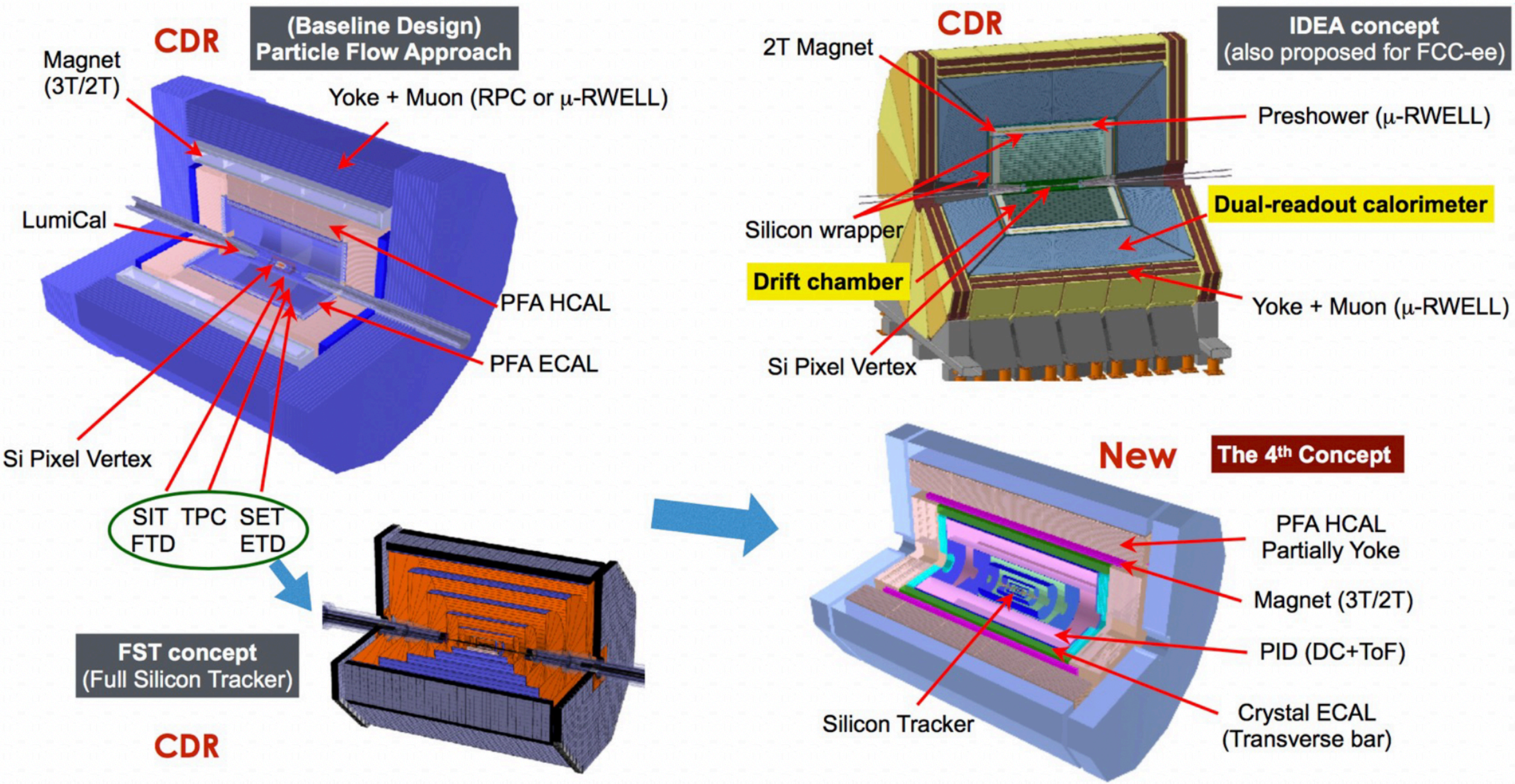
CEPC 2023 International workshop
Edinburgh
06/07/2023

Summary of the Workshop - Detectors

Paolo Giacomelli
INFN Bologna

A very special thank to A. Andreazza, R. Farinelli and I. Vivarelli for their help!

