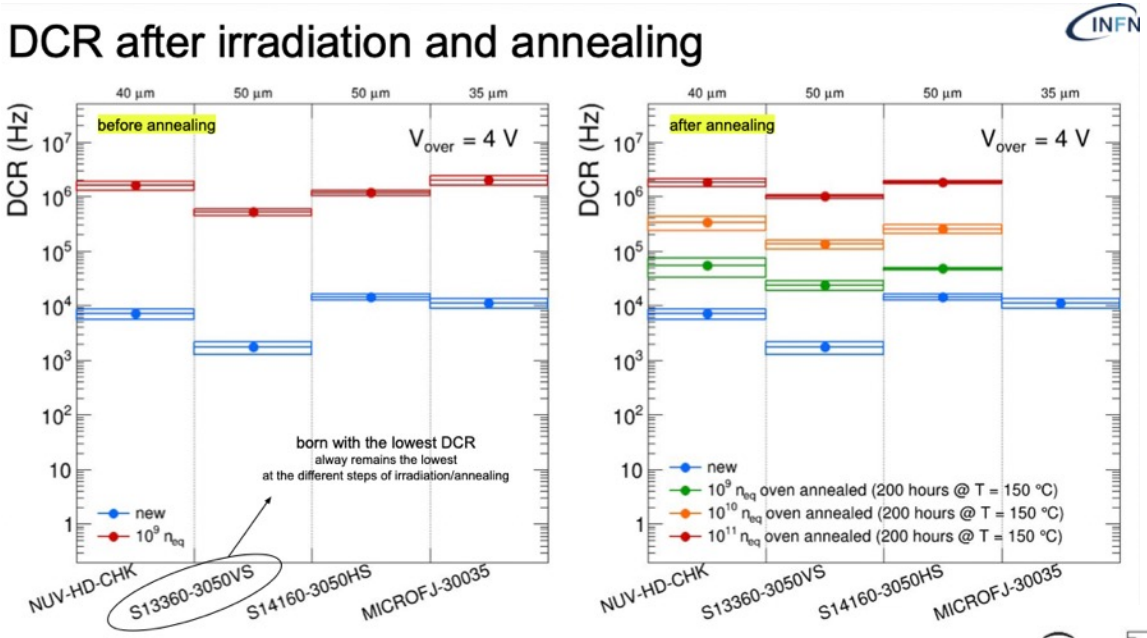
Next steps (will be reported tomorrow)

- Laser measurement
- Local Cooling (SiPM





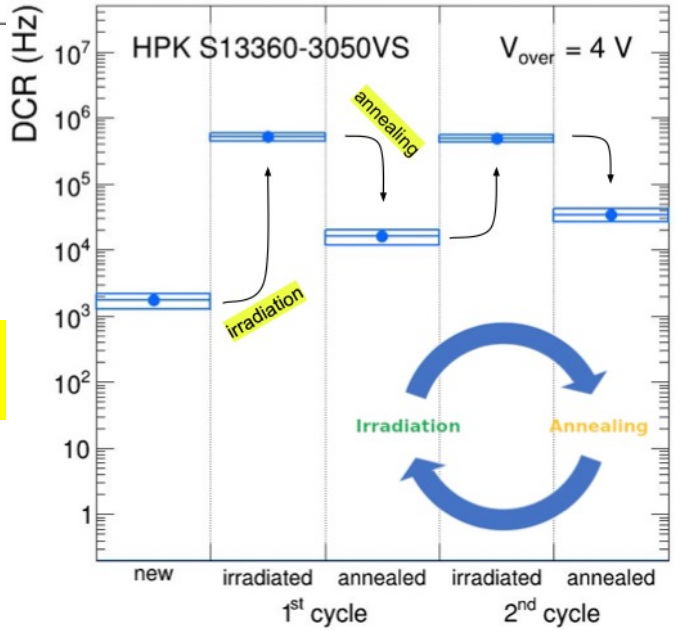
Some results on irradiation campaigns

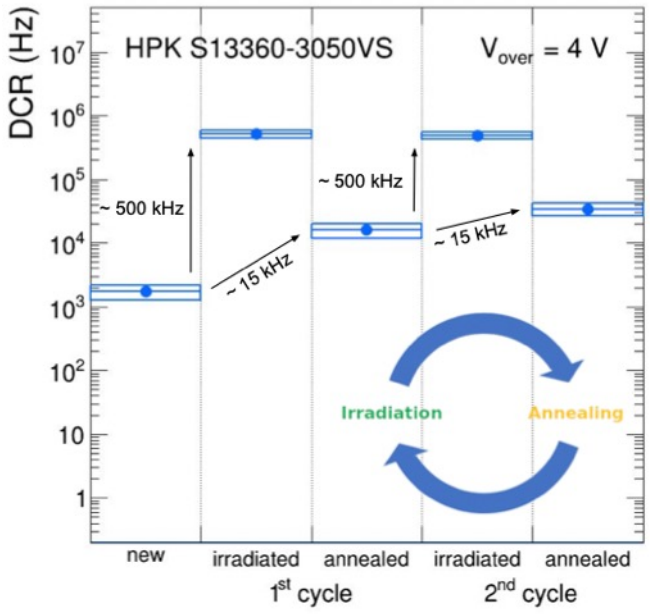


Irradiation at Centro di Protonterapia @ Trento
2021 campaign: irradiation at different levels + 1 annealing cycle
2022 repeated (small) irradiation and annealing cycles

Next steps:
- Complete 2022 campaign (Nov/Dec)
- Investigating effects with neutron source at LNL
- Use data to model annealing cycles in the experiment (pre-TDR!)
- Timing analysis with laser
- "dRICH cooled tile" possibly going to -40 C (or -50 C) **[LHCb synergy]**

Next steps:
- Investigating ALCOR capabilities in gated mode
- Preparing for ALCOR v3
- Test methodology for in-situ annealing
- Bring on board "Southern Italy cluster" CS-CT-SA





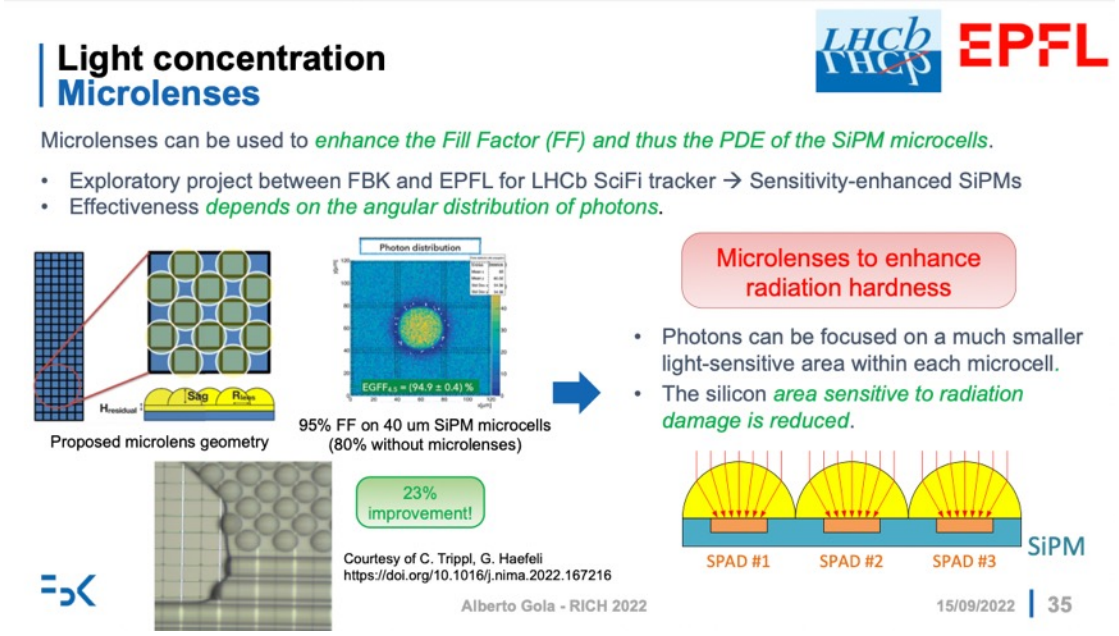
Run with FBK?

