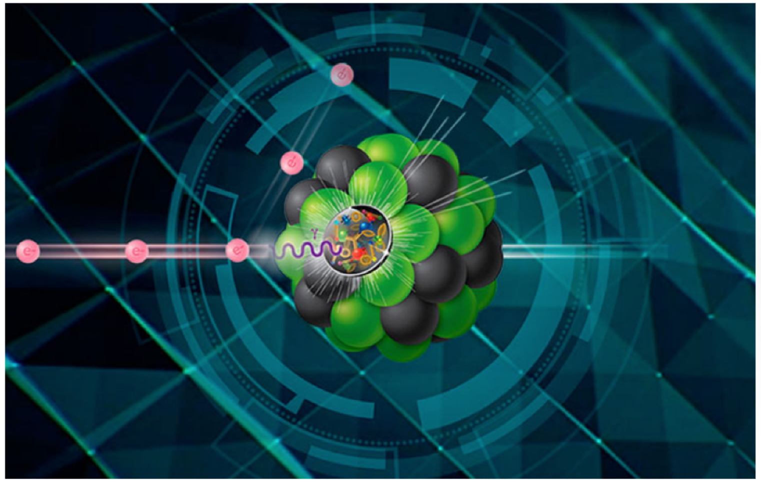
EIC_NET Summary of R&D activities
(mainly a 2020 summary + 2021 outlook)

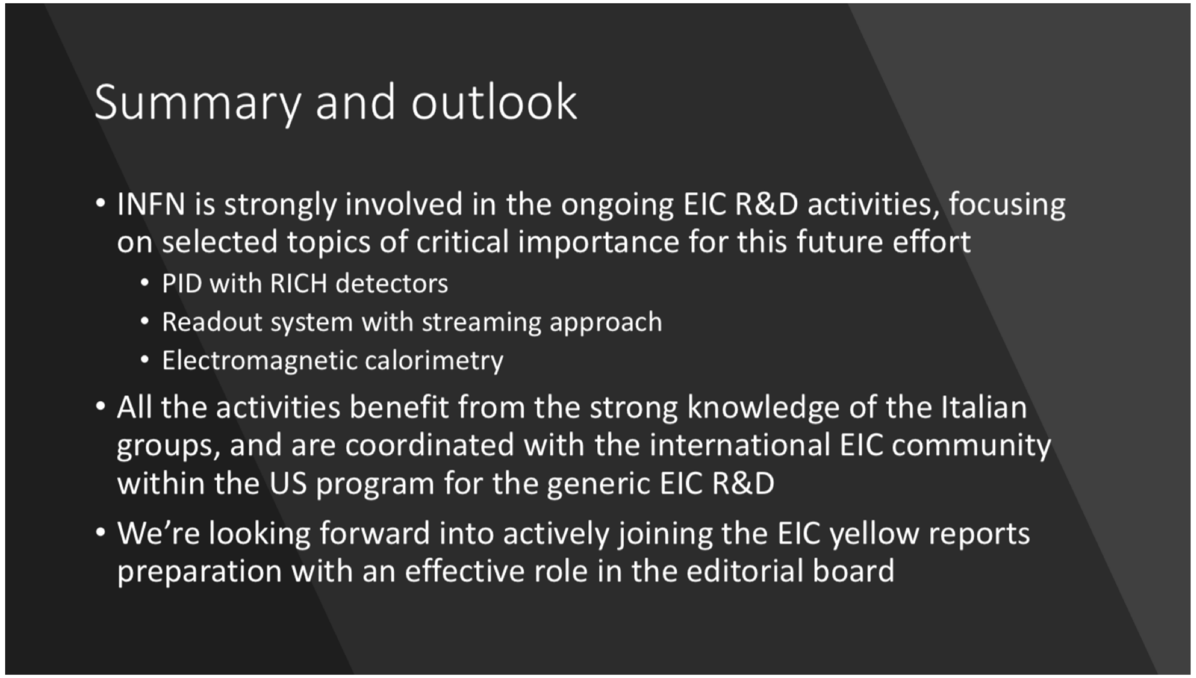


P. Antonioli
INFN/Bologna

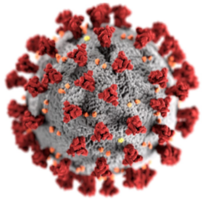
Many thanks to the **many** people helped me to put together this presentation!

Where we are?

As starting point use as reference Andrea's summary at last EIC_NET meeting (Bari 2019)
https://agenda.infn.it/event/20360/contributions/103554/attachments/68350/84356/EIC_GENOVA_CELENTANO.v2.pdf



Andrea's last slide Nov 2019

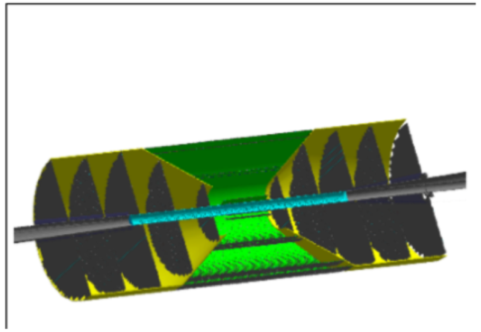
What more/less?
What we achieved (despite )?

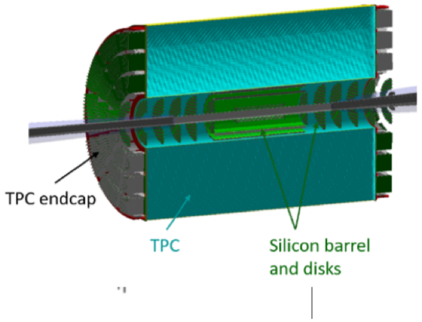
- different Covid-impact depending on the type of 2020 planned activities
- from networking to virtual networking

Caveat:
- many references
- despite many slides, focus on overview not on details
- link to EoI + YR

YR SNAPSHOT
https://indico.bnl.gov/event/9913/attachments/31448/49647/EIC_YR_SNAPSHOT_19NOV2020-75MB.pdf

Where our R&D fits in?



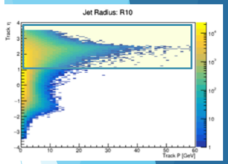


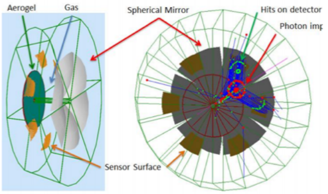
all-silicon and hybrid tracking
detectors baseline (YR4 "Berkeley")

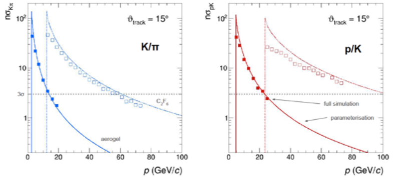
https://indico.bnl.gov/event/9913/contributions/43313/attachments/31469/49682/2020_11_20_YR_detector_concepts_tracking_LG_2.pdf

Forward Direction

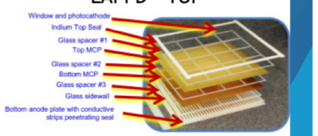
system	system components	reference detectors	detectors, alternative options considered by the community	
h-PID	forward, high p	fluorocarbon gaseous RICH	double RICH combining	high pressure Ar RICH
	forward, medium p	aerogel	aerogel and fluorocarbon	
	forward, low p	TOF	dE/dx	
e/h separation at low p	forward	TOF & areogel & gaseous RICH	adding TRD	







K/π and p/K separation as a function of momentum



- Cherenkov is only route to PID at extreme momentum.
- Layered indices to combat high threshold in low index material.
- Dual-RICH internally does two ranges.
- LAPPD is present best TOF (OK in end caps, B-field trouble in barrel).

Hadron Arm Technology	Range (GeV/c) e - π	π - K
CsI RICH	0.0150 - 20	14.75 - 50
dRICH (aerogel)	0.0025 - 5	2.46 - 16
dRICH (gas)	0.0127 - 18	12.34 - 60
dRICH (overall)	0.0025 - 18	2.46 - 60
TOF (LGAD)	0 - 1	0.00 - 5
TOF (LAPPD 4m 5psec)	0 - 2.5	0.00 - 16
TRD	1.0 – ∞	–

From PID overview YR4:
https://indico.bnl.gov/event/9913/contributions/43315/attachments/31471/49692/PID_in_the_Yellow_Report.pptx

From CDR draft report (table shown by Rolf Ent at YR4)
https://indico.bnl.gov/event/9913/contributions/43303/attachments/31409/49584/EIC_Detector_CDR_111720.pdf

+ **INFN EoI**:

system	system components	reference detectors	detectors, alternative options considered by the community		
tracking	vertex	MAPS, 20 um pitch	MAPS, 10 um pitch		
	barrel	TPC	TPC [a]	MAPS, 20 um pitch	MICROMEGAS [b]
	forward & backward	MAPS, 20 um pitch	GEMs with Cr electrodes		
ECal	barrel	Pb/Sc Shashlyk	SciGlass	W powder/ScFi	W/Sc Shashlyk
	forward	W powder/ScFi	SciGlass	Pb/Sc Shashlyk	W/Sc Shashlyk
	backward, inner	$PbWO_4$	SciGlass		
	backward, outer	SciGlass	PbWO4	W powder/ScFi	W/Sc Shashlyk [c]
h-PID	barrel	High performance DIRC & dE/dx (TPC)	reuse of BABAR DIRC bars	fine resolution TOF	
	forward, high p	fluorocarbon gaseous RICH	double RICH combining	high pressure Ar RICH	
	forward, medium p	aerogel	aerogel and fluorocarbon		
	forward, low p	TOF	dE/dx		
	backward	modular RICH (aerogel)			
e/h separation at low p	forward	TOF & areogel & gaseous RICH	adding TRD		
	backward	modular RICH & TRD	Hadron Blind Detector		
HCal	barrel	Fe/Sc	RPC/DHCAL	Pb/Sc	
	forward	Fe/Sc	RPC/DHCAL	Pb/Sc	
	backward	Fe/Sc	RPC/DHCAL	Pb/Sc	

+ DAQ
(streaming readout)

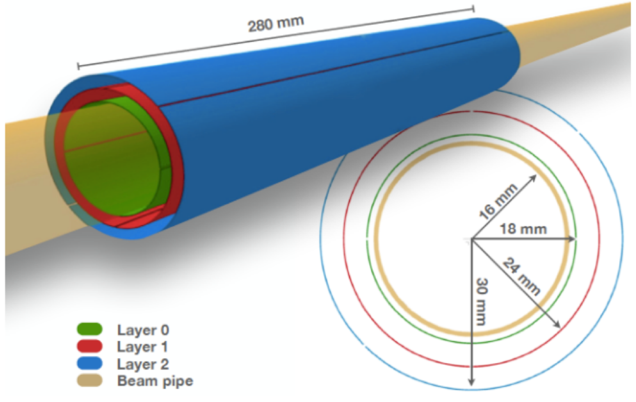
(+ software/computing)

Vertexing

INFN-BA/ALICE & ITS 3project

Contributions to Si-vertex R&D as from INFN EoI:

- already started in the framework of the YR preparation:
  - ✓ MC and detector/physics performance studies (started in the framework of the current YR preparation) → talk Andrea B.
- ongoing for ALICE ITS3, largely synergic in view of EIC (2021-2024):
  - ✓ techniques and tools for thinning, bending and interconnection of wafer-scale MAPS sensors based on 65 nm CMOS process;
  - ✓ pixel-chip sensor test and characterization procedures;
  - ✓ solutions for cooling, mechanical support structure and assembly procedure.



From YR4 workshop discussing tracking options

Inner Tracking Silicon technology options

Lawrence Berkeley National Laboratory

ITS3 silicon design parameters

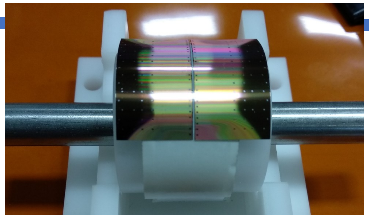
Parameter	Wafer-scale sensor (this proposal)
Technology node	65 nm
Silicon thickness	20-40 µm
Pixel size	O(10 x 10 µm)
Chip dimensions	scalable up to 28 x 10 cm
Front-end pulse duration	~ 200 ns
Time resolution	< 100 ns (option: <10ns)
Max particle fluence	100 MHz/cm^2
Max particle readout rate	100 MHz/cm^2
Power Consumption	< 20 mW/cm^2 (pixel matrix)
Detection efficiency	> 99%
Fake hit rate	< 10^{-7} event/pixel
NIEL radiation tolerance	10^{14} 1 MeV n$_{eq}$/cm^2
TID radiation tolerance	10 MRad

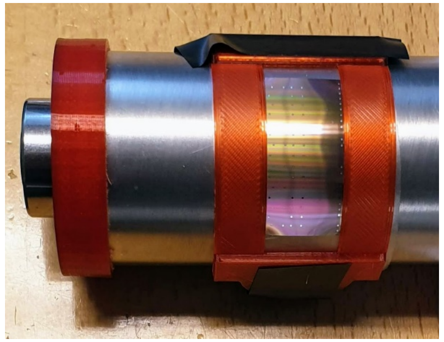
Tracking detector component	Stave X/X0
ITS3 like vertexing	0.05-0.1%
ITS3 like barrel (up to 1.5 m length)	0.55%
ITS3 like disc (up to 60 cm diameter)	0.24%

	Si + gaseous	All Si
Attributes for consideration	• dE/dx in gas for PID (TPC) • Well understood technology - less R&D needed. • Costs less (likely) • Less material in tracking region but more in the endcap region. • Worse single point resolution but more position samples	• Readout faster than TPC • Better momentum resolution than TPC at higher momentum (>~5GeV/c) • Can be made more compact • Less material in endcap regions • Very high single point resolution

EICUG YR workshop LBNL Tracking YR content - 2020_11_20

Bending



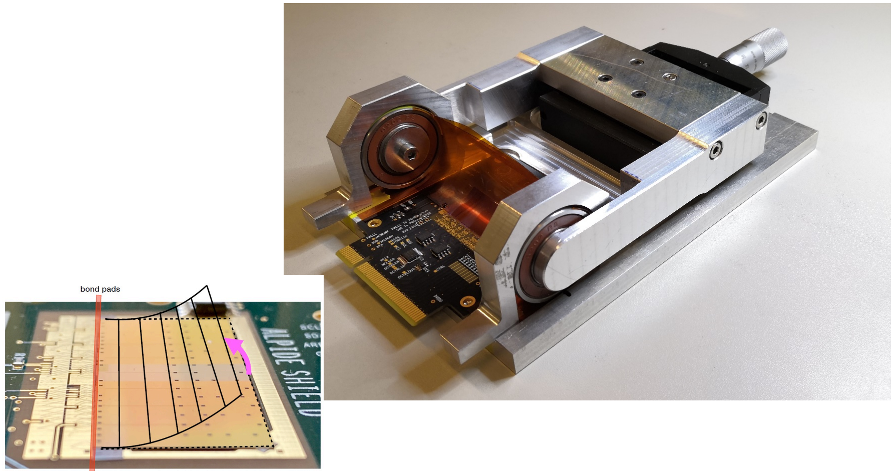


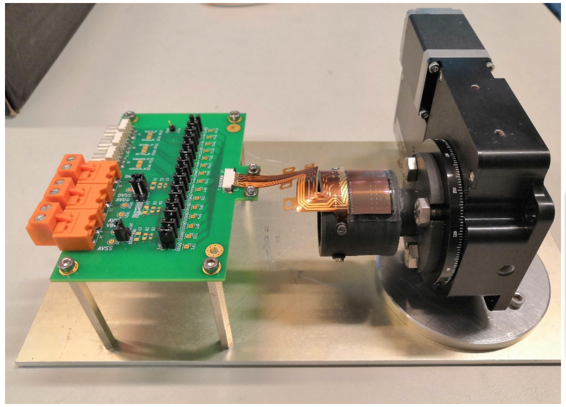
Pixel sensor bending

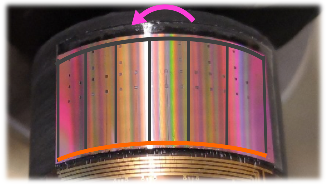
Design and production of sensor bending tools