CEPC detector concepts



What was expected from me

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- Beam optics design for the CEPC collider ring — Yiwei Wang — Lecture Theatre C, 40 George Square
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I followed (almost) all the presentations, but decided not to make a normal summary.

Caveat

Any omission or mistake is only mine

Where I would have liked to be instead

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Copyright of this idea: Guy Wilkinson

Where I would have liked to be instead

Many of the most interesting discussions happen outside the sessions.

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Where I would have liked to be instead

Many of the most interesting discussions happen outside the sessions.

There you often hear the real questions and issues that concern people. Here I highlight the most frequent topics of conversations, and give some responses.

Copyright of this idea: Guy Wilkinson

Silicon detectors - the pub perspective

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Silicon Tracker Session

- 10 presentations, covering the vertex detector, tracker and wrapper
- Focused on monolithic pixel sensors
  - R&D for CEPC detectors and other experiments
  - Many processes in the market, CMOS and SOI
- Interesting progresses on advanced technological options
  - stitching for wafer-size detectors
  - 3D integration
  - Mechanics
- TOF detector to complement central tracker dE/dx

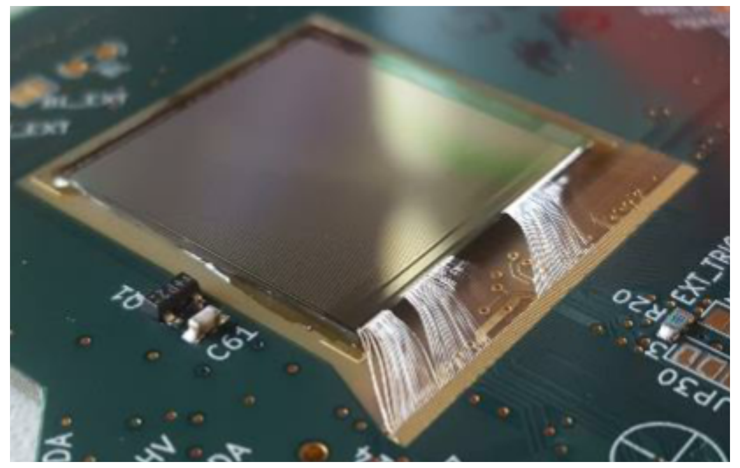
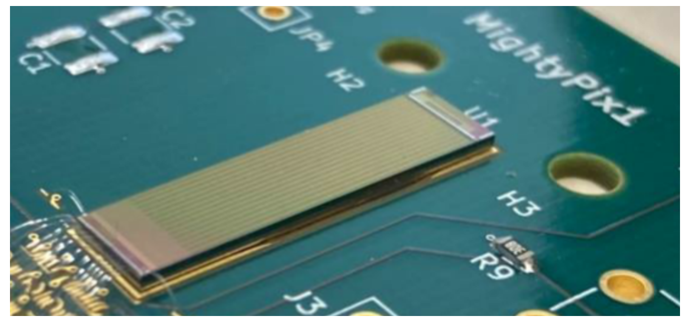
Submission	Process	Time-scale	Target	Main Institute	Comment
LF-Monopix 2	LF 150 nm	v2 produced	rad. hard	Bonn/CPPM	Follow from ATLAS R&D
RD50-MPW 3/4	LF 150 nm	v4 in 0.5-1.0 yr	rad. hard, high granularity	Liverpool	R&D
CACTUS	LF 150 nm	mini-CACTUS v2 submitted	timing	CEA	LHC upgrade & beyond
TJ-Monopix 2	TJ 180 nm	v2 produced	high granularity	Bonn	Belle II, follow up by Obelix
MALTA 2/3	TJ 180 nm	v3 in ~0.5 yr	high granularity	CERN	LHC upgrade & beyond
ARCADIA	LF 110 nm	next version ~0.5 yr	high granularity	INFN	Demonstrator
TJ 65 nm	TJ 65 nm	2nd iteration just submitted	high granularity	IPHC	R&D, ALICE