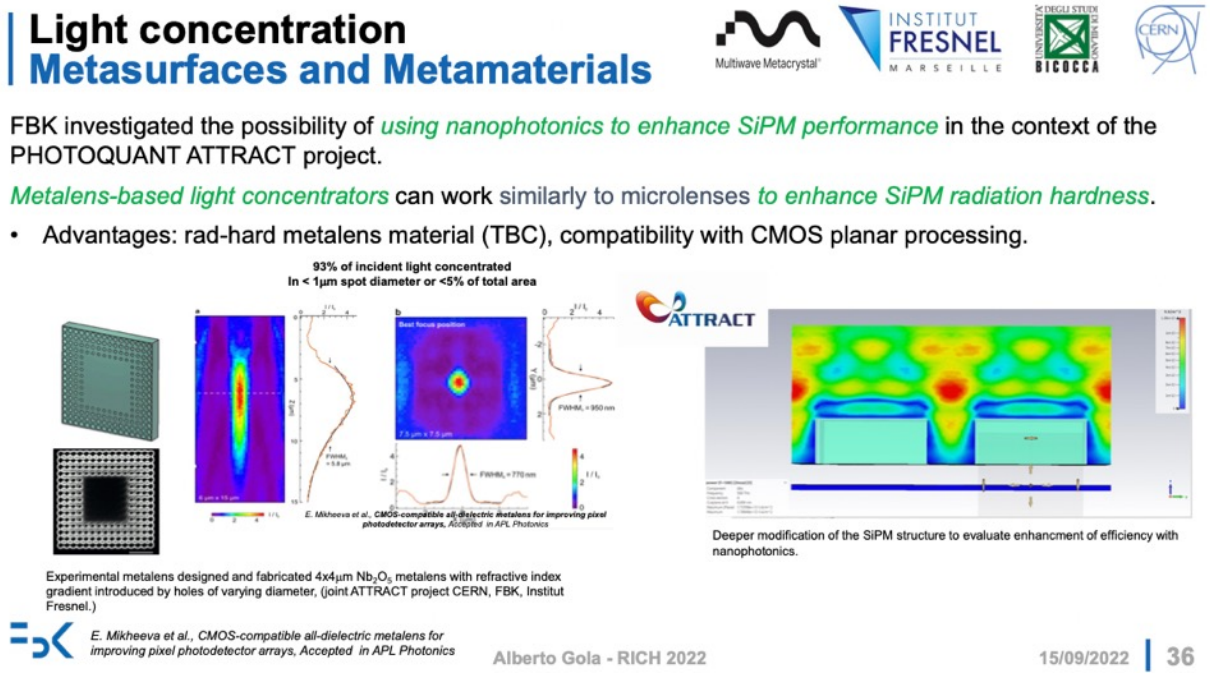
Agree with FBK a devoted run (under convenzione INFN-FBK) to explore:

1. Improvements on DCR standard rate [“optimization”]
2. Development of monolithic mini-tiles (2x2 or 4x4) to optimize geometrical acceptance
3. Light concentration (microlensing or nanophotonics approaches)

A successful run with FBK might be “win-win” operation for TDR/CD-3

Note recently released results from FBK, A. Gola @RICH2022

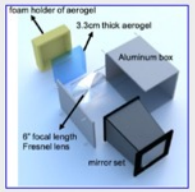




LAPPD / HRPPD

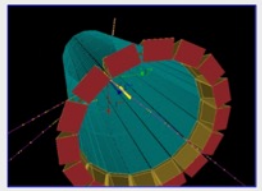
OVERWIEW dei sensori di singolo fotone per PID a EIC

Backward: mRICH
Proximity focusing aerogel RICH with Focalisation by Fresnel lenses



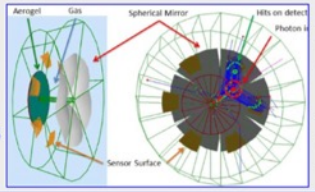
mRICH: fotosensori
- **SiPM** (validazione del principio, livello radiazione?, materiale per il cooling, hit rate in streaming read-out)
- **LAPPD** (campo B, intensita' e allineamento)
  - Offrirebbe in parallel misure di TOF

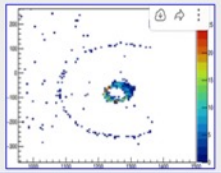
Barrel: high-performance DIRC
Focusing DIRC with lenses



hpDIRC: fotosensori
- **MCP-PMT, Photonis** (come in PANDA, allineamento campo B, costo!)
- **LAPPD**, se validati !

dRICH
2 radiators: Aerogel & gas





dRICH: fotosensori
- **SiPM** (validazione del principio, hit rate in streaming read-out)
- Backup: LAPPD, se validati !

31/8/2022 S. Dalla Torre

- SiPM and LAPPD validation would make PID@EIC "safe"
- LAPPD are "large size" MCPs at moderate cost
- Large gain and low noise, uses ALD to increase lifetime
- INCOM → spin-off of Argonne + Chicago Univ.
- Strips readout, prototypes available with capacitive coupling (pixelated version)

The table of candidate photosensors

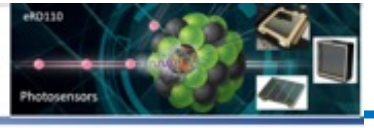
	MCP-PMT/Planacon 	SiPM 	LAPPD 
Area	5x5 cm²	Tiles available 5.76 cm²	20x20 cm²
Pixel		3x3 mm²	25 x 25 mm available → 3x3 mm in future?
Magnetic field	Seen drop in collection efficiency at angle > 10 deg	insensitive	0.7 T on 20 µm MC seems ok, depending orientation. Smaller MCP's for larger field
Radiation	insensitive	needs test + assess mitigation protocol (annealing)	No data, but reasonable to expect not a problem
Availability	In stock*	In stock*	"In-stock" for 20 µm
Manufacturers	Photonis/Photek	many (HPK, OnSemi, FBK/L-Foundry, Ketek/Boradcom)	Incom
Price	$ 15-20 k$ each (few units)	1 k$ /(8x8 tile 3x3 mm)	$25-50K each LAPPD (20x20 cm² or 10x10 cm² similar price)
Unit price	16 k$/25 cm² = 600 $/cm²	≈50-100 $/cm²	62.5-500 $/cm²
Concerns	cost	DCR increase with radiation	Cross talk, integration, availability
Risks	None	None if mitigation of DCR increase "manageable"	Achievable with risk, time schedule challenging