- Prototyping of bending tools for existing sensors
- Extension to wafer-scale sensors
- Bent sensor surface description

INFN-TS/ALICE & ITS3 project





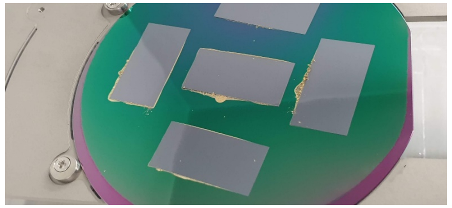


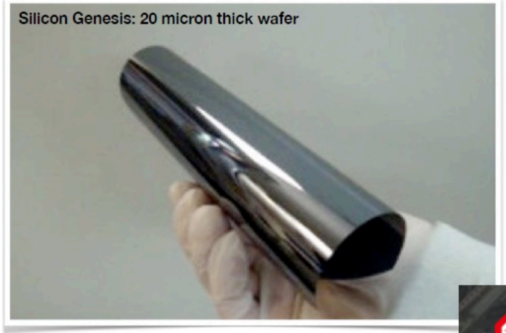
Ref: More on ITS3 results at G. Contin@SVT-EIC workshop
https://indico.jlab.org/event/400/contributions/6536/attachments/5413/6745/EIC_workshop_20200903_Contin.pdf

Thinning, interconnections and characterization

Development and validation of wafer thinning techniques

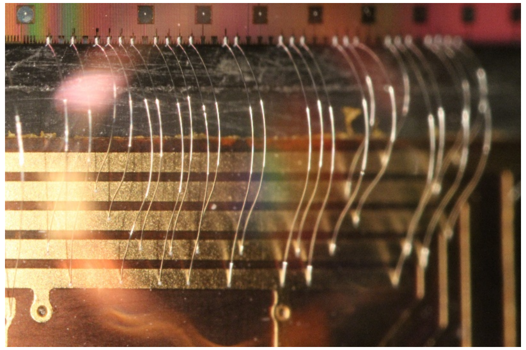
- Target thickness: 20-40 um
- With mechanical and etching processes
- Handling tool development



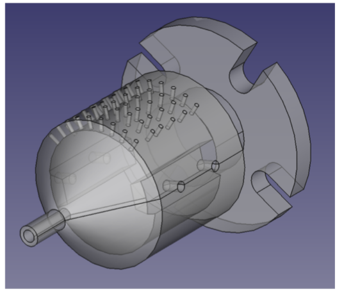


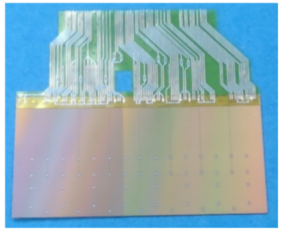
Development and application of wire/tab bonding techinques

- Bond-after-bending and bend-after-bonding techniques
- Design and production of bendable printed circuits
- Design and production of bonding tools for bent silicon



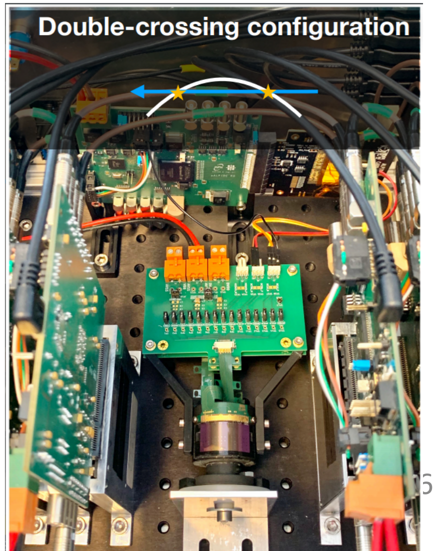
INFN-TS/ALICE & ITS3 project





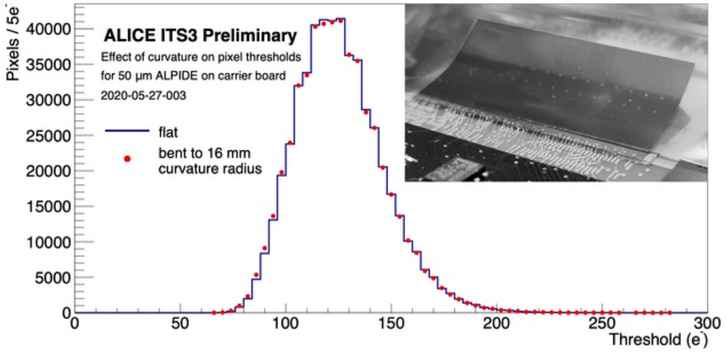
Chip performance comparison bent/flat

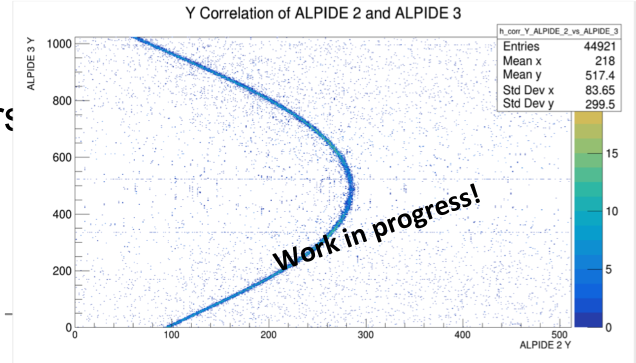
- Electrical tests and standalone characterization
- Detection efficiency and cluster shape in testbeams



65 nm CMOS process sensor characterization

- Test structures
- Sensor prototypes
- Wafer-scale sensors



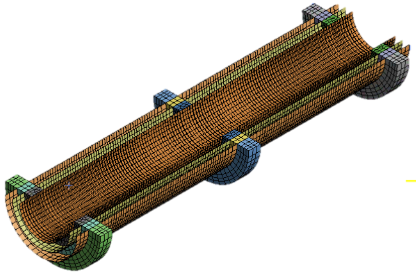


Mechanics & cooling

INFN-BA/ALICE & ITS3 project

- selection/characterization of carbon foam materials (structural/thermal prop.)

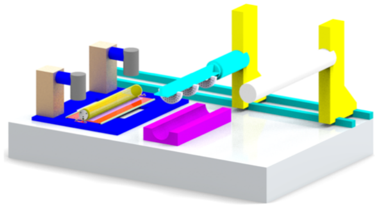
Due to the difficulty in accurately modelling all the details that influence the performance of the cooling system, experimental tests will be performed in order to validate the results o initial Computatation Fluid Dynamics (CFD) simulations. The vibrational response and the position stability of the large curved sensor areawill be assessed by Finite Element Modal and Dynamic Response Analysis. CFD analysis will be used to simulate the forced air flow between the layers and will aim to drive the design of the carbon-foam heat exchanger rings, for optimum thermal management. Different carbon foams with best thermal properties and low-pressure drop, as well different configuration patterns will be analysed. Their shape will be optimized to reduce impedance and to achieve the best flow distribution and the optimum angles between the half-layer and the flow direction. The definition of a correct CFD model will require experimental tests, aiming at measuring the heat transfer and pressure drop across different samples of porous carbon foam.



cooling opportunity vs stability

- development of the assembly procedure

it must allow bending to shape the half-layers and freezing the position in the detector barrel layout. Verify achieved half-layers positions through metrology. Glued joints/procedures will be developed in order to guarantee the best mechanical/thermal connections. Develop all the necessary tooling to provide alignment reference

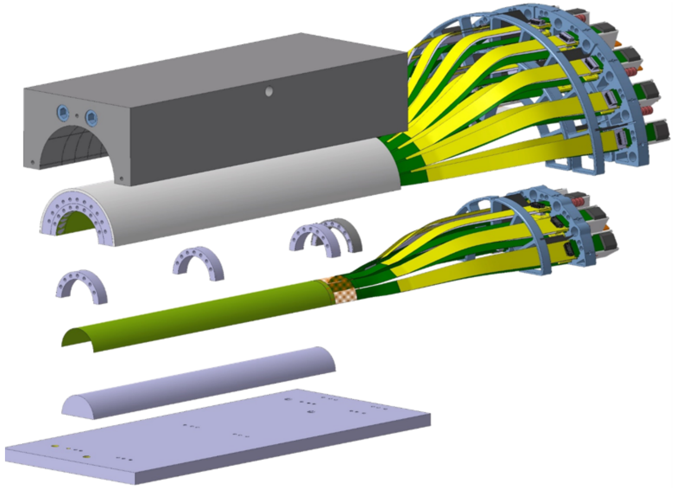


- development and production of prototype support structures

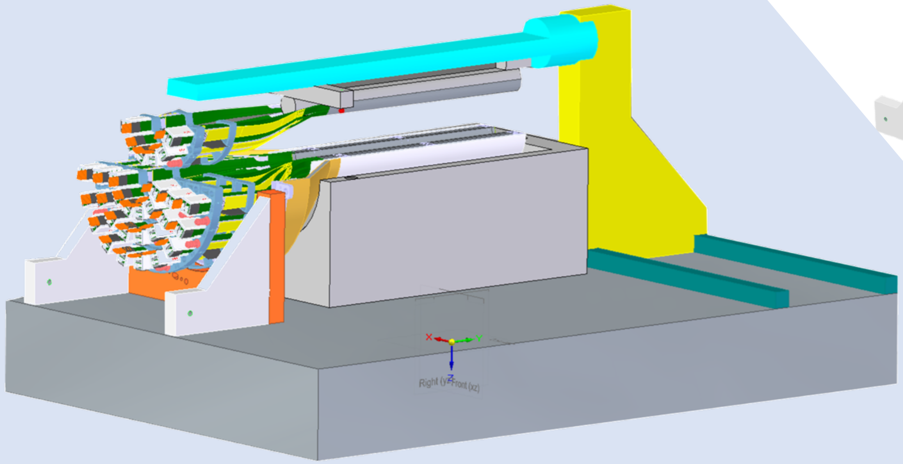
Similar aspects now under investigation for the developing of the ITS3 structural support can be faced for R&D steps of the new EIC detector. Carbon foam parts as rings and/or bars will be the baseline for the mechanics and cooling systems. Additional sheet in carbon fibre could be used to improve the connection in the glued joints and for a more stable alignment between layers and other parts (FPC, external support structure, ventilation system, etc.)

- development of tooling for the assembly procedure

Vacuum jig will be used for the first precision alignment of the sensors. An optical system combined with a micrometrical movement chuck (manual or automatic) will guarantee the correct alignment between chips and a vacuum mandrel for the chip bending step. Different moulds will provide and fix the nominal position of the bent chips during the glue polymerization phase. An external reference system will guide all the vacuum jigs and mandrels in the sequential assembly steps.

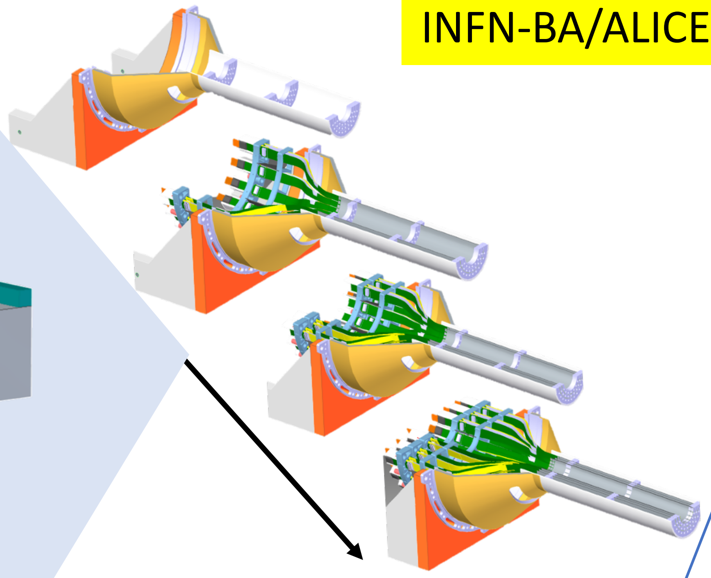


Assembly station



If assembling from outer to inner layer all revers to the Cone , no added errors

Sequence from outer to innermost layer:



INFN-BA/ALICE & ITS3 project

Outlook

https://indico.jlab.org/event/400/contributions/6533/attachments/5409/6741/EIC-SVT-Si-tech-v1.pdf

ITS3/EIC projects overlap

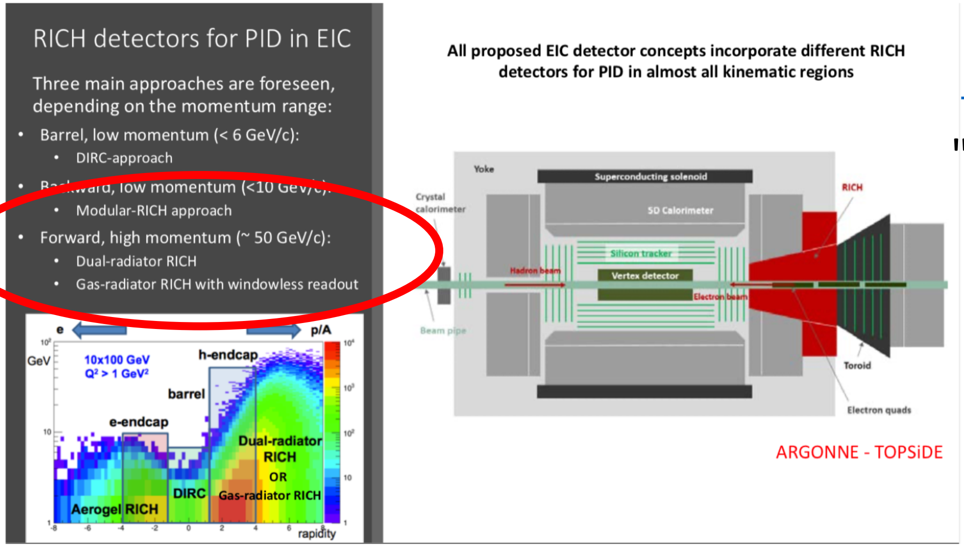
- The ALICE ITS3 project aims at developing a new generation MAPS sensor at the 65 nm node with extremely low mass for the HL-LHC
  - See Giacomo's talk
- As presented by Leo Greiner (LBNL) at the EIC Yellow Report Kick-Off meeting, this effort is particularly interesting for the EIC
  - The ITS3 **sensor specifications and development timescale** are largely compatible with those of the EIC
  - **Non-ALICE members are welcome** to contribute to the R&D to develop and use the technology for other applications
- Joining the ITS3 collaboration, the EIC can leverage on a large effort at CERN, sharing development costs, to design an innovative sensor solution at the 65 nm node, suited for an experiment starting in ~ 2030

This has been identified has the most efficient way forward

L. Gonella | Overview of silicon sensor technology | SVT EIC workshop, 3.9.2020 12

This approach is being mirrored / visible in Italy (work presented so far was under ALICE, now - since 2021 – factorized in EIC_NET!)