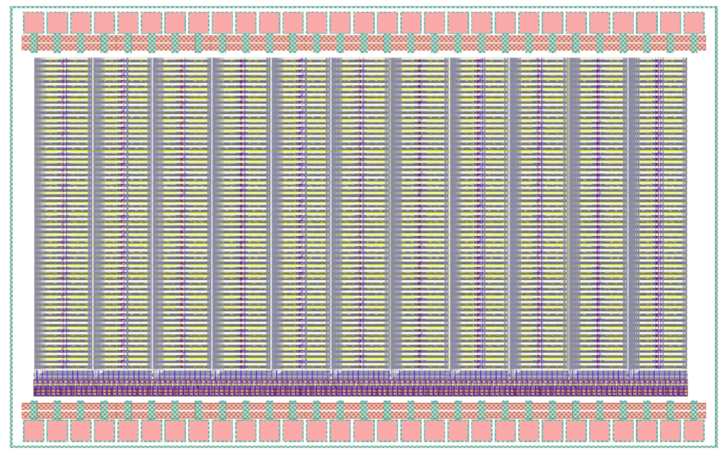
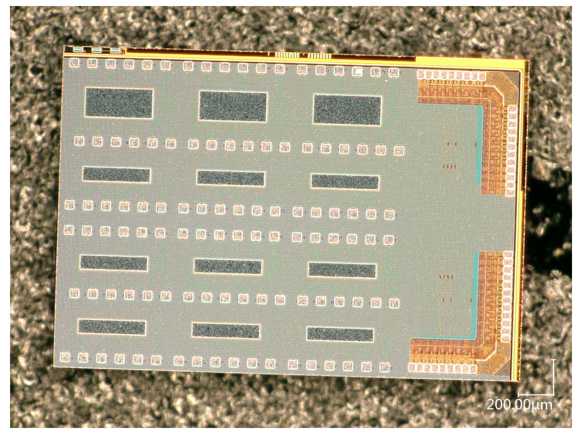
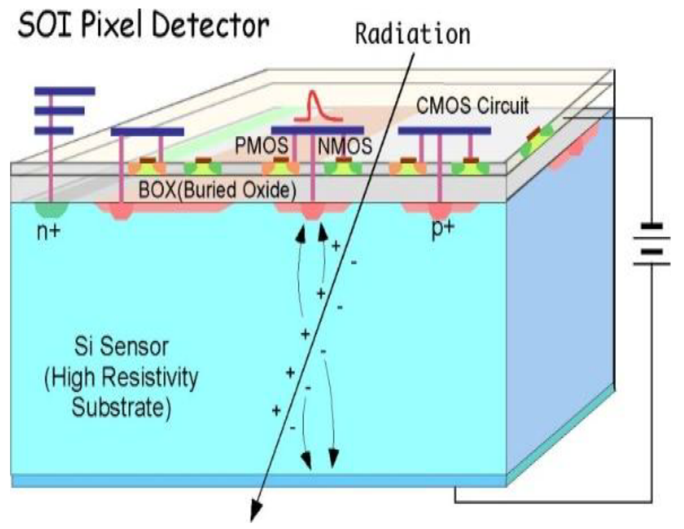
Note:
TJ: Tower
LF: LFoundry

S. Grinstein

But also:
- TSI 180 nm (ATLASPix, MightyPix)
- HLMC 55 nm, SMIC 55 nm
- lapis Semiconductor 200 nm FD-SOI