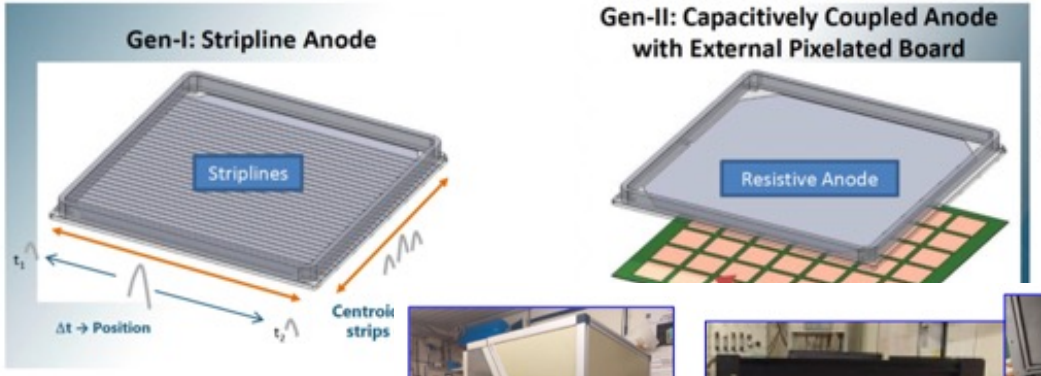
8 June 2022 P. Antonioli - eRD110 5

- LAPPD R&D kept "open" for dRICH (plan B if SiPM is not validated). Strategic for INFN to achieve know-how on this sensor. GE TS
- Large interest in the community. First LAPPD workshop on 21 March 2022 by INFN TS, BNL and ANL https://indico.bnl.gov/event/15059/

S. Dalla Torre, Meeting with INFN referees

LAPPD R&D highlights

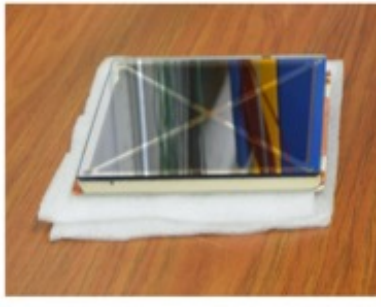




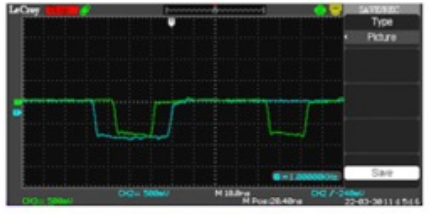
capacitively coupled allow user flexibility for pixelation
better spatial resolution expected
timing resolution preserved

"from one photon – one hit to a multi-pixel cluster"

2021 results in US



Initial dark-box; then, optimized dark-box modified to improve light-tightness and operative needs



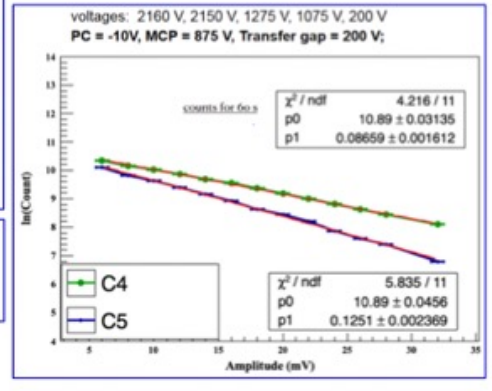
Single photoelectron condition using a pulse LED

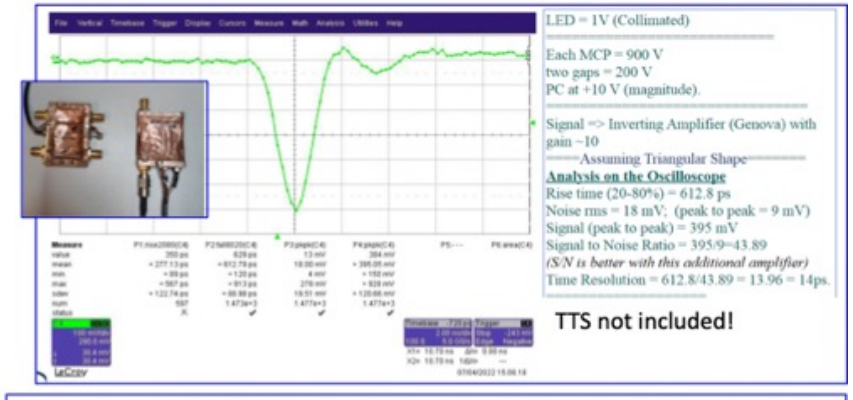
(see for more info the recen
May 22-28, 2022, La Biodola
https://agenda.infn.it/event/22092/

8 June 2022

Setup lab in TS, joint effort with GE (readout) in 2022!

Example of dark-pulse signal and studies of the dark-pulse rate

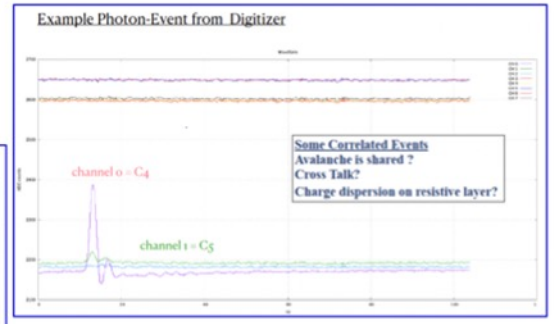




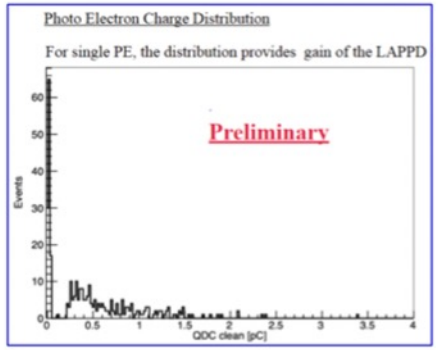
TTS not included!

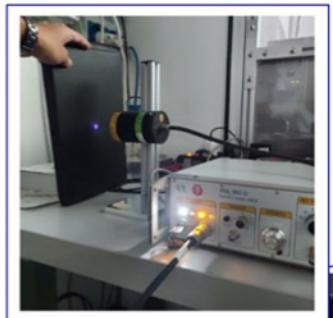
Using the pre-amplificator: signal analysis at the scope