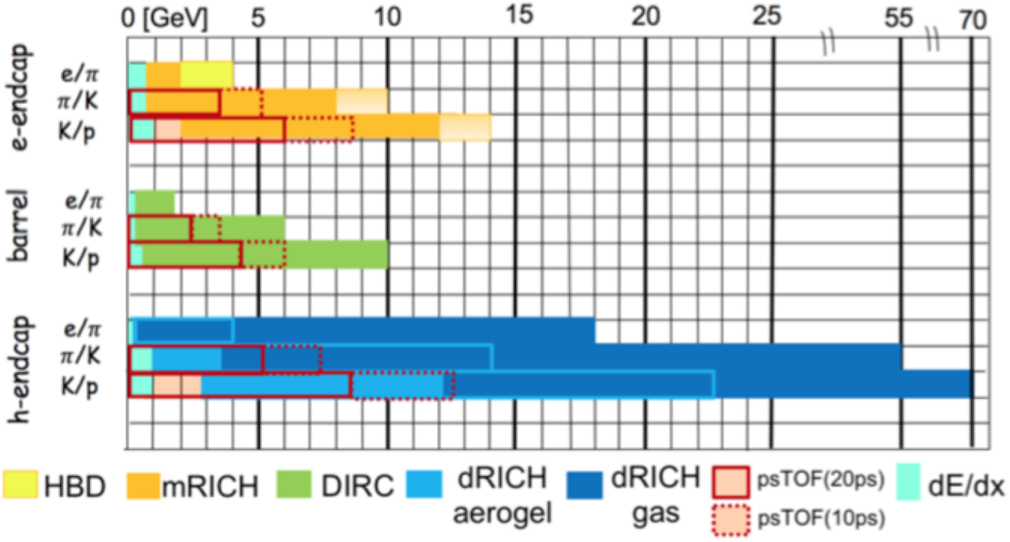
PID



EIC handbook:
http://www.eicug.org/web/sites/default/files/EIC_HANDBOOK_v1.2.pdf

" Simulations show that in order to satisfy the physics goals of the EIC, it is desirable to provide π/K identification in the central barrel up to 5-7 GeV/c, in the electron-going endcap up ~10 GeV/c, and in the hadron-going endcap one would need to reach ~50 GeV/c. "

INFN very active with many groups (BA, BO, FE, LNF, LNS, RM1, TO, TS) under two EIC eRD-initiatives (eRD-6 and eRD-14)



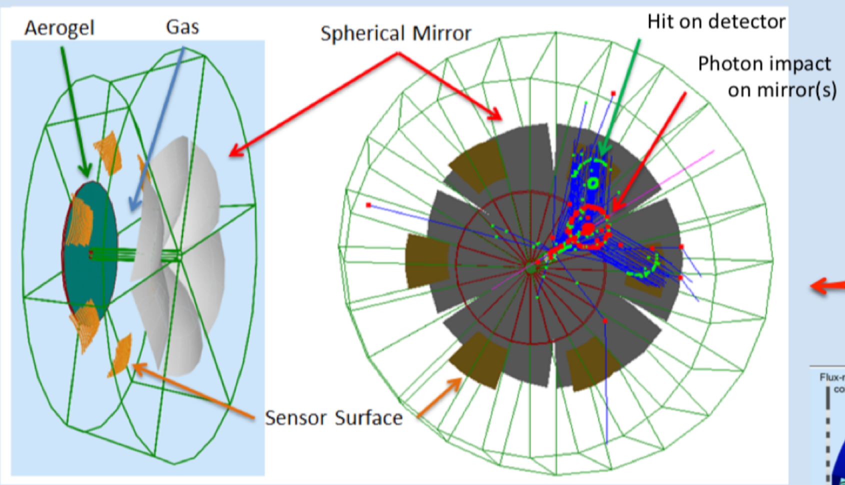
(taken from: https://www.jlab.org/user_resources/meetings/JLUO_6_19/Romanov.pptx)

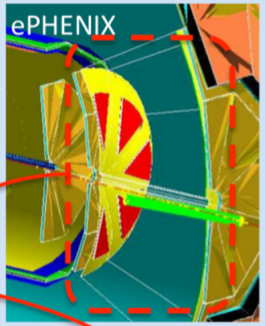
Required large p coverage brings to RICH technique, with challenges @EIC associated to radiators and photodectors

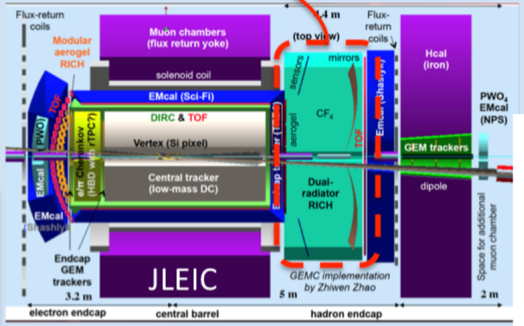
- dual-radiator RICH → R&D on photodetectors ("B immune") – wide λ range
- windowless CsI-based gas photodector (MPGD) – narrow λ range

https://wiki.bnl.gov/eic/upload/ERD6_ProgressReport_201907.pdf
https://wiki.bnl.gov/conferences/images/8/8e/ERD14_Jan-2020.pdf

dRICH: the idea







dRICH: flexible configuration (JLEIC, ePHENIX)

Radiators: Aerogel (n_{AERO}~1.02) + Gas (n_{C2F6} ~ 1.0008)

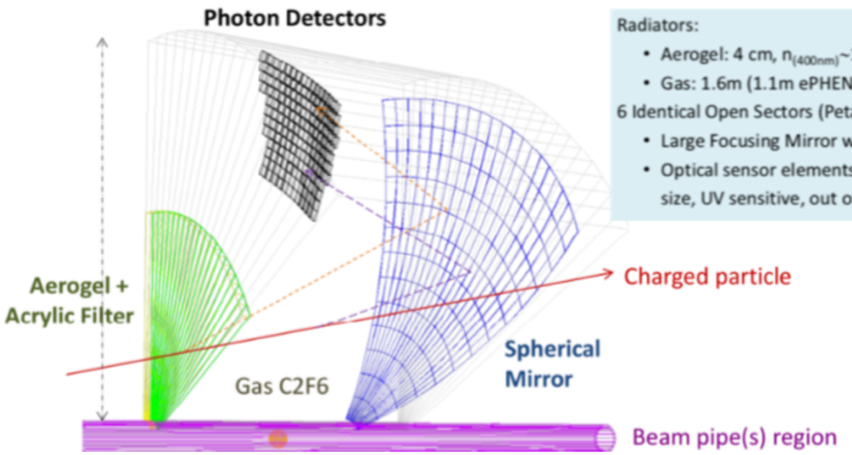
Detector: 0.5 m²/sector , 3x3 mm² pixel

Single-photon detection in ~1T magnetic field

Outside acceptance, reduced constraints

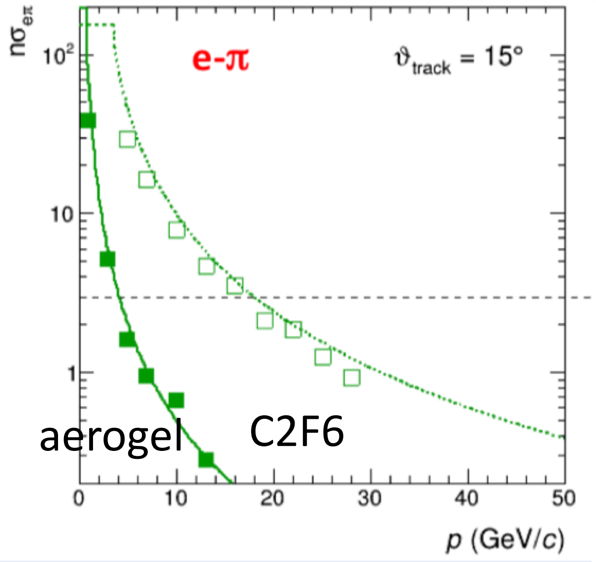
→ best candidate for SiPM option

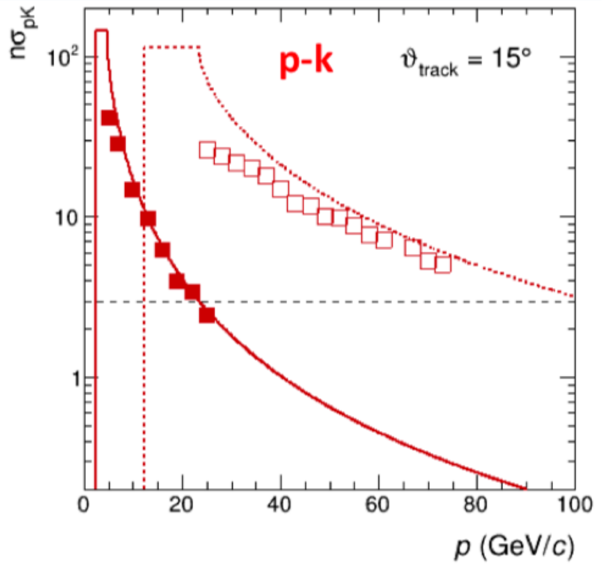
Phase Space:
- Polar angle: 5-25 deg
- Momentum: 3-60 GeV/c



Radiators:
- Aerogel: 4 cm, $n_{(400nm)}$~1.02 + 3 mm acrylic filter
- Gas: 1.6m (1.1m ePHENIX), n_{C2F6}~1.0008

6 Identical Open Sectors (Petals):
- Large Focusing Mirror with R ~2.9m (~2.0m ePHENIX)
- Optical sensor elements: ~4500 cm²/sector, 3 mm pixel size, UV sensitive, out of charged particles acceptance

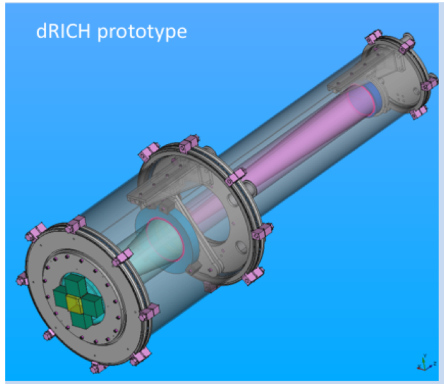


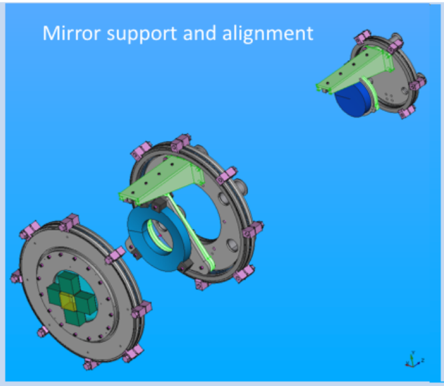


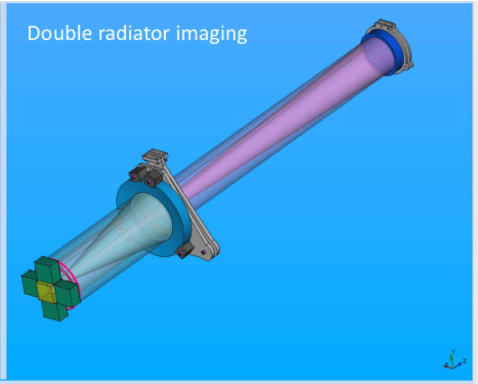
INFN work on:
- simulations
- design prototype towards procurement → test beam in 2021
- sensors + readout electronics study

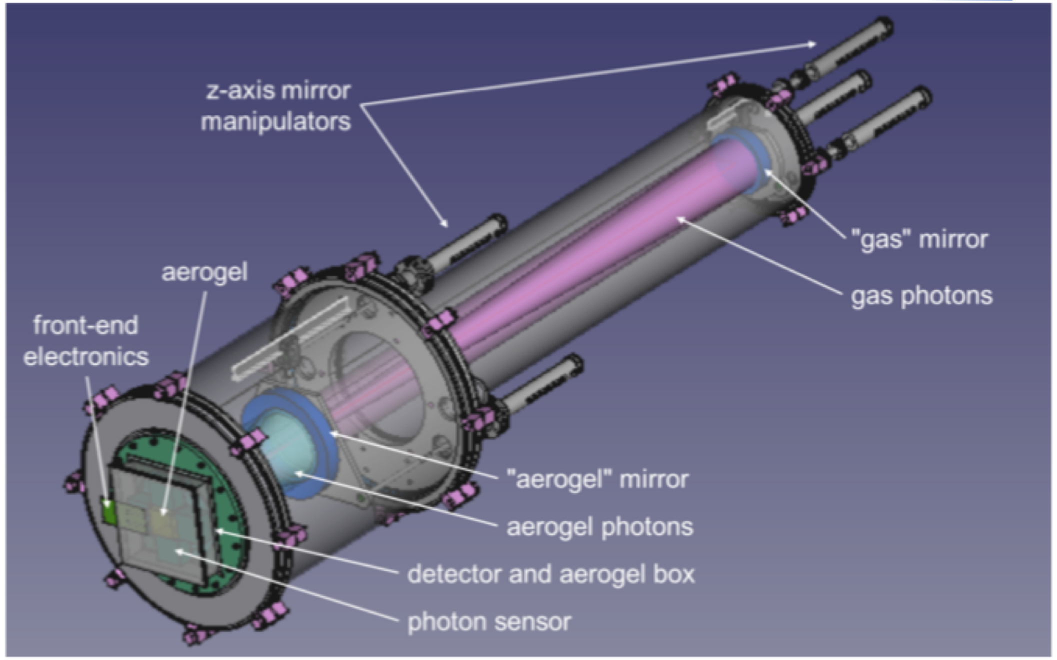
NEW

dRICH: optimizing design and preparing prototype → test beam 2021







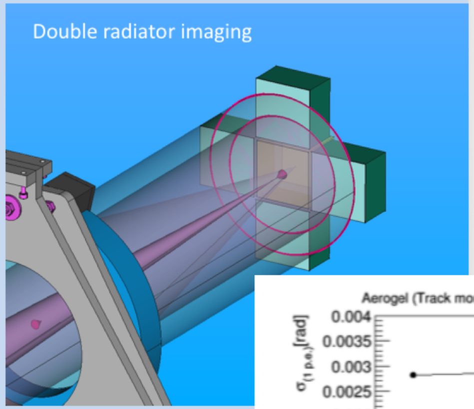


- **Mechanics**
  Define details for production
  Stage: production

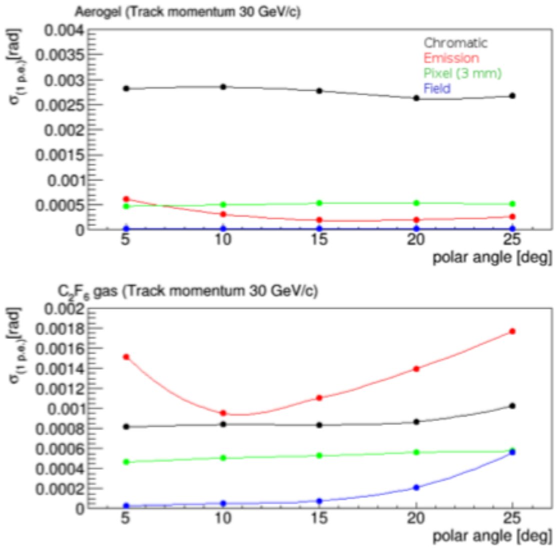
- **Gas and erogel:**
  (n=1.0008 C_2F_6 and n=1.02 aerogel)
  Stage: procurement

- **Mirrors:**
  Stage: procurement

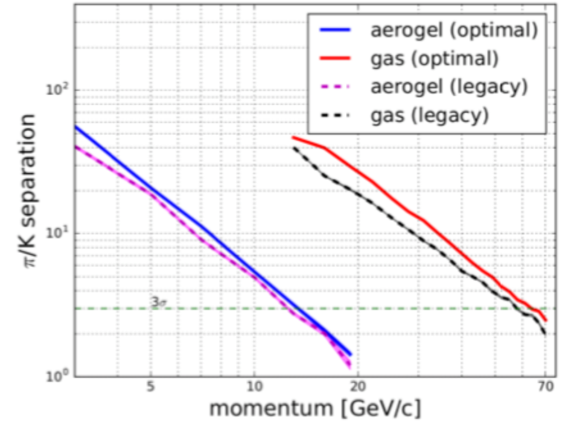
- **Support and alignment**
  Stage: design



INFN-FE/RM1/LNF/CT



Bayesian optimization of det. parameters
E. Cisbani et al.
https://iopscience.iop.org/article/10.1088/1748-0221/15/05/P05009/pdf