Y. Li
Y. Zhou

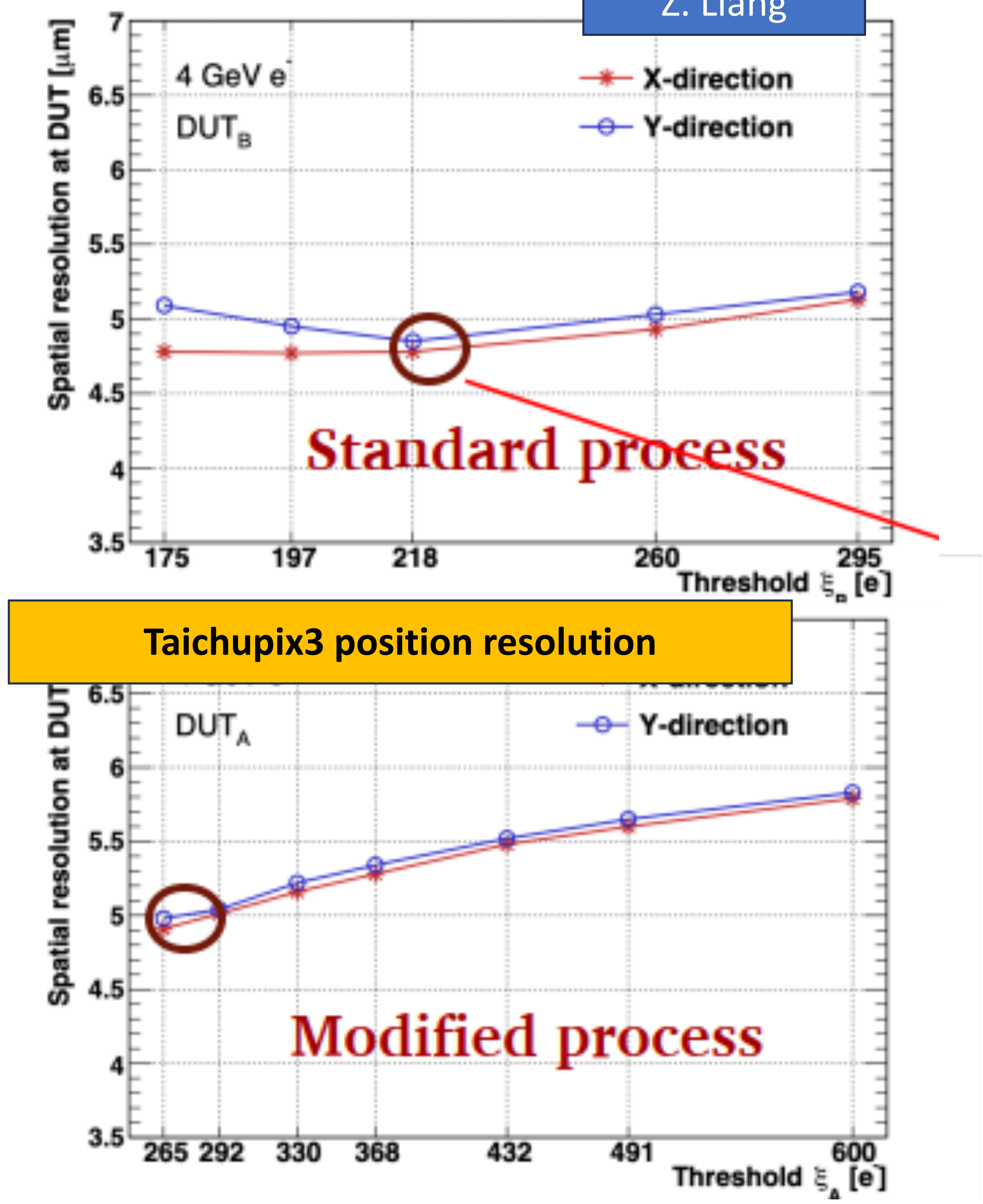



Silicon Tracker: DMAPS