Starting activities in 2022 and next steps



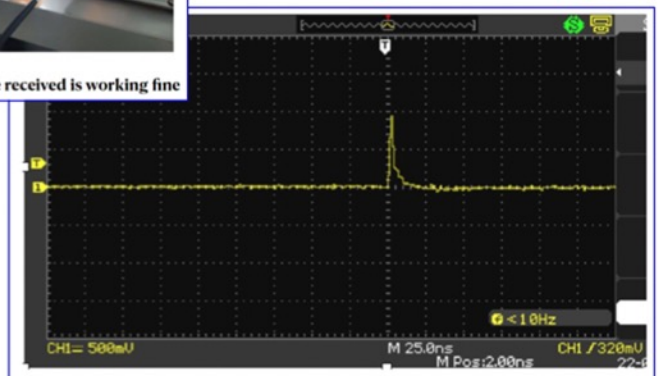
First exercises with the digitizer





The LASER as we received is working fine

Getting familiar with the new head (405 nm) of the PICOQUANT pulsed laser source



A pulse from the LAPPD with the LASER incident on it

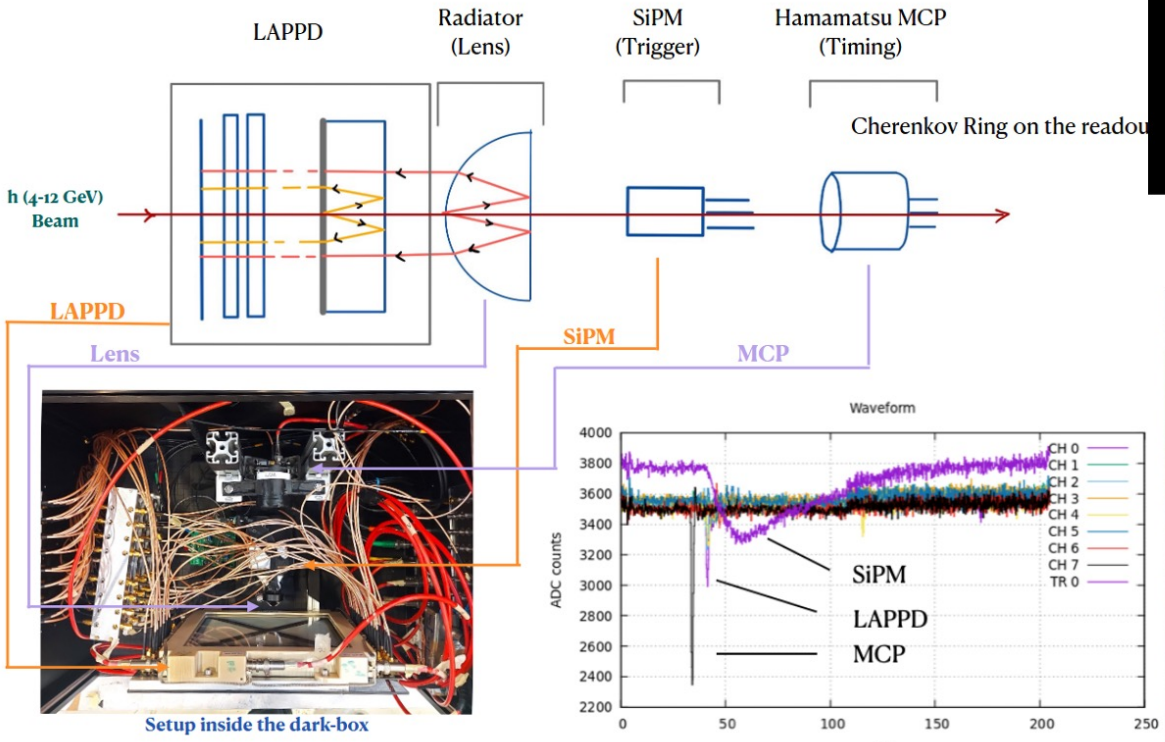
Next steps

- Time resolution measurements at test beam
- Space resolution measurement in the lab (existing laser, needed motor stage)
- Test variation of gain/efficiency in magnetic field → test planned in US and in Italy

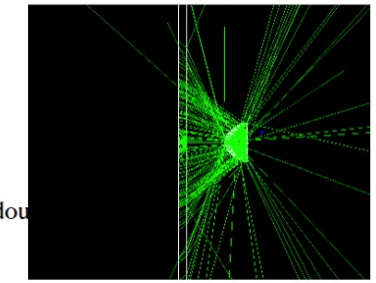
CERN test-beam (October 2022)

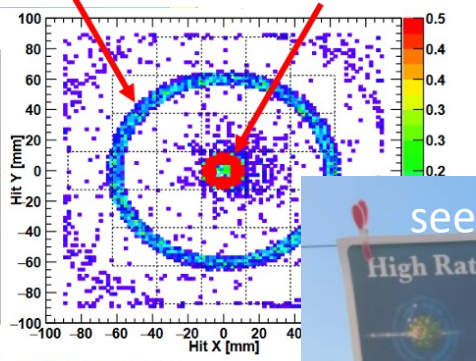
Goal: **Measuring the Single Photoelectron time resolution of the LAPPD**

Overview of the Test beam setup — Illustrative Schematic: NOT TO SCALE

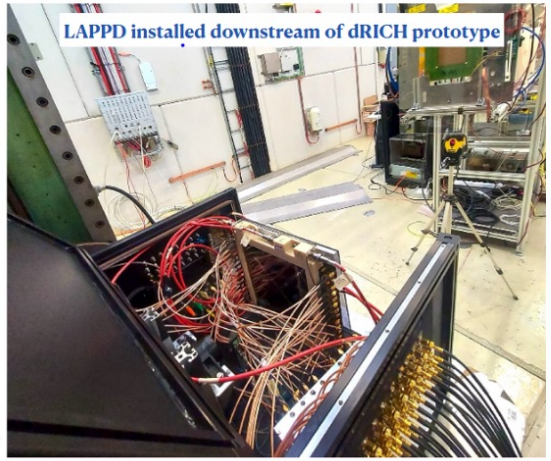


backward reflection

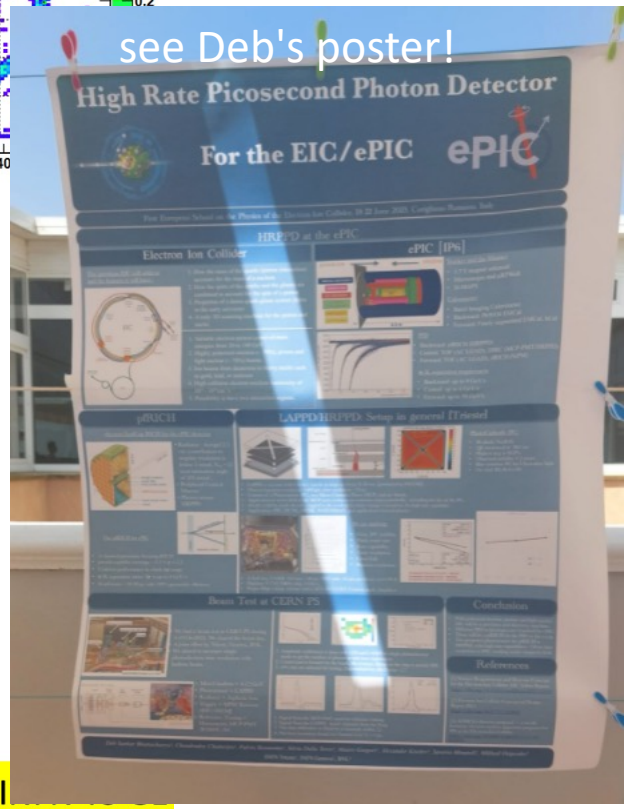




Geant4 simulatons



see Deb's poster!

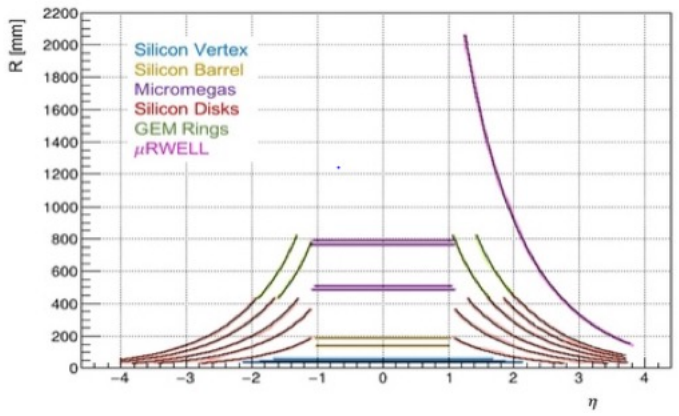


BNL, Incom Inc., I

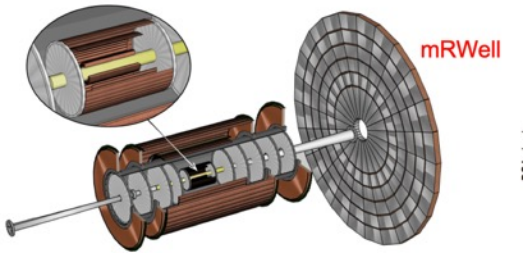
Silicon tracker (vertexing)

In both initial detector proposals (ATHENA and ECCE) "ITS3" MAPS ALICE technology selected