L. Barion et al. https://iopscience.iop.org/article/10.1088/1748-0221/15/02/C02040/pdf

Sensors for RICH: SiPM

dRICH Key Hardware Components 2/2

Component	Function	Specs/ Requirements	Risk	Mitigation
Photon Detector	Single photon spatial detection	Magnetic field tolerant and radiation hardness; ~ few mm spatial resolution	MCP-PMT is likely duable, but expensive. Need to find alternatives	LAPPD may represent an alternative. **R&D on SiPM:** a promising, quicky improving, wordwide pursued, and cheap technology.
Electronics	Amplify and shape single photon analog signal, convert to digital, transfer to DAQ nodes	Low noise Time res. ~ 0.5 ns μs signal latency; High density	No major risk but need to be tailored to photon sensors	MAROC3 based readout available for prototyping; final choice will depend on sensor. **ASIC development for optimised streaming readout (discrimination vs sampling)**

EIC R&D committee explicitly asked for such a program

In-depth EIC R&D Review Report (11/25/2019): *"An important remaining issue is the SiPM noise rate after irradiation which should be clarified. We expect that it will take 2-3 years to fully understand if SiPMs can be used in RICH detectors at EIC".*

18th EIC R&D Meeting Report (01/30/2020): *"The committee again recommends the group to re-examine options that do not rely on waveform sampling, e.g., a TOT-based design like the TOPFET2 ASIC, which is radiation hard, has low power consumption and has achieved a very good resolution per single photon with SiPMs."*

R&D needed for SiPM:

1. Proof of "feasibility": DCR & operating conditions, single photon detection etc.
2. Readout electronics: ASIC (+ streaming readout)
3. Radiation tolerance

- "dRICH based" for test beams and parameters selection, but expected R&D outcome might extend beyond

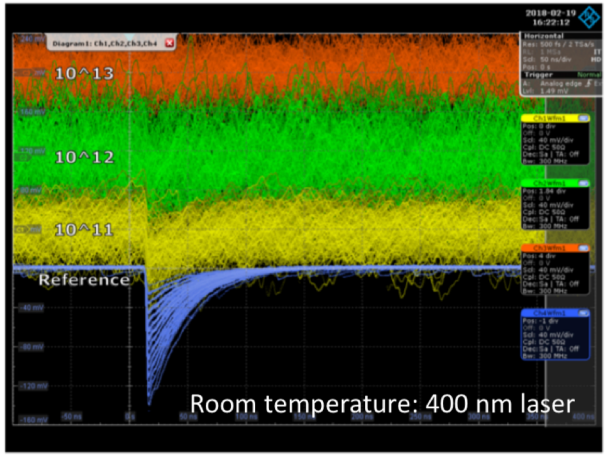
Groups involved: FE, LNF, RM1, CT, BO, TO, TS
"new" activity since 2020 used to "build the plan"
→ 2021 to deliver results

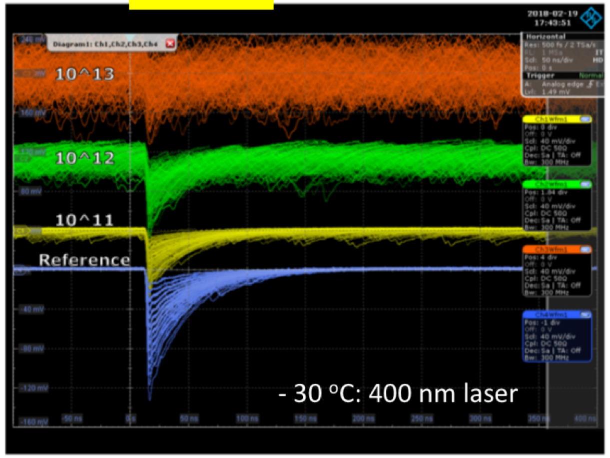
- 6 x 4500 cm^2 = **O(3 m^2)** active sensors
- **3x3 mm$_x$mm pixel size**

→ Single Photon Detection (**PDE** ↑)
→ **Temperature** vs DCR ("not cryogenic")
→ Use **timing** to help filter DCR
→ **Radiation** tolerance (expected@EIC **10^{11} n$_{eq}$/cm^2**)
→ Sampling vs **discrim. + TOT**

Radiation damages and recovering via annealing (@175 °C)

Radiation tolerance

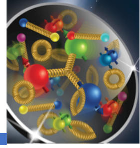


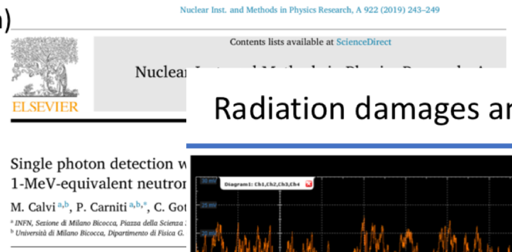


Hamamatsu S13360-1325CS (1.3x1.3 mm^2 – 25 μm)
Hamamatsu S13360-1350CS (1.3x1.3 mm^2 – 50 μm)

Effect of radiation (10^{11} 10^{12} 10^{13}):
- loss of baseline
- room temperature not an option

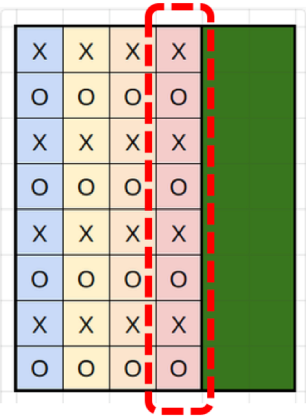
Ref:
M. Calvi et al.
Nuclear Inst. and Methods in Physics Research, A 922 (2019) 243–249



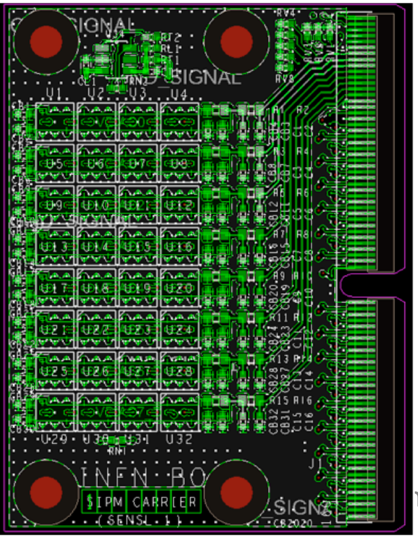


Irradiation campaign @Trento
+ annealing cycles (BO/FE)

8x4 matrix
different SiPM



irradiation	0	e9	e10	e11

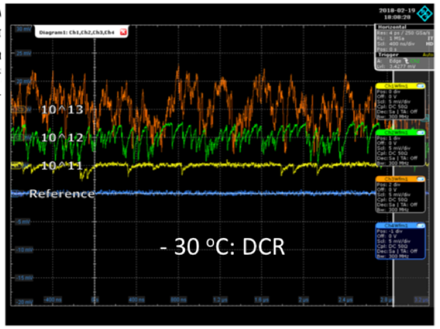


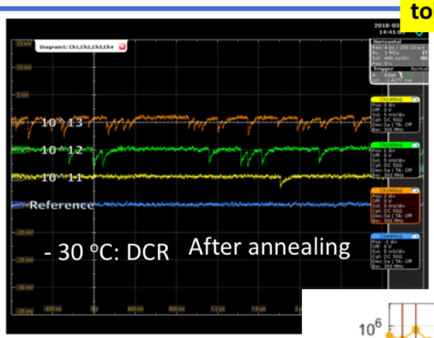
SiPM selection:
- OnSemi
- Hamamatsu
- FBK

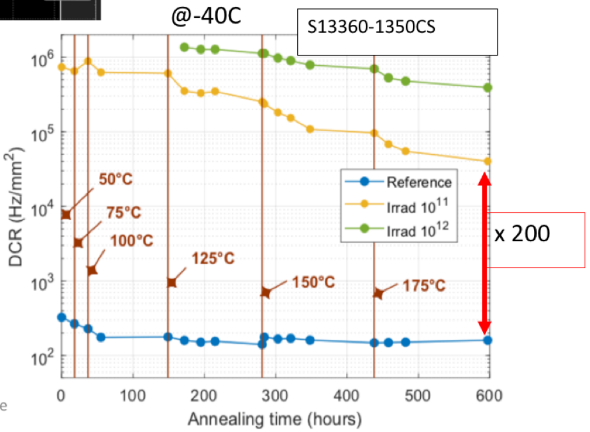
INFN-BO

Radiation damages and recovering via annealing (@175 °C)

Radiation tolerance



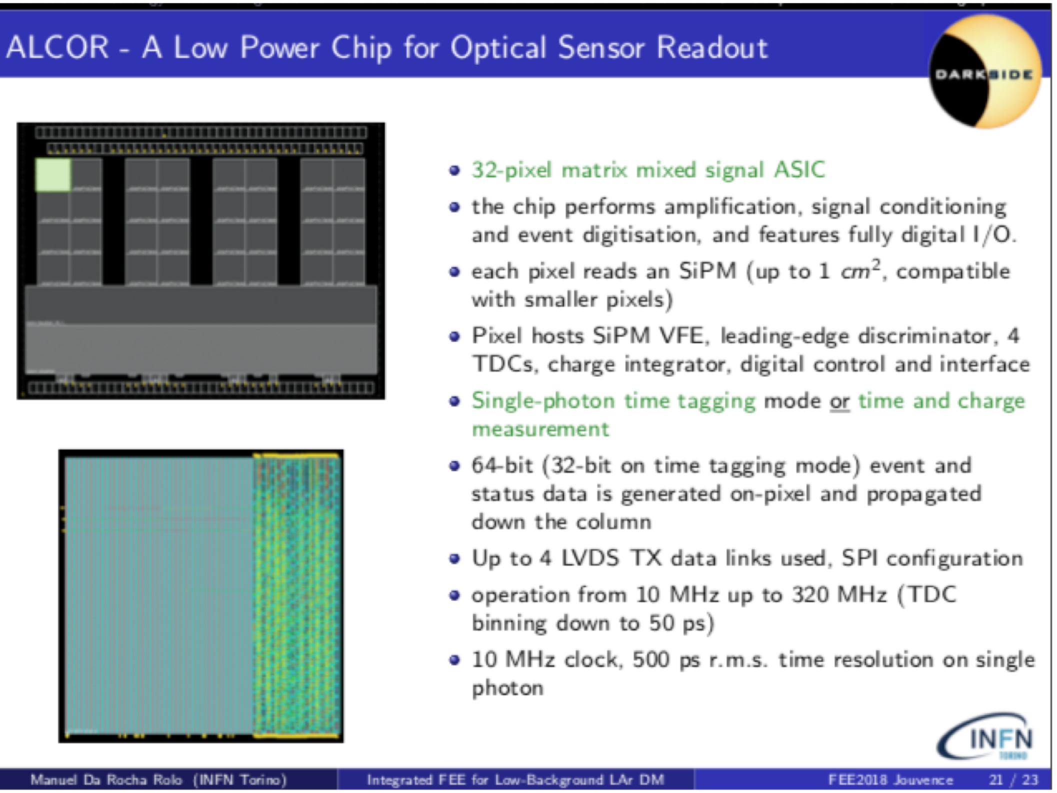




- SPD looks possible at -30°C/-40°C after annealing!
- 10^{11} seems a manageable fluence for annealing
- DCR penalty factor (pre-irradiation – post-annealing)@10^{11}: **200**
- Further lowering temperature is another option to explore
- Note, however, that with a 200 penalty factor we would have a $2 \cdot 10^5$ Gbit/sector throughput, still manageable... (and close to what "declared" @Temple)

Ref:
M. Calvi et al.
Nuclear Inst. and Methods in Physics Research, A 922 (2019) 243–249

Front-End electronics for SiPM

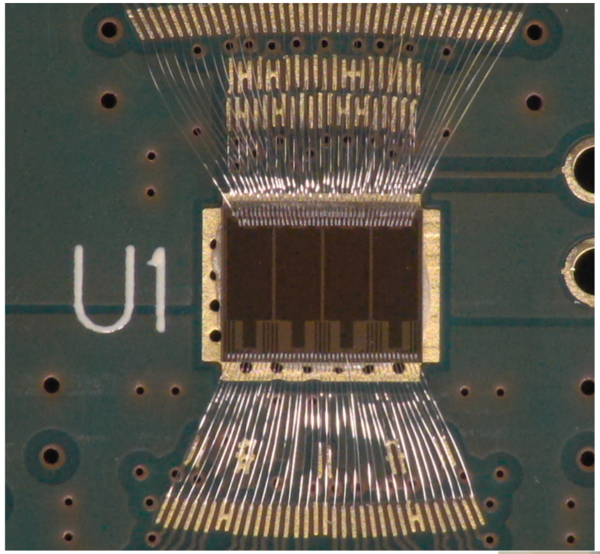


ALCOR:

- Developed by INFN Torino originally for a Darkside application
- Optimized for cryo operation
- First samples received from foundry in 2020

- Specs would match – at first order – requirements for EIC, but an ALCOR++ optimised for RICH application will be next step
- INFN Torino → characterization with a FBK SiPM sensor
- INFN Bologna → development of readout card FPGA-based (connected to ASIC carrier via fast serial links: as in DAQ for ARCADIA)

INFN-TO



- Test of the ASIC expected to end by ~2020
- Based on 2020 results and coupling with SiPM → 2022 for an ALCOR v2.0 better tailored for EIC requirements

"smoke test done, absorption ok (6 mW/ch), comms. test with FPGA on-going"

"Drawing phase"

SiPM Readout

Activity in the last 3 months:

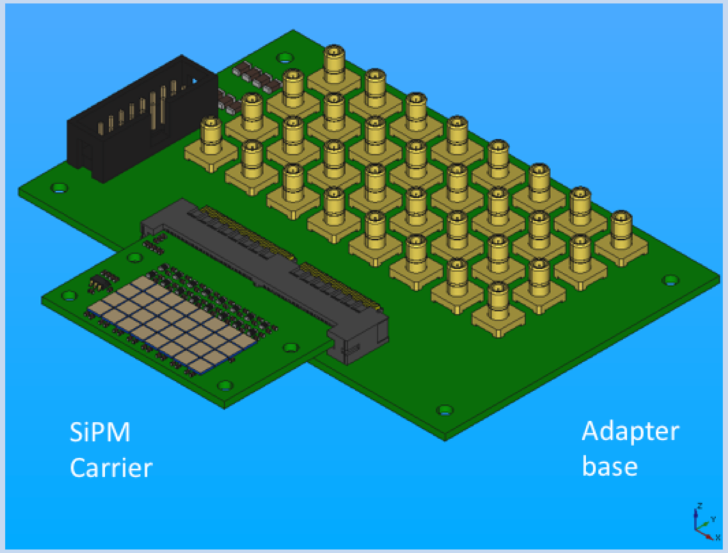
5x **SiPM Carriers**
Hamamatsux2, SensL, Bradcom, FBK
Minimum components + edge connector for irradiation and anneling
Stage: design and procurement

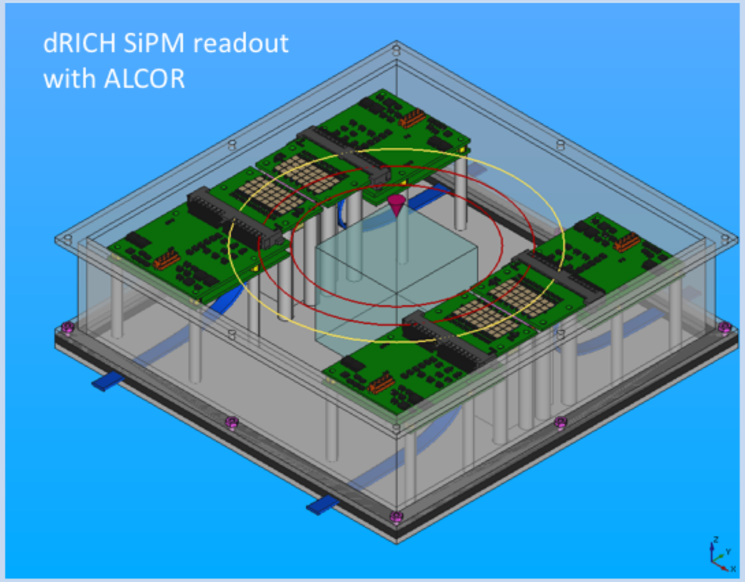
2x **Adapters_base**
Slow and fast SiPM signals
Direct connection for characterization
Stage: design and procurement