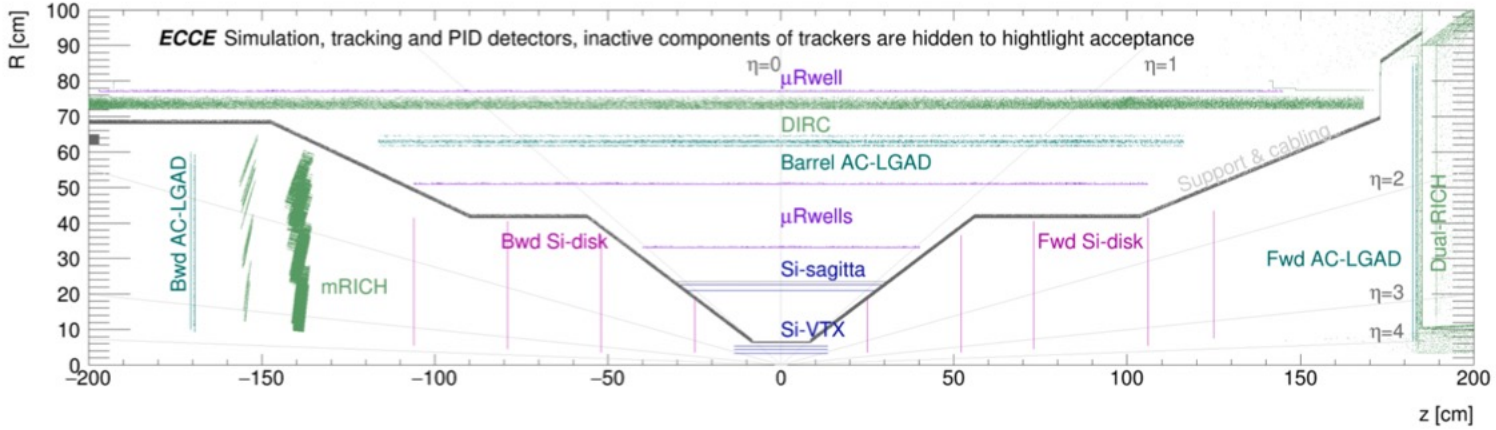
ATHENA



- Si Vertex Tracker: 3 layers (R_0~33mm)
- Si inner barrel Tracker: 2 layers
- 5+6 Si Tracker disks (including GEMs)



ECCE



✓ vertex layers:

adopt ALICE ITS3 65 nm CMOS monolithic sensors and ITS3 detector concept

→ crucial interaction with ALICE ITS3 Project to access the technology

✓ sagitta layers and disks:

create a smaller version of the ITS3 sensor

develop EIC-dedicated support structures and cooling infrastructure

Silicon tracker (vertexing)

BA PD TS

ALICE ITS3 sensor and detector concept:

- three layers vertex detector with 0.05% X_0 per layer

Wafer-scale, low-power sensor design in 65 nm CMOS technology, thinned and bent around the beampipe

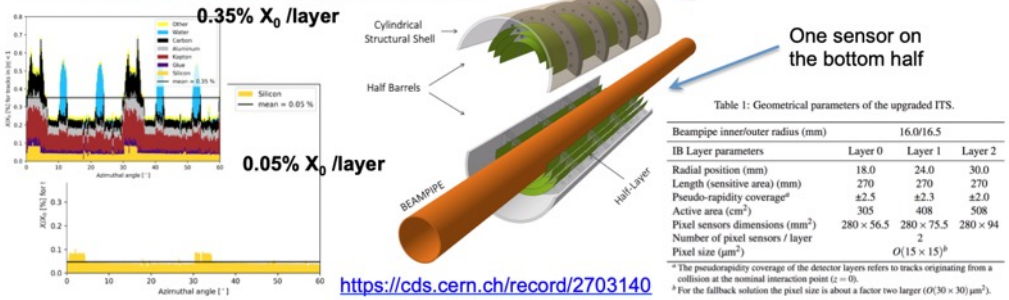


Table 1: Geometrical parameters of the upgraded ITS.

Beampipe inner/outer radius (mm)		16.0/16.5	
IB Layer parameters	Layer 0	Layer 1	Layer 2
Radial position (mm)	18.0	24.0	30.0
Length (sensitive area) (mm)	270	270	270
Pseudo-rapidity coverage[a]	±2.5	±2.3	±2.0
Active area (cm^2)	305	408	508
Pixel sensors dimensions (mm^2)	280 × 56.5	280 × 75.5	280 × 94
Number of pixel sensors / layer		2	
Pixel size (μm^2)		$O(15 \times 15)$[b]	

[a] The pseudorapidity coverage of the detector layers refers to tracks originating from a collision at the nominal interaction point ($z = 0$).
[b] For the fallback solution the pixel size is about a factor two larger ($O(30 \times 30)$ μm^2).

https://cds.cern.ch/record/2703140

INFN EIC groups working on EIC Silicon vertex:

- are active members in ITS3/ALICE: access to 65 nm technology
- R&D activities within ITS3 / ALICE so far
- + work in EPIC tracking WG → “stitched sensors” scheme for EIC (see next slide)

R&D for ITS3/EIC in Bari and Trieste (III)

Assembly procedure:

- done using dummy sensors so far

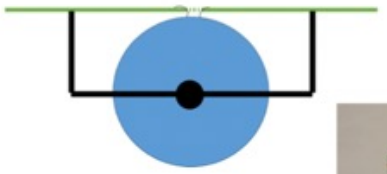
→ assembly with working sensor in September-October

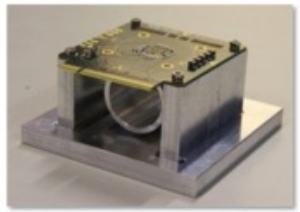
R&D for ITS3/EIC in Bari and Trieste (IV)

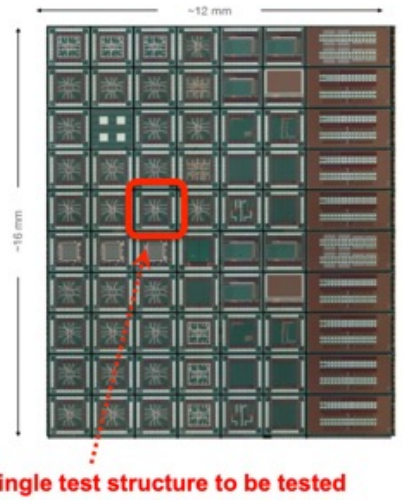
MLR1 test structure characterization:

- MLR1 bending tool development in Trieste

Bent chip support tool





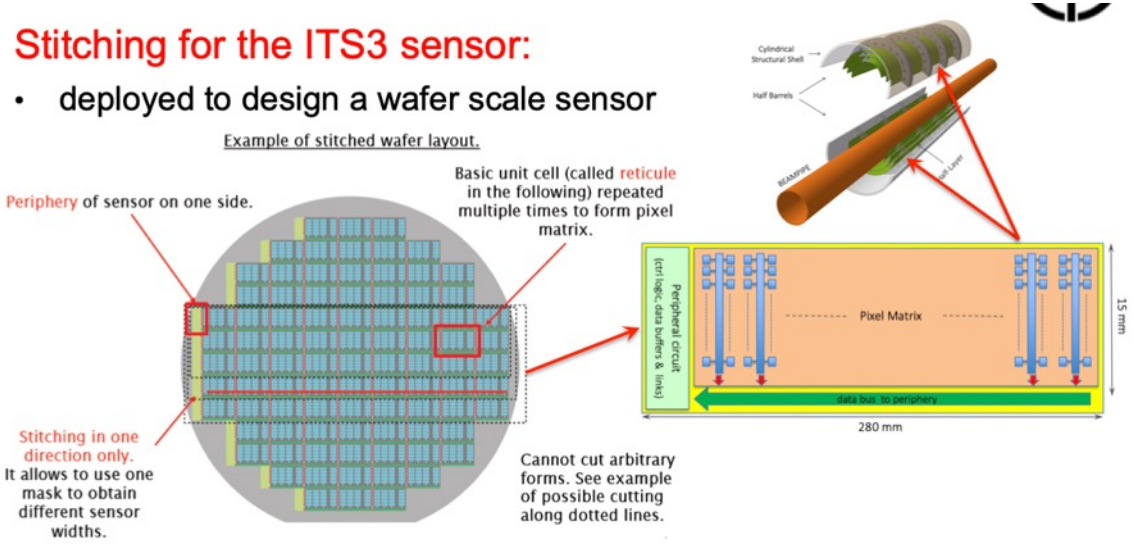


Single test structure to be tested

Silicon tracker (vertexing)

Stitching for the ITS3 sensor:

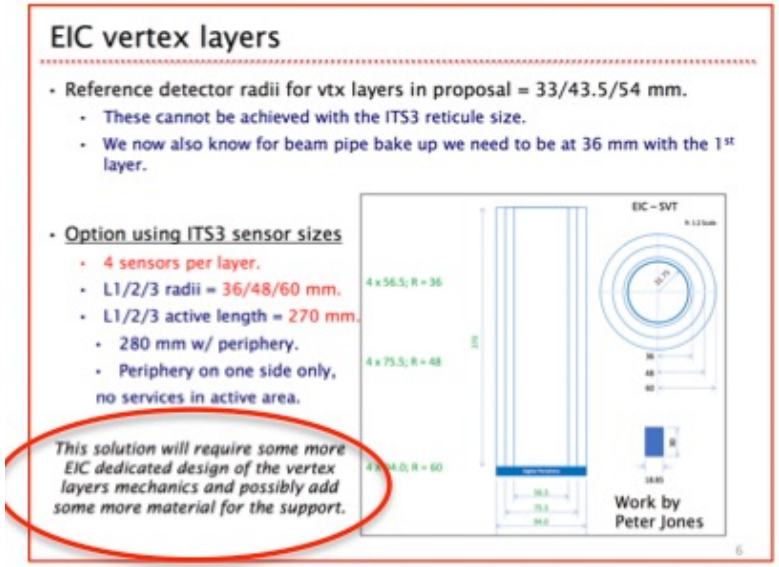
- deployed to design a wafer scale sensor

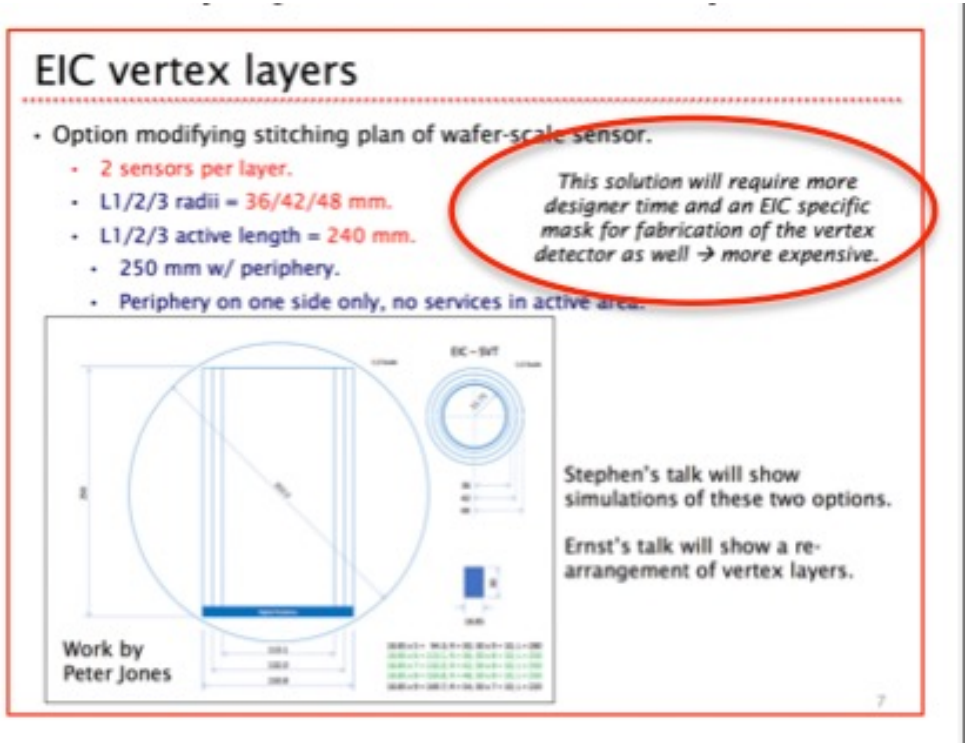


Synergy with ALICE can be really a win-win operation for INFN vis a vis EIC project.

INFN consider synergistic investment on 65 nm technology for ALICE and ePIC

Different options under discussion:





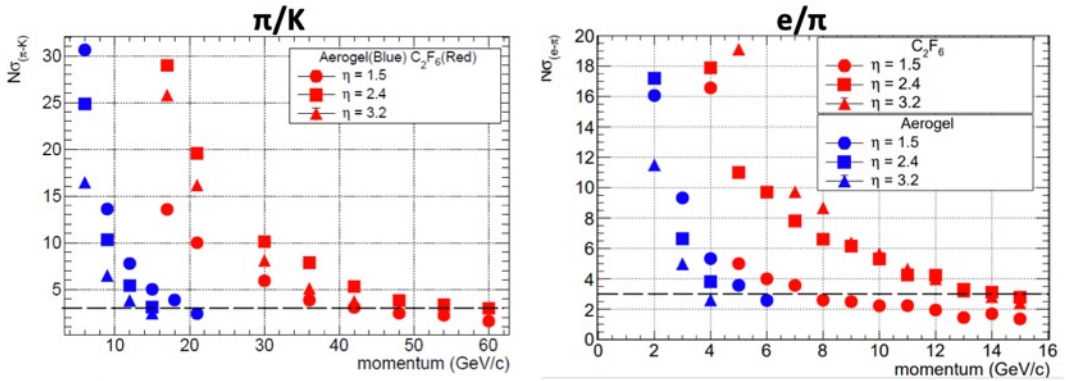
Simulation (dRICH)

dRICH - Nσ Separation

Slides by Chandra Chatterjee

Forward direction

YR requirement: e-K-p separation up to 50 GeV/c

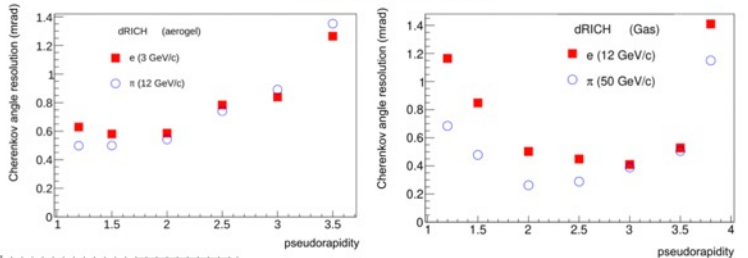


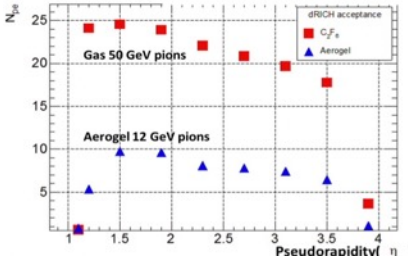
YR prescription achievable.