2x. **Adapter_alcor**
Slow and fast SiPM signals
Connection to ALCOR and Firefly readout
Stage: design

1x **ALCOR test board**
ALCOR chip validation
Stage: delivered and under test

1x **FireFly DAQ**
ToT based readout
Stage: under development and test





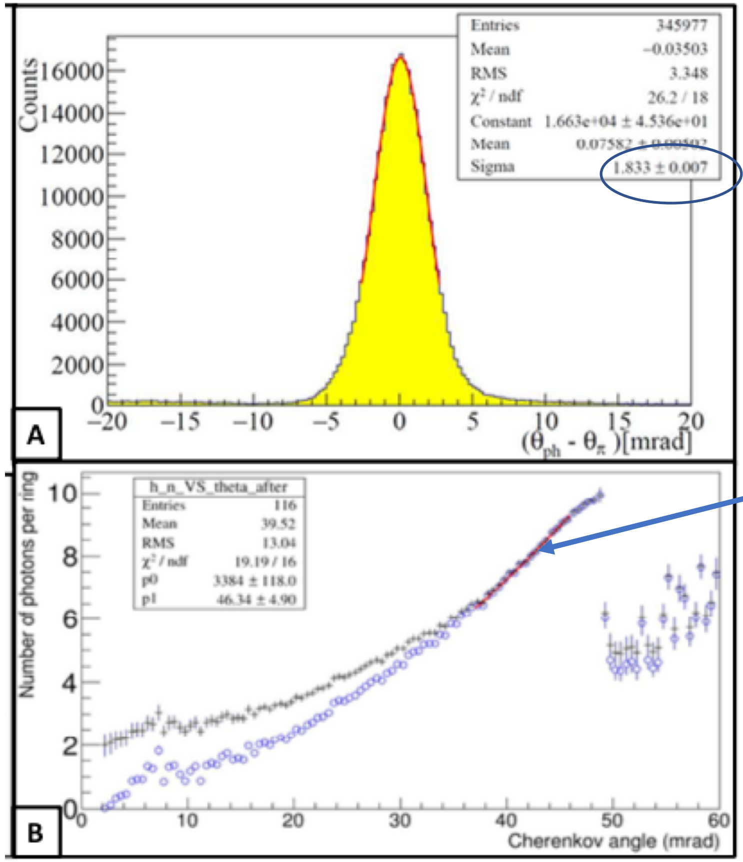
INFN FE/BO/TO

Sensors for RICH: MPGD-based photon detectors

INFN-BA/TS

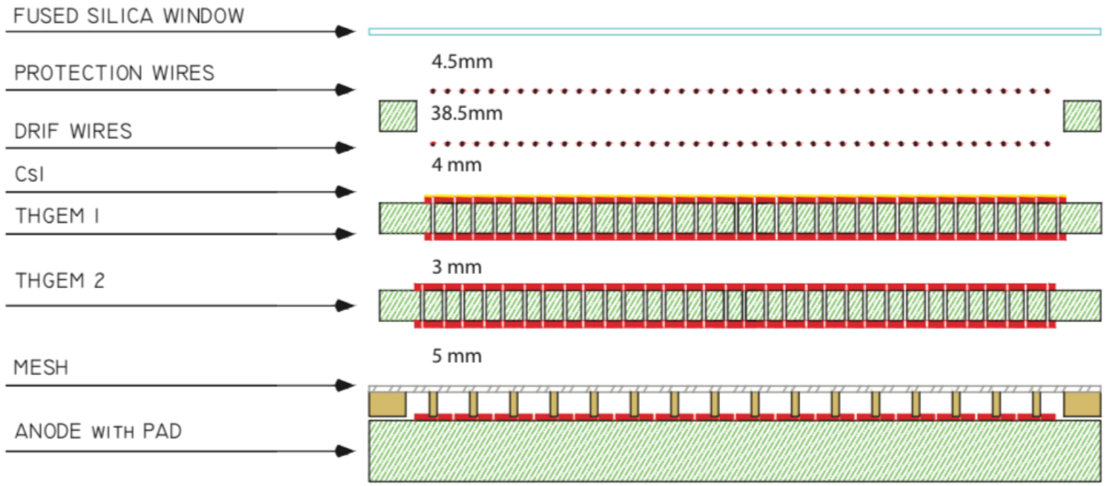
context: COMPASS RICH, sensors in operation since 2016

MPGD-based photon detector
recent COMPASS performance report:
https://arxiv.org/abs/2006.10447



1.8 mrad

from the fit 10-12 photons
at Cerenkov angle saturation

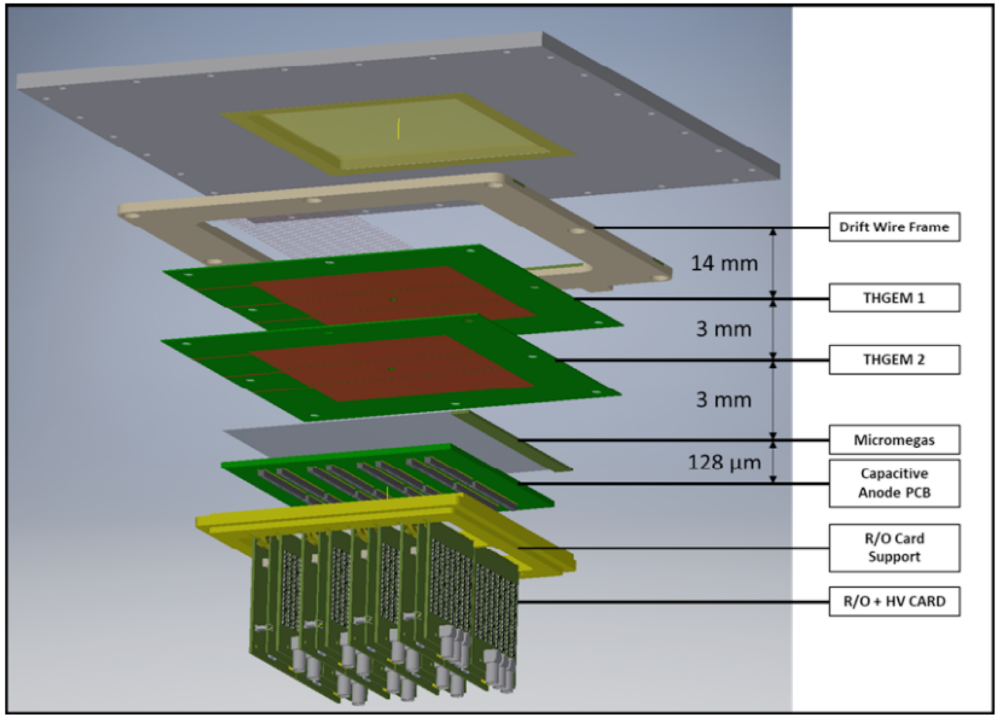


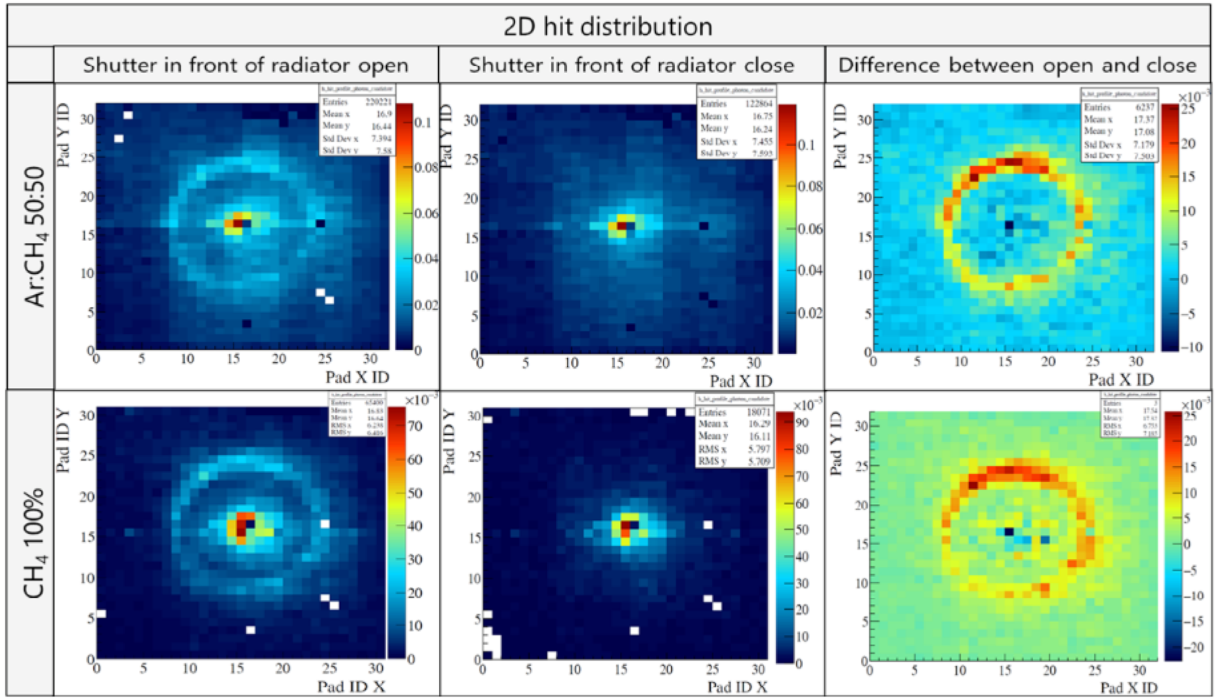
7.5 x 7.5 mm^2 pads

key R&D:
- GEM vs THGEM → improve photoelectron extraction yield?
- improve spatial resolution
- & related electronics!

5 Future prospectives

The THGEM-MM hybrid PD technology could be used for other applications, for instance for a RICH dedicated to PID of high momentum particles at experiments at the future EIC collider [17], where higher space resolution of the PD would be needed because of the more compressed geometry that imposes a reduced lever arm.





https://arxiv.org/abs/2006.10447
https://arxiv.org/abs/1908.05052

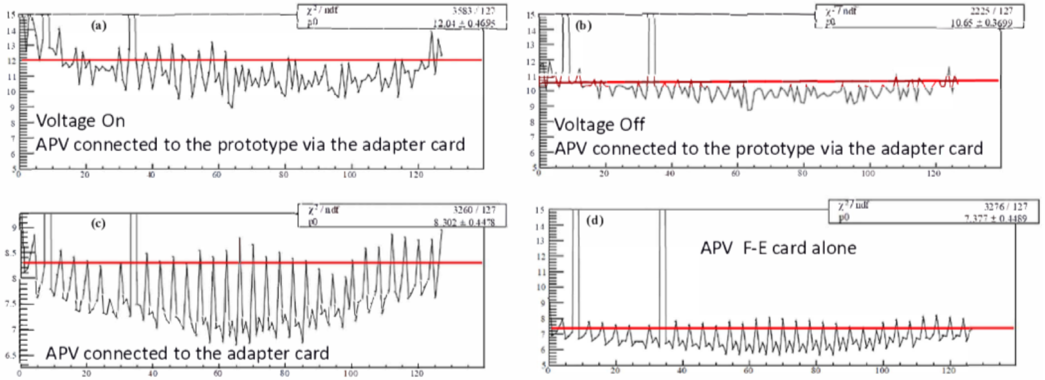
prototype with 3.5 x 3.5 mm^2 pads (mini-pad prototype)
quartz radiator

Noise studies (from lab+test beam data 2018): noise @3300 el-eq (Compass: 900)

noise level too high for single photon detection:

3σ thr @ 10 k electrons eq!

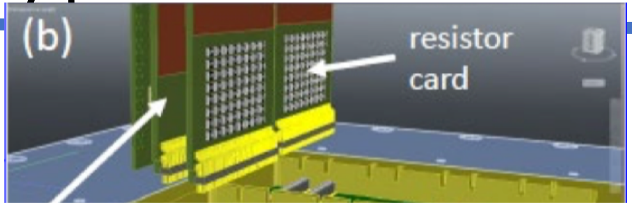
too noisy to determine spatial resolution + efficiency limited at 70%



Optimizing the minipad prototypes

INFN-TS

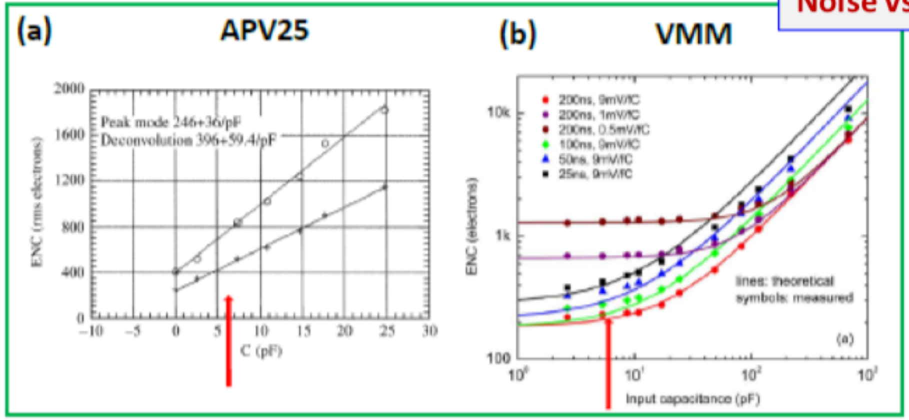
Various improvement strategies to reduce noise problems modifying: HV distribution + FE electronics + PCB design



resistor cards providing HV to individual pads near and parallel to FEE cards

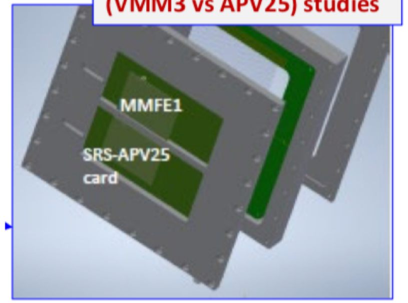
Moving from APV25 to VMM read-out board based:
- low noise at high C + trigger less operations

Noise vs C



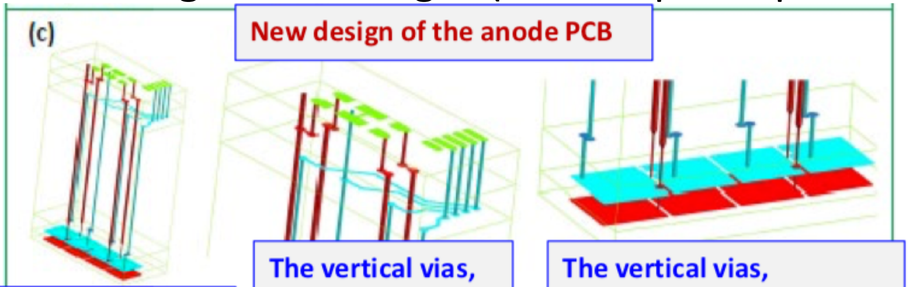
APV25: https://cds.cern.ch/record/1069892/files/cer-002725643.pdf
VMM: http://cds.cern.ch/record/2093606/files/ATL-MUON-SLIDE-2015-822.pdf?version=1

MM for comparative (VMM3 vs APV25) studies



Vertical vias to minimize crossing signal lines + equalization of signal line length (same input capacitance)

New design of the anode PCB



The vertical vias

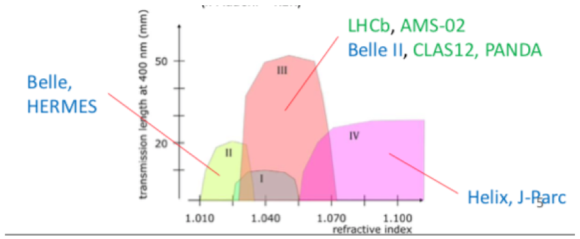
The vertical vias, zoomed view at connector face