dRICH – Resolution & acceptance

Slides by Chandra Chatterjee

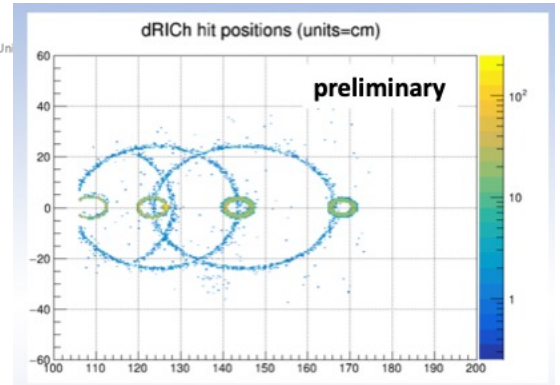
Forward direction



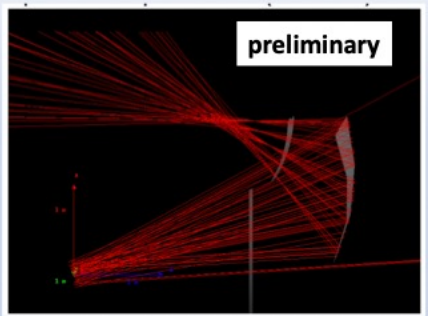


- **YR requirement:** acceptance for the dRICH is $1.0 \leq \eta \leq 3.5$

These reference numbers were taken as a guidance for the ATHENA design



Example of EPIC dRICH sensor hit positions



Simulation work for dRICH mainly from TS (a post-doc) + Duke University

Convened dRICH software group at EPIC level (the only one PID detector) with INFN-DUKE-NISER-(BNL)

Miniworkshop sharing experience among RICH detectors on reconstruction algorithms

TS

Simulation (tracking)

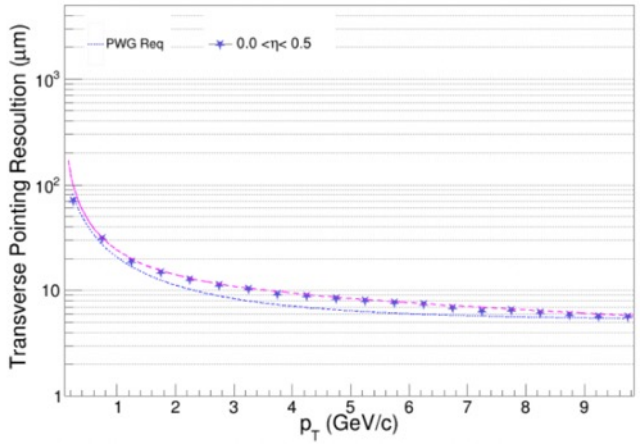
Internal parameters tuned to the ECCE's vertex detectors and B field

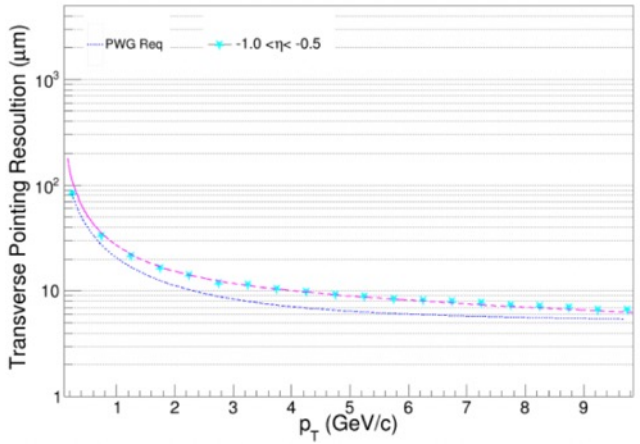
Blue points: Full simulation

Magenta line: Fast Simulation Tool

Blue line: PWG requirement

FS tool well under control





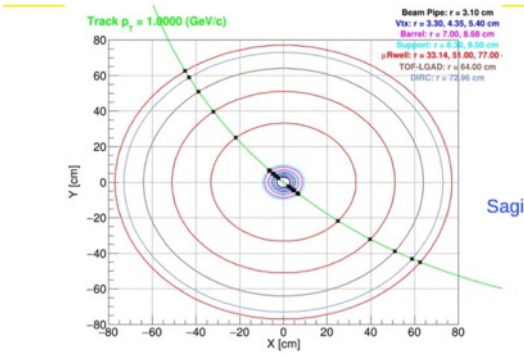
BA

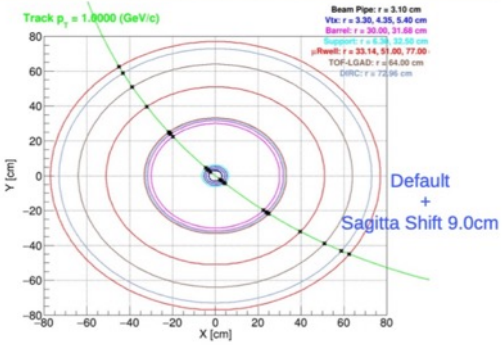
LNS SA joining BA TS on simulation efforts

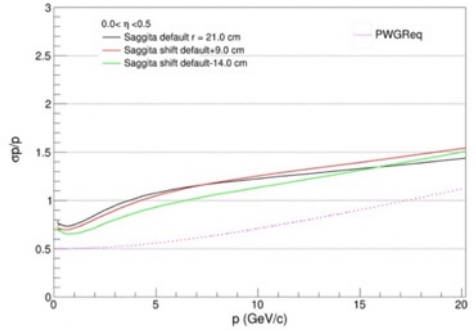
BA developed fast simulation tool that is well suited to give feedback on different configuration

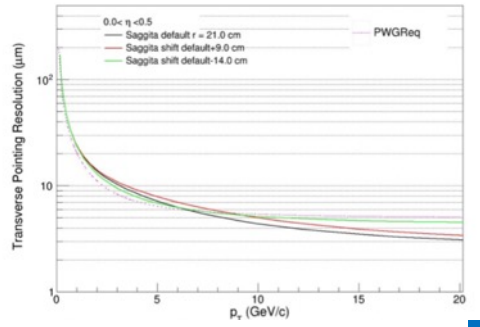
Already adapted from ATHENA to ECCE
→ EPIC

Versatile tool for simulation



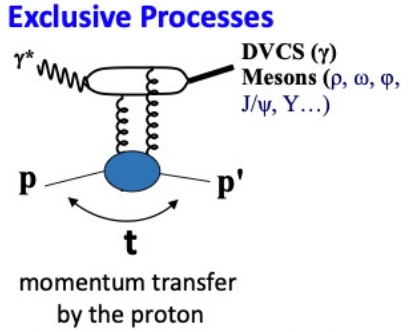






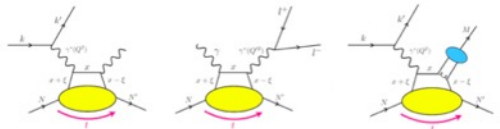
Physics (last but not least!)

Activity in CS (S. Fazio) on exclusive processes (critical for GPD studies) generators



The EpIC generator

- **EpIC:** an event generator for exclusive reactions
  - Named after EIC and the philosopher *Epicurus*
  - Note: we inspired the name for EIC detecor-1 ☺
- EpIC uses the PARTONS framework (http://partons.cea.fr), takes advantage of:
  - two state-of-art GPD models (GK, KM20)
  - flexibility for adding new models
- Multiple channels: DVCS, TCS, π^0
  - Initial and final state radiative corrections are implemented based on the collinear approximation
  - flexibility for adding all exclusive mesons



87 [hep-ph] 3 May 2022

EpIC: novel Monte Carlo generator for exclusive processes

E. C. Aschenauer[a,1], V. Batozskaya[b,2], S. Fazio[c,3], K. Gates[d,4], H. Moutarde[e,5], D. Sokhan[f,g,4], H. Spiesberger[e,6], P. Sznajder[b,2], K. Tezgin[a,1]

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[3] University of Calabria & INFN-Cosenza, Italy
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[5] IRFU, CEA, Université Paris-Saclay, F-91191 Gif-sur-Yvette, France
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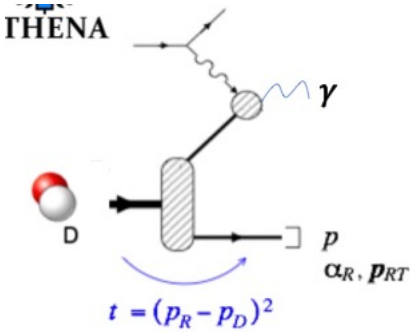
Received: date / Accepted: date

Abstract We present the EpIC Monte Carlo event generator for exclusive processes sensitive to generalised parton distributions. EpIC utilises the PARTONS framework, which provides a flexible software architecture and a variety of modelling options for the partonic description of the nucleon. The generator offers a comprehensive set of features, including multi-channel capabilities and radiative corrections. It may be used both in analyses of experimental data, as well as in impact studies, especially for future electron-ion colliders. like separations. In case there is no momentum transfer to the nucleon, i.e. in the forward limit, certain GPDs become equivalent to PDFs. Additionally, the first Mellin moments of GPDs are related to elastic form factors. In this regard, GPDs may be viewed as a unified concept of elastic form factors studied via elastic scattering processes and one-dimensional parton distribution functions studied via (semi-) inclusive scattering processes. Another key aspect of GPDs is their relation to nucleon tomography. The Fourier transform of GPDs are related to the impact parameter space distri-

arXiv:2205.01762

Accepted for publication on: EPJC

Example: DCVS on deuterium gives access to neutron structure measurement



Other interests:
- TO: diffractive
- dRICH → SiDIS
- Vertexing → HF

PV CS TO

A map end of 2022

dRICH

FE TS LNF (RM1)

optics mechanics

radiators

aerogel

FE BA

pressurized Argon vs C_2F_6

TS LNS + BNL/JLab

TS BA LNS SA + Duke + NISER

photosensors

BO FE CS-SA-CT

SiPM

ALCOR

TO

LAPPD

GE TS

PV CS TO

DAQ for dRICH

SiTracker

BA TS PD

MAPS 65 nm technology

streaming readout

GE RM2

El. cal. @JLAB + TRIDAS

Toward detector definition and optimization, simulation capacity will be key: a big working space for all our groups

Simulation & computing

TS CT CS BA

Physics (SIDIS, Exclusive tagging, diffractive, hadron spectroscopy and hadronization, ...)

some update (not all)

dRICH

FE TS LNF (RM1)

optics mechanics

radiators

aerogel

FE BA

pressurized Argon vs C_2F_6

FE LNS + BNL/JLab

photosensors

BO FE CS-SA-CT

SiPM

ALCOR

TO

LAPPD

GE TS

DAQ for dRICH

PV CS TO

SiTracker

BA TS PD PV

MAPS 65 nm technology

µRWELL

GE RM2

exploring this possibility!

BO (+ RM2/GE)

TS BA LNS SA + Duke + NISER

Simulation & computing

TS CT CS BA

Physics (SIDIS, Exclusive tagging, diffractive, hadron spectroscopy and hadronization, ...)

Toward detector definition and optimization, simulation capacity will be key: a big working space for all our groups

Magnet

- New 1.7 T SC solenoid

Tracking

- Si Vertex Tracker MAPS/ITS3 wafer-level stitched sensors
- Si Tracker MAPS/ITS3/EIC barrel and disks
- MPGDs (μRWELL/MMG) cylindrical and planar

PID

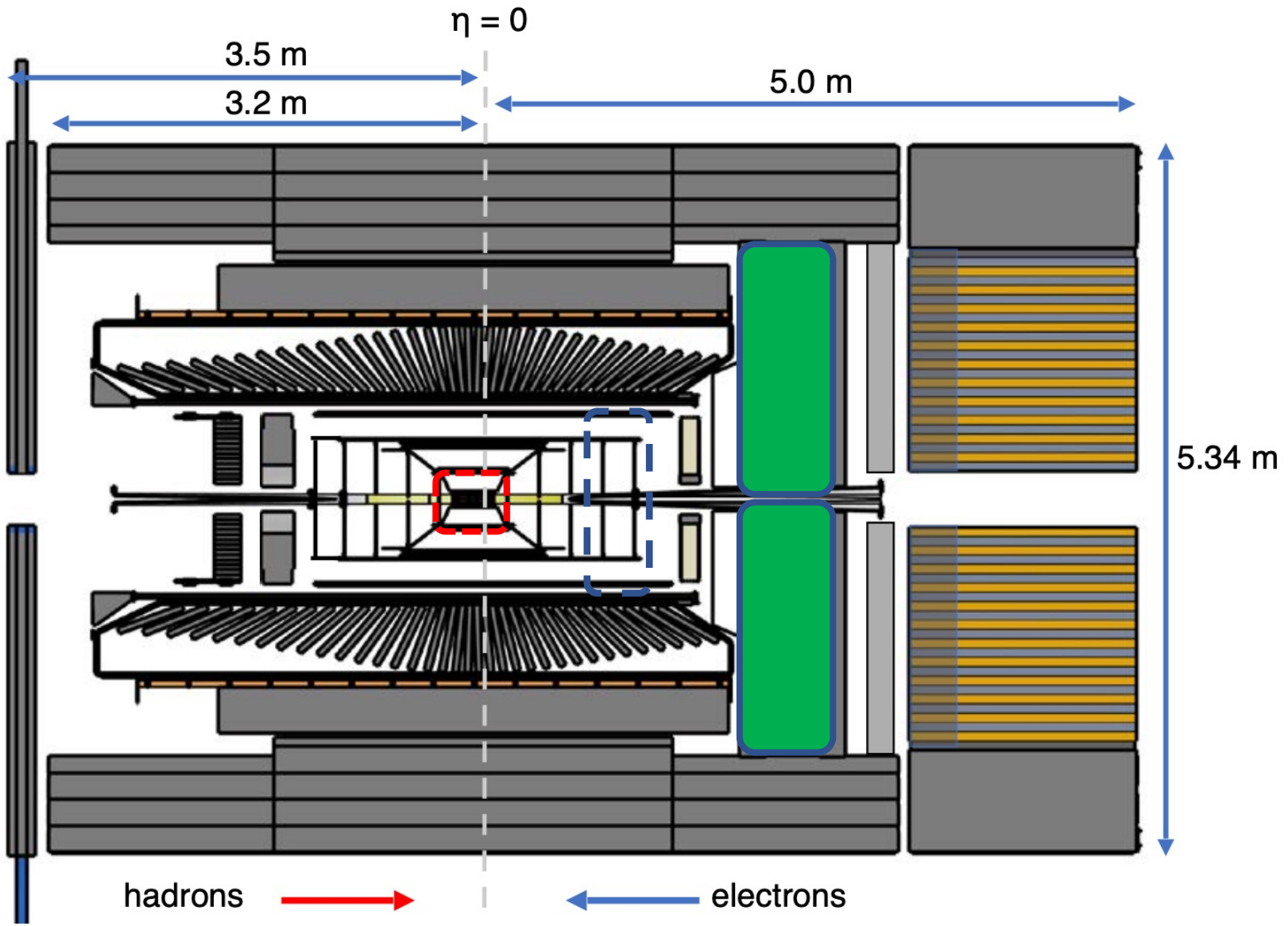
- high performance DIRC (hpDIRC)
- dual RICH (aerogel + gaseous)
- aerogel proximity focusing pfRICH
- ToF using AC-LGAD

EM Calorimetry

- imaging EMCal
- finely segmented W/SciFi EMCal
- $PbWO_4$ EMCal

Hadron Calorimeter

- re-used sPHENIX Fe/Sc
- long. separated Fe-W-Sc calorimeter w/ high-η insert



My == Your!

~~The Italian~~ Contribution to the Electron Ion Collider

?

Detector

Physics