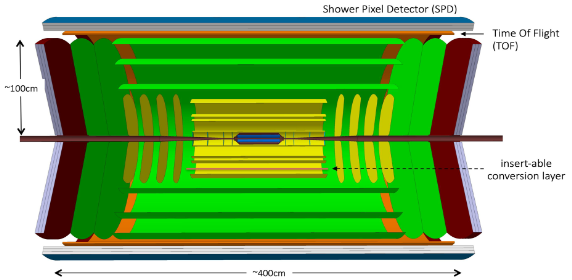
The vertical vias, zoomed view at pad face (in front of micromesh)

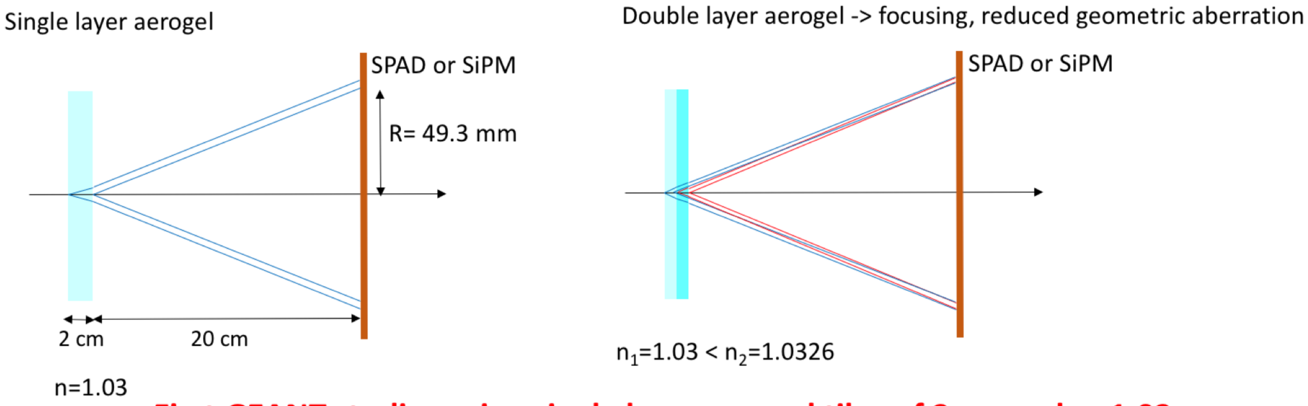
Actually, this was already the 2020 plan, highly penalized by COVID (lab closed @INFN-TS) ☹ → moving these studies to 2021

Radiators for RICH: aerogel

- Aerogel critical component behind dRICH design. Currently two main producers Budker (Russia) [CLAS12 supplier] (hydrophobic) and Chiba University (hydrophilic)
- 2020 Developments (INFN-BA) Meeting with Belle II experts (I. Adachi and M. Tabata) on 15th of May
  - Reviewed main production procedures and aerogel parameters, good improvement of transparency (l_{scatt} = 70 mm at 400 nm for n ~ 1.03-1.05)
  - Production timeline: 60 batches of 28 tiles of 18x18x2 cm^3 in 1 y, to cover 25 m^2 with two layers assuming a yield of 60% one needs 90 batches ~ 1.5 y
  - Cost ~ 10 kEuro/ batch
- Aerogel samples procurement with LHCb from Chiba University in progress, (agreement with LHCb for common R&D) → Optical characterization to be performed in lab and test-beam
- Synergy with an ALICE initiative (consider a RICH within ALICE 3.0 to complement TOF at high-p)



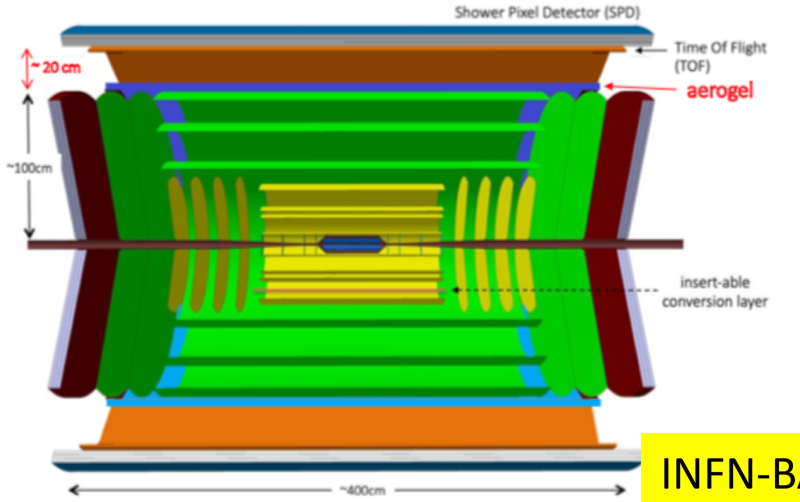




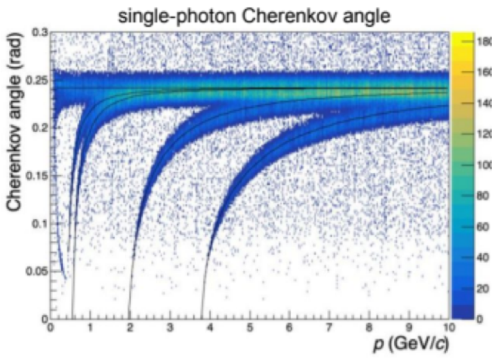
First GEANT studies using single layer aerogel tiles of 2 cm and n=1.03

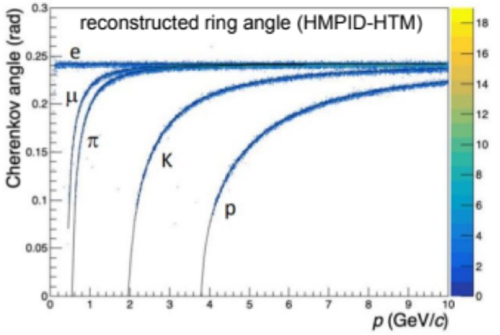
1

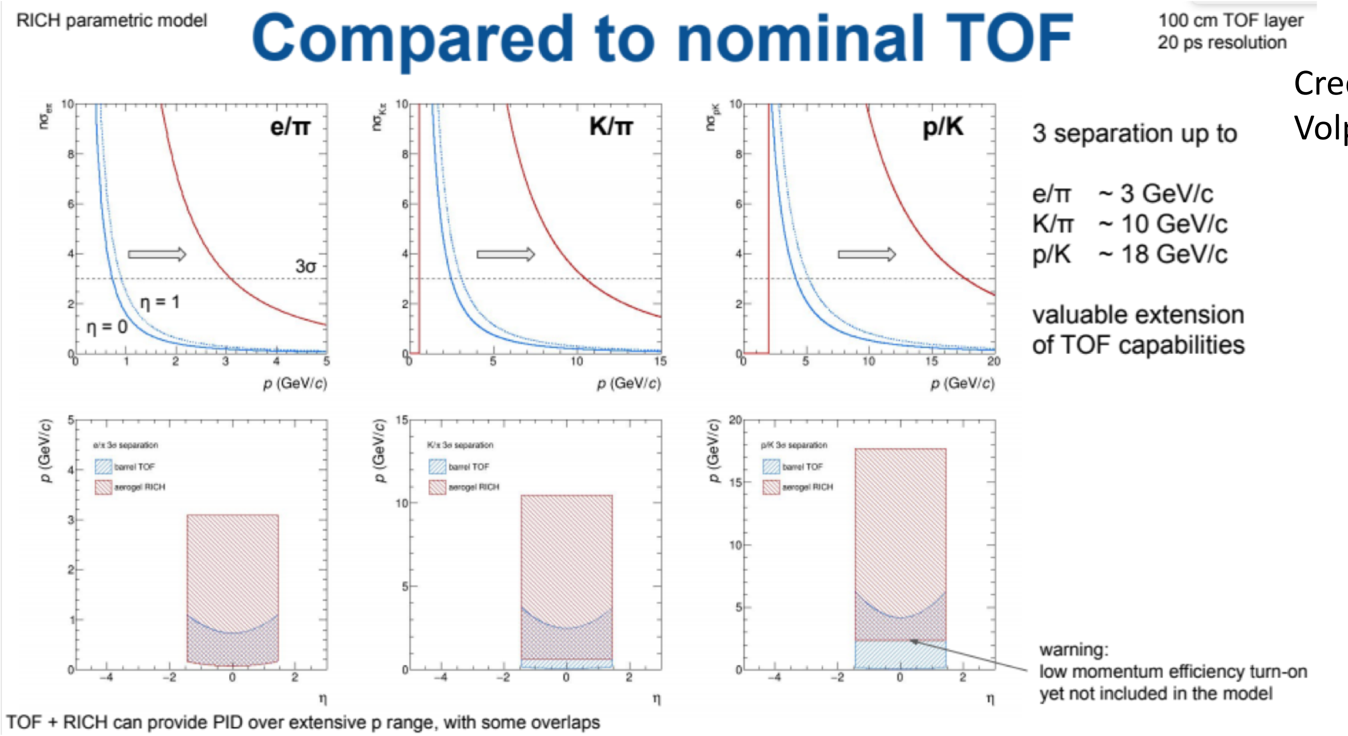
mary



Aerogel for RICH: simulations and synergies







Credits: E. Nappi, R. Preghenella, G. Volpe + A. Di Mauro

Synergies

ALICE → EIC: access to a 2nd potential provider for aerogel (a radiator critical for RICH@EIC)

EIC → ALICE: R&D for the silicon-based sensor (which could possibly allow both MIPs and single photon detection) → see SiPM studies (radiation tolerance, Single Photon + timing)

Radiators for RICH: Argon

Ref. Silvia@YR1 ("Philadelphia"): https://indico.bnl.gov/event/7449/contributions/35912/attachments/27095/41303/DallaTorre_RICH_high-p_March2020_Temple.pdf

The issue: fluorocarbon gas mixtures are not eco-friendly!

→ not easy to predict availability & costs in ten years from now

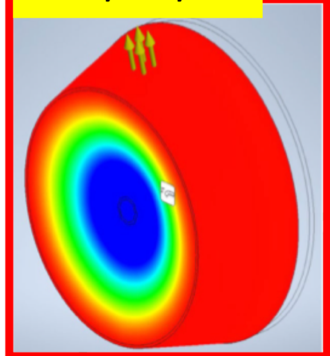
GWP: CF_4 4400, C_2F_6 6200, C_4F_{10} 4800

Why fluorocarbon?
"dense" → many photons
small chromaticity → good angular resolution

Idea: use noble gas (Ar) at high pressure (low chromaticity and make it dense)

- → develop vessel studies (keep high pressure/limited material budget) + simulations (LNS/BA)
- → test with dRICH prototype (FE, RM1, LNF)
- → (at Stonybrook activity looking at MPGD operating at high pressure)

LNS/BA/TS



PRESSURIZED Ar vs FLUOROCARBONS

		VISIBLE (bialkali with ext. UV glass window)						CsI & quartz window						CsI ~ 120 nm (windowless RICH)					
gas	P (bar)	(n-1) $*10^6$	σ (n-1) $*10^6$	θ_max (mbar)	σ_θ (mbar)	σ_θ / θ_max (chrom. only) (%)	n_ph/m (β = 1)	(n-1) $*10^6$	σ (n-1) $*10^6$	θ_max (mbar)	σ_θ (mbar)	σ_θ / θ_max (chrom. only) (%)	n_ph/m (β = 1)	(n-1) $*10^6$	σ (n-1) $*10^6$	θ_max (mbar)	σ_θ (mbar)	σ_θ / θ_max (chrom. only) (%)	n_ph/m (β = 1)
CF_4	1	497	11.5	31.5	0.4	1.2	10.0	545	[illegible]	[illegible]	[illegible]	0.6	2.5			33.2	0.83	2.5	12.2
C_4F_{10}	1	1367	46	52.3	0.9	1.7	27.5	1564	[illegible]	[illegible]	0.5	1.0	7.2						
Ar	1	294	10	24.2	0.4	1.7	5.9	340	[illegible]	[illegible]	0.3	1.1	1.6						
Ar	1.5	441	15	29.7	0.5	1.7	8.9	510	11	[illegible]	0.3	1.1	2.3						
Ar	2	588	19.5	34.3	0.6	1.7	11.8	580	14	34.1	0.4	1.2	2.7						
Ar	3	882	29.5	42.0	0.7	1.7	17.7	1020	[illegible]	45.1	0.5	1.1	4.7						
Ar	3.5	1029	34.5	45.3	0.8	1.7	20.7	1190	[illegible]	48.8	0.5	1.1	5.5						

Not enough photons

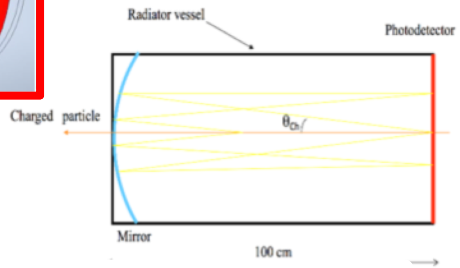
?

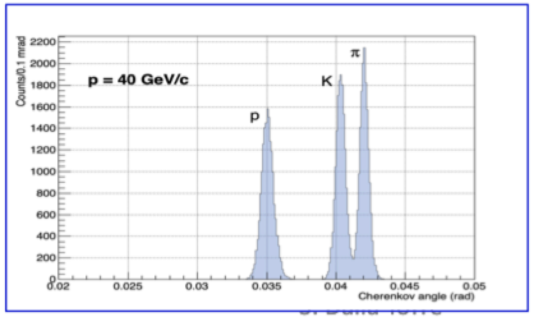
Promising: enough photons and Chromatic effect as for C_4F_{10}

The promising testbeam results with CF_4 suggest exploration here
If successful →
minimum material budget

1st YR meeting, 19-21 March 2020

h-PID @ high p





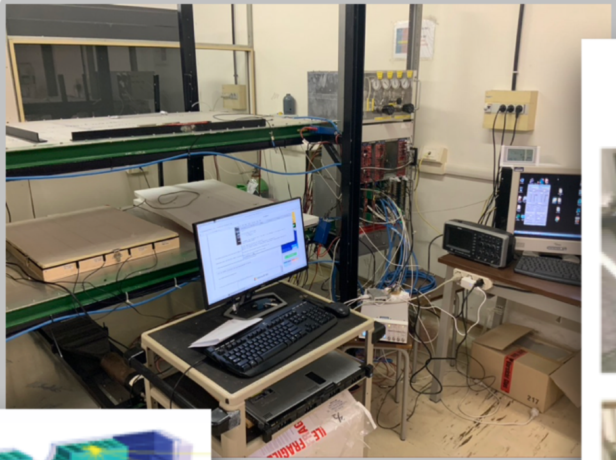
Streaming Readout (SRO) (+ calorimetry)

Goal:

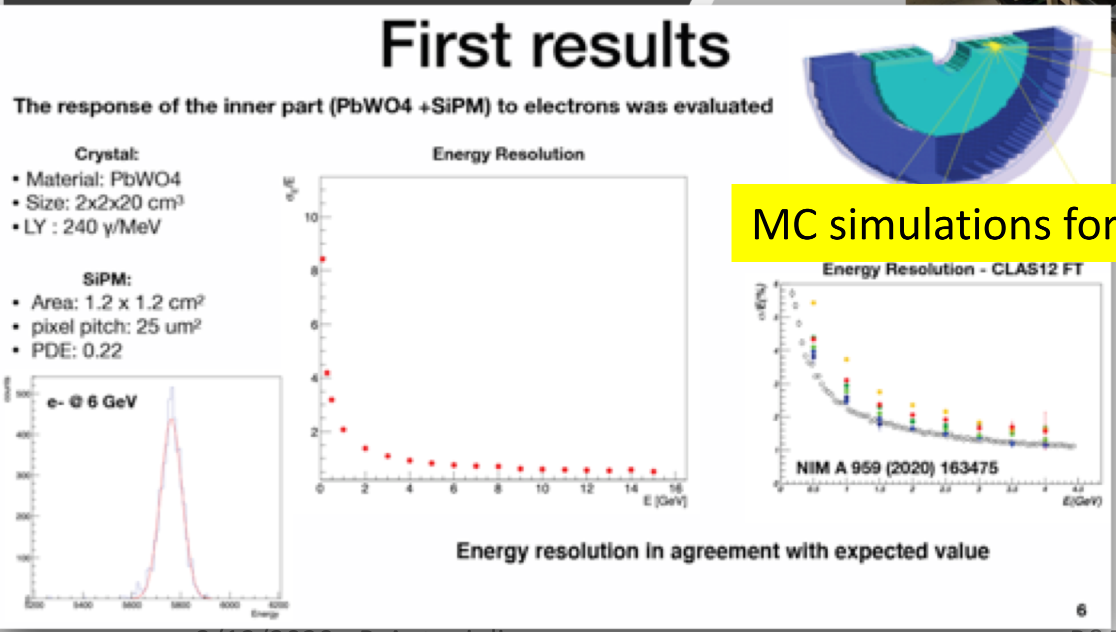
- Measure the main parameters of a large number of samples (light yield, rad. length, timing)
- Test different readout options

Infrastructure:

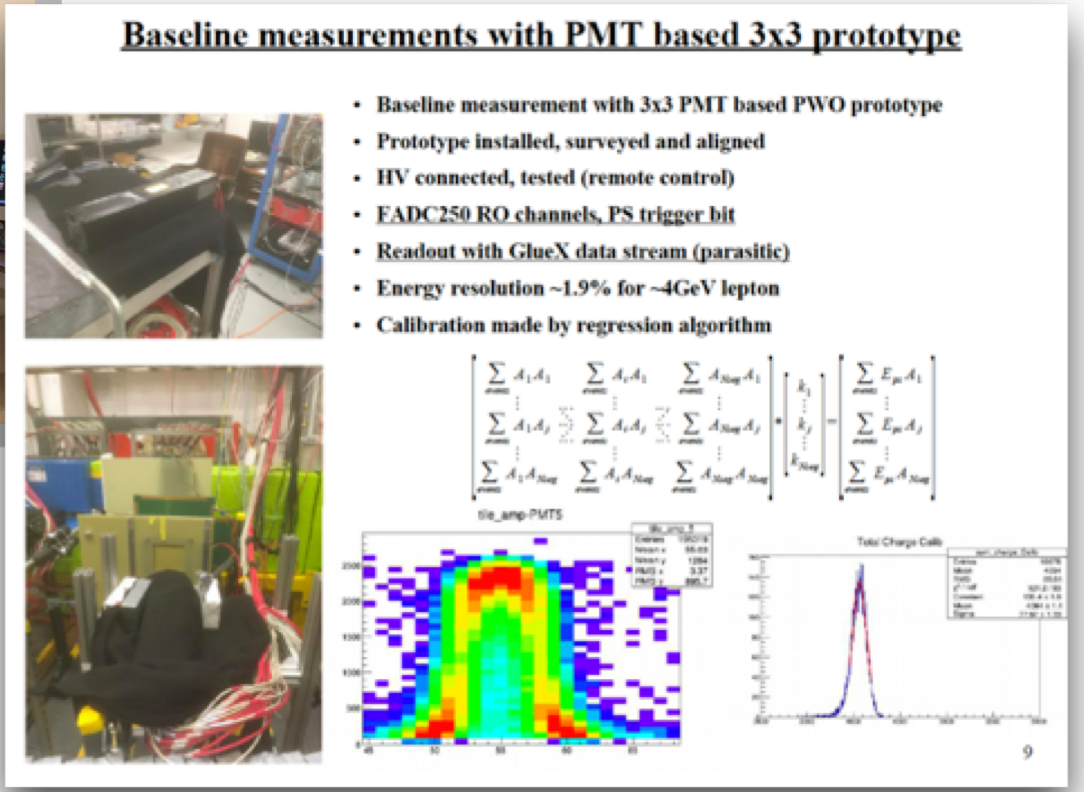
- A EEE-like telescope (three Multi-gap Resistive Plate Chambers, 80x160 cm^2) has been assembled to map out material response over large area in short time – synergy with ALICE/EEE
- Using streaming readout boards developed at INFN for EIC streaming readout – compatible with PMT/SiPM/APD
  - Absolute time stamp from readout board allows to correlate hits with cosmic—rays tracks from chambers
- Streaming readout system currently being assembled (milestone 2020). Based on WaveBoard digitizer + TriDAS DAQ SRO system
  - GPS synchronization between telescope and SRO verified
  - SRO DAQ under installation
  - Test setup while waiting for scintillating glass samples: plastic scintillator plate with 4 SiPM readout. Test coincidence between two systems



As part of EIC eRD1, INFN-GE supports R&D on PbWO and new Scintillating Glass (activity led by CUA): characterization



MC simulations for EIC EM calo



•Participate to the Hall-D beam-test (2020/2021), providing expertise for a SiPM-based readout and participating to the data analysis.

Credit: M.Bondi, V.Berdnikov, S.Grazzi

SRO: validate the new DAQ approach

As eRD23 + YR, INFN is contributing to define a SRO framework for EIC by defining the EIC SRO specs (YR) → new FE electronics on-site + testing solutions @JLab (Hall-B and Hall-D)

Strong involvement in the YR activity and development/test of the FE digitiser (WaveBoard) designed by INFN-RM1 and INFN-GE.

2020 SRO VI workshop
https://indico.jlab.org/event/378/

Streaming readout activity @ INFN 2019/2020

- We participate to the eR&D-23 activity: monthly phone meetings and dedicated workshops (twice per year).
  - Last meeting: May 2020 (remote-only)
- Strong involvement in the EIC »Yellow Report» initiative.
  - A. Celentano is co-convener of the «Readout and DAQ» working group.
- Main experimental activity: **validation of the new DAQ approach.**

DAQ/Electronics

July 2020
- 30 Jul July meeting

June 2020
- 25 Jun Readout ASICs meeting: VMM and Saclay chips
- 19 Jun Readout ASICs meeting: SAMPA and TIGER

April 2020
- 29 Apr Second April Meeting
- 15 Apr April meeting

March 2020
- 11 Mar Yellow report meeting - preparation for Temple

February 2020
- 17 Feb Kick-off meeting

EIC DAQ
Ongoing discussi

The current focus of the working group, concerning the DAQ system, triggering and building is necessary and (ii) if we should save raw dat

Conveners' mail after Temple meeting:

Dear colleagues,
at our last meeting (see: https://indico.bnl.gov/event/8222/) we had contributions from Markus Die strategies, and from Rosen Matev, who presented the ongoing efforts at CERN for streaming-read interesting thoughts regarding the points that we, as Readout and DAQ working group, should thi system. You can find these in the last slides of Markus presentation.

- Is software event triggering and building necessary?
- Could we drop raw data and keep only the reconstructed part?
- Same question concerning the event selection?
- What sort of calibrations would be necessary?

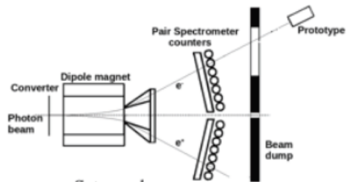
In the following, we'll briefly review the status of the ongoing discussio for this at the end of this meeting!
- *Can we all agree on a possible general scheme for the EIC detect*
- *What is required next?*

Dedicated personel:
- 1 post-doc hired to work through "Ministero degli Esteri - progetti di Grande Rilev
- 1 master thesis student, currently applying to PhD program

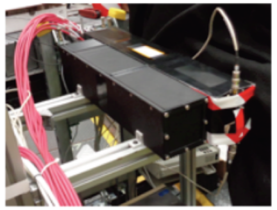
Streaming RO - Hall-D tests

V.Berdnikov, T.Horn

- HallD parasitic test beam area, secondary lepton beam with energy range (3-6) GeV
- *Triggered* DAQ with NPS and FCALII prototypes (baseline)
- New prototypes PbWO/SciGlass SiPM or PMT photosensors (3x3 matrix)
- SRO: preamps, fADC or WaveBoard digitizers



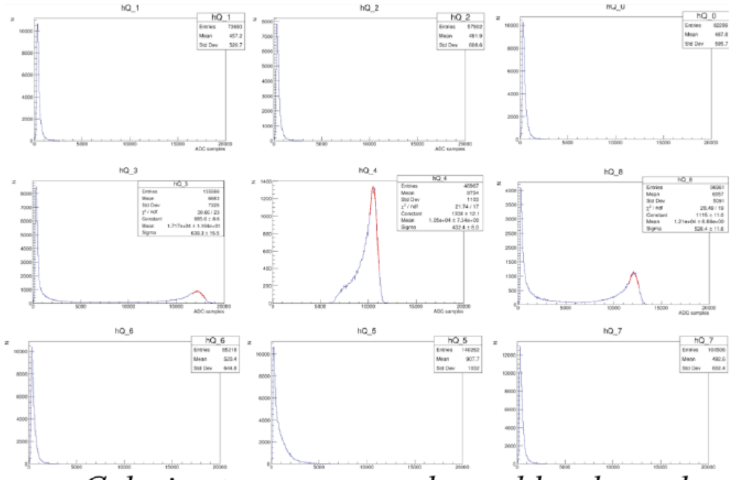
Setup scheme


SiPM(left) & PMT(right) cal. prot.


Waveboard

Spring/summer run 2020 HallD tests:
- 3x3 PMT based PWO prototype installed
- Baseline performance established with GlueX triggered DAQ (parasitic mode)
- Central cell events hits (PS tile 59) correspond to ~ 4.5GeV lepton
- INFN WaveBoard fADC for SRO tests
- Scintillator pads in front of central cell installed for software L2 trigger
- SRO DAQ cabled/connected and tested

Data analysis in progress


Calorimeter response, channel by channel

On-Beam tests at JLab/Hall-D: a matrix of PbWO+SiPM has been exposed to 4 GeV secondary electron/positron beam using the WaveBoard as front-end readout and TRIDAS + JANA as back end

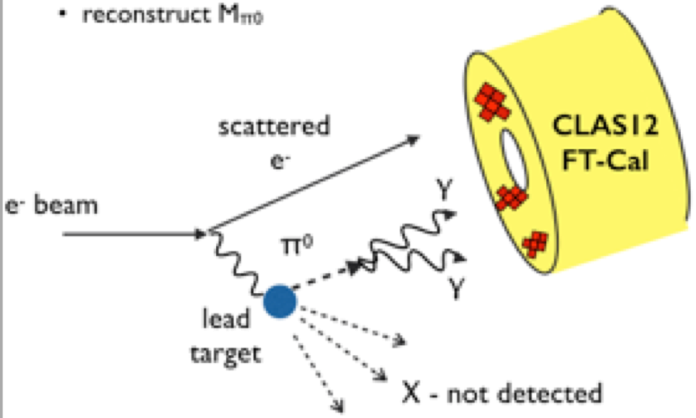
The SRO "demonstrator" at JLab – Hall B (I)

Streaming RO - CLAS12-FT tests

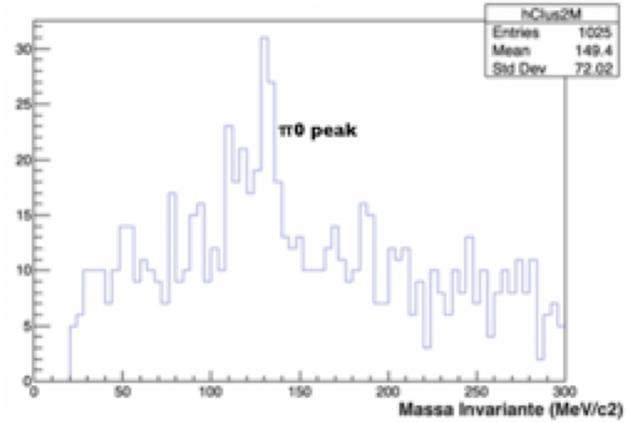
- SRO DAQ full chain test: FE + RunControl + Streaming ROsw + Rec
- On-beam tests
  - Run1: 10.4 GeV electron beam on Pb target in Jan/Feb 2020
  - Run2: 10.4 GeV electron beam on H2 and D2 targets in Aug/Sept 2020
- Hall-B CLAS12 Forward Tagger: Calorimeter + Hodoscope + (Tracker)

Goal:
- collect data with 1-2-3 clusters in FT-CAL
- Identify the reaction
  e H/D2/Al/Pb → (X) e' π^0 →(X) e' γ γ
- reconstruct $M_{\pi 0}$

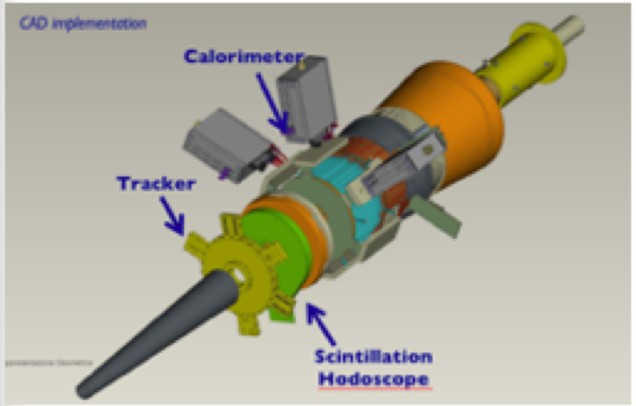
Test equipment
- FT-Cal: 332 PbWO crystals (APD)
- 10+12 fADC250 boards + 2 VTPs (in 2 crates/ROCs)
- FT-Hodo: 232 plastic scintillator tiles (SiPM)
- 15 fADC250 boards

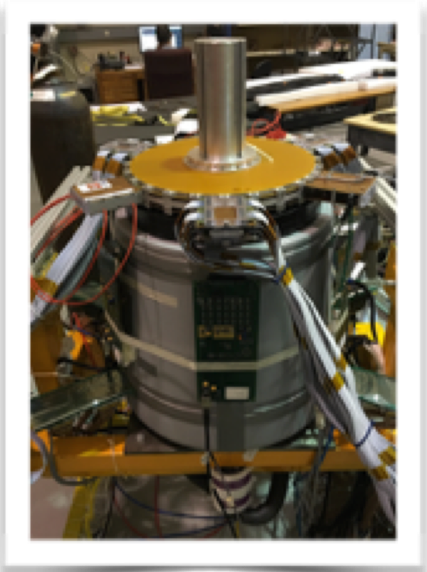


double-clusters (π0) mass obtained from FT-Cal RG-A data fed to TRIDAS



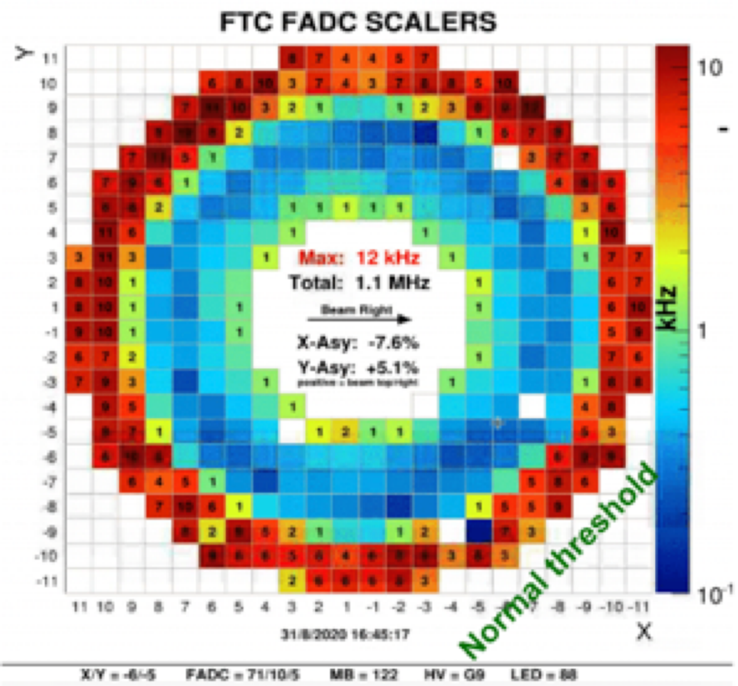
- On beam test in Hall-B used the INFN CLAS12 Forward Tagger as a bench test for a SRO DAQ



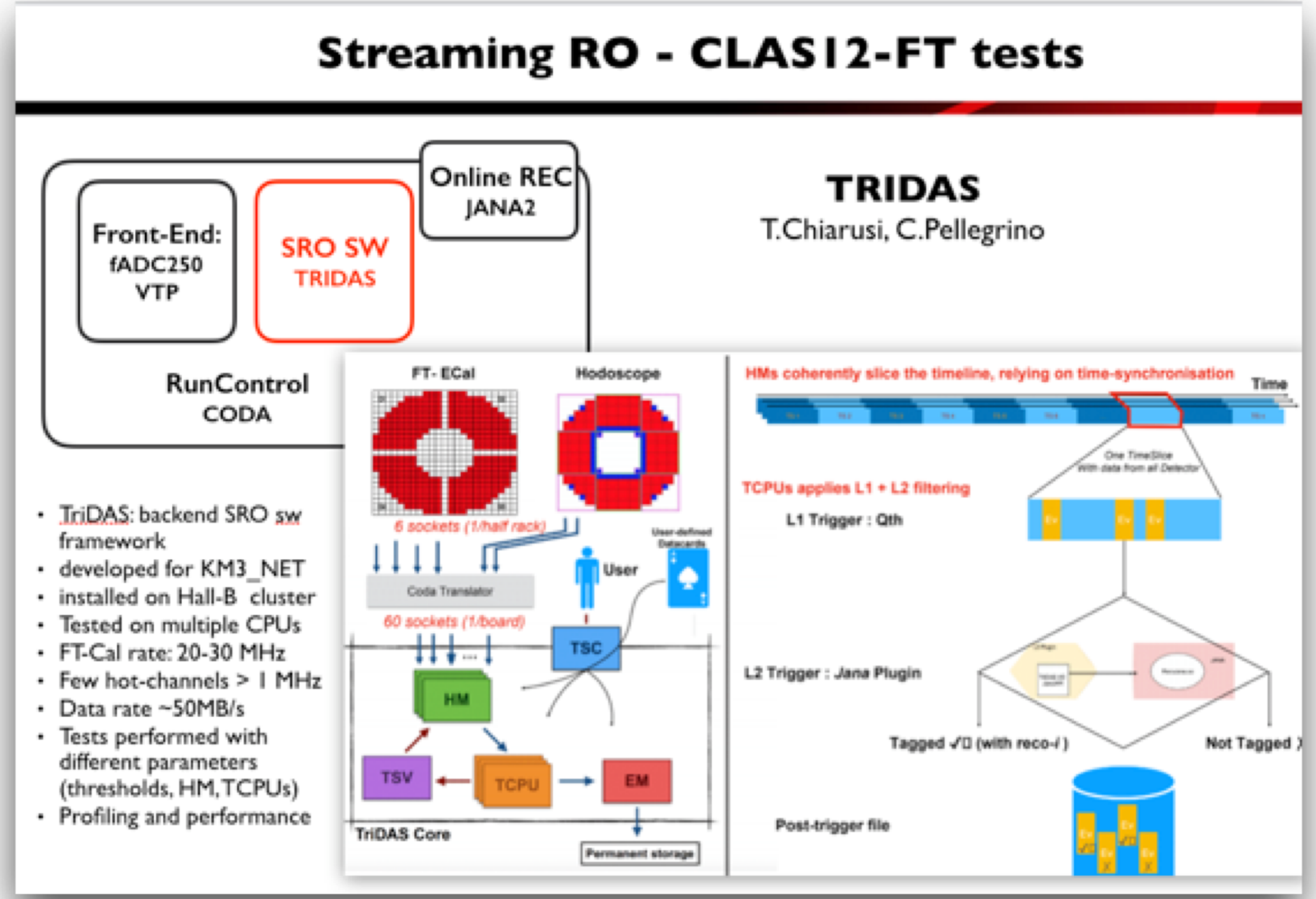


The SRO demonstrator (II)

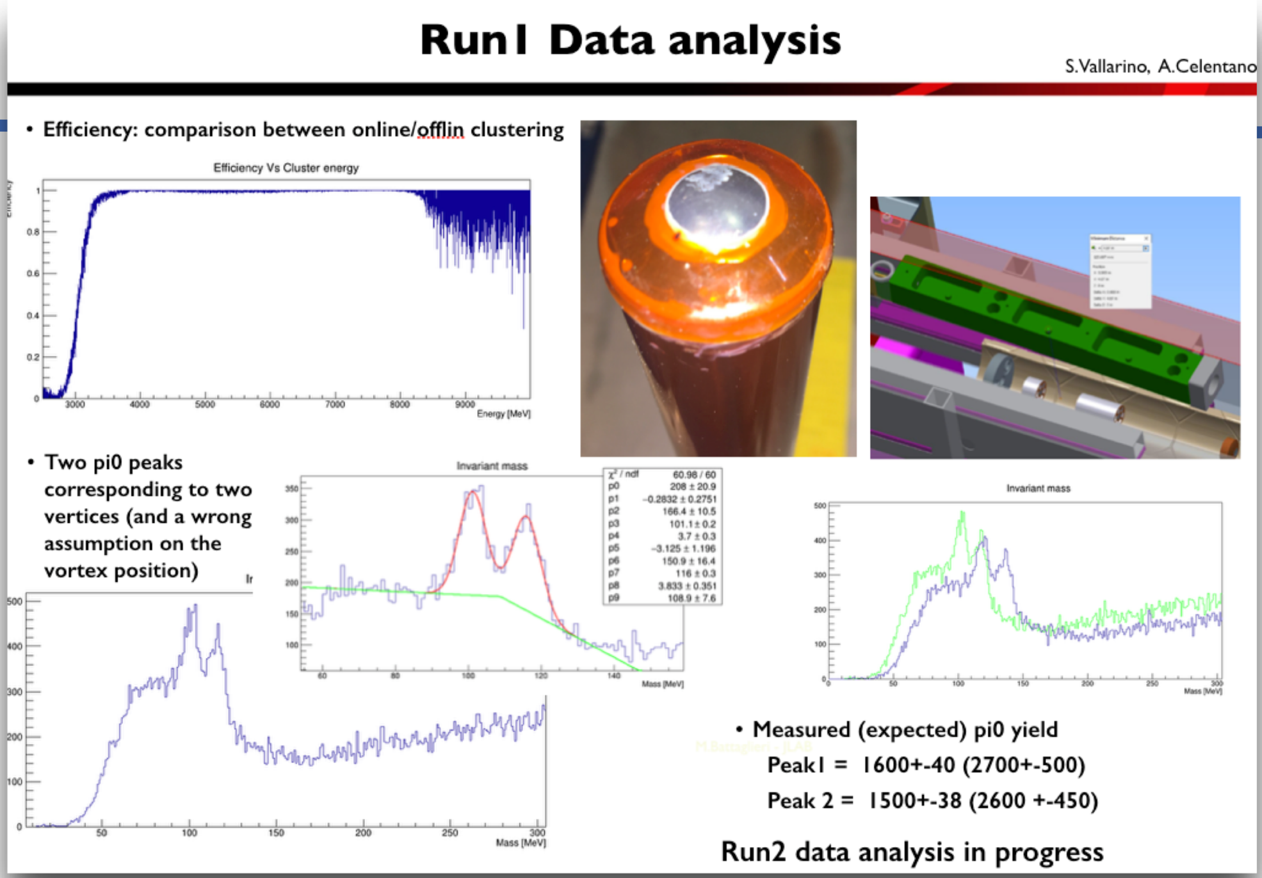
- Tests ran the TRIDAS (INFN-BO) back-end developed for KM3_NET



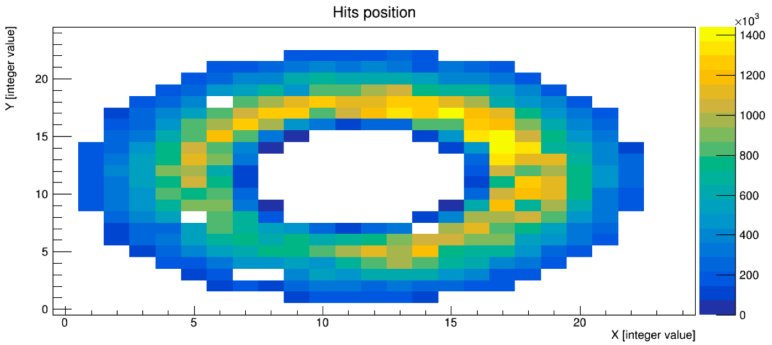
- On-line scalers during Run2



[JLAB Digitizer + VTP (SRO-ready)] + TRIDAS (KM3-NET) + JANAS (GLUEX) → scaled up to 600 channel

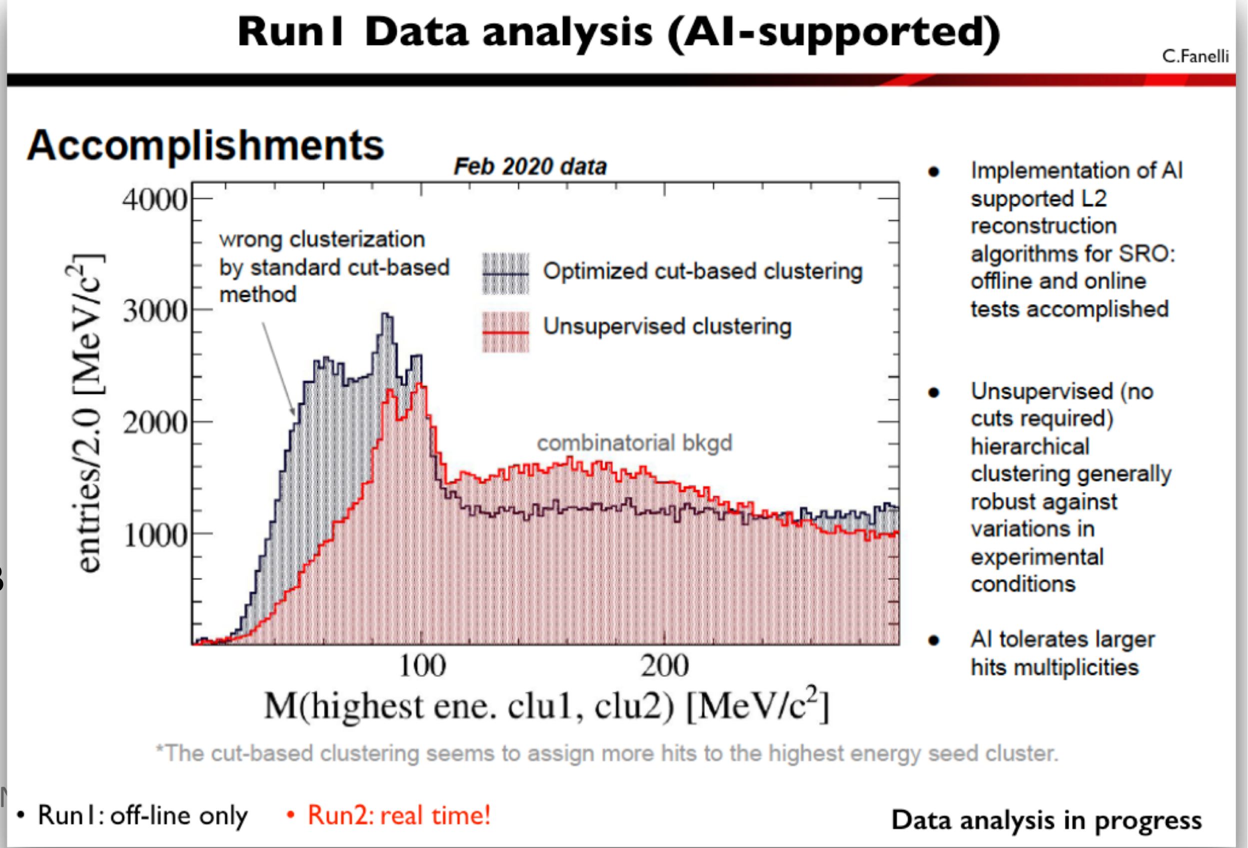


- Preliminary results demonstrated the validity of the framework
- Data analysis is still in progress



hit map Run 1

First use of AI/ML in a real-time Streaming DAQ system



- Based on positive results, join effort JLab/INFN-BO to build a possible EIC SRO framework to be tested with the whole CLAS12 detector
- Expected a deeply involvement of INFN-CNAF in the SRO framework in 2021
- <u>August 2021 target integration up to **5000 ch**</u> + more detectors in Hall-B

Credit: F.Ameli, M.Bondi, R De Vita, T.Chiarusi, C. Fanelli, L.Marsicano, P.Musico, C.Pellegrino, S.Vallarino

A tentative mapping summary & outlook....

R&D focus	INFN	impact on...	INFN synergies	EIC synergies
MAPS/ITS3	BA/TS	detector	ALICE	EIC is joining ITS3
dRICH	FE/RM1/LNF/CT	detector	CLAS12	eRD14
SiPM	BO/FE/TO/TS	sensor + FEE	DARKSIDE (ARCADIA)	eRD14
MPGD	BA/TS	sensor + FEE	COMPASS (ATLAS)	eRD6
aerogel	BA/BO	radiator	ALICE	
high pressure Ar	BA/LNS/TS	radiator		Stonybrook
calorimetry	GE/RM1	detector		eRD1 / CUA
streaming readout	GE/RM1/(BO/CNAF)	DAQ	KM3-NET	eRD23

(+ eRD20 simulations)

- R&D well integrated with EIC main initiatives
- strong synergy for **tracking** with ALICE:
  - 2020 was a good year to integrate this in EIC flow
- promising contributes in different **PID** areas:
  - 2021 will be a key year to deliver results needed to steer choices
- we are leading as coordinator the **SRO** proposal. Other INFN streams of work should now become part of this integration/demonstration effort

system	system components	reference detectors	detectors, alternative options considered by the community		
tracking	vertex	MAPS, 20 um pitch	MAPS, 10 um pitch		
	barrel	TPC	TPC [a]	MAPS, 20 um pitch	MICROMEGAS [b]
	forward & backward	MAPS, 20 um pitch	GEMs with Cr electrodes		
ECal	barrel	Pb/Sc Shashlyk	SciGlass	W powder/ScFi	W/Sc Shashlyk
	forward	W powder/ScFi	SciGlass	Pb/Sc Shashlyk	W/Sc Shashlyk
	backward, inner	$PbWO_4$	SciGlass		
	backward, outer	SciGlass	PbWO4	W powder/ScFi	W/Sc Shashlyk [c]
h-PID	barrel	High performance DIRC & dE/dx (TPC)	reuse of BABAR DIRC bars	fine resolution TOF	
	forward, high p	fluorocarbon gaseous RICH	double RICH combining aerogel and fluorocarbon	high pressure Ar RICH	
	forward, medium p	aerogel			
	forward, low p	TOF	dE/dx		
	backward	modular RICH (aerogel)			
e/h separation at low p	forward	TOF & areogel & gaseous RICH	adding TRD		
	backward	modular RICH & TRD	Hadron Blind Detector		
HCal	barrel	Fe/Sc	RPC/DHCAL	Pb/Sc	
	forward	Fe/Sc	RPC/DHCAL	Pb/Sc	
	backward	Fe/Sc	RPC/DHCAL	Pb/Sc	

+ DAQ
(streaming readout)

(all this despite a very difficult 2020 R&D Zoom-mode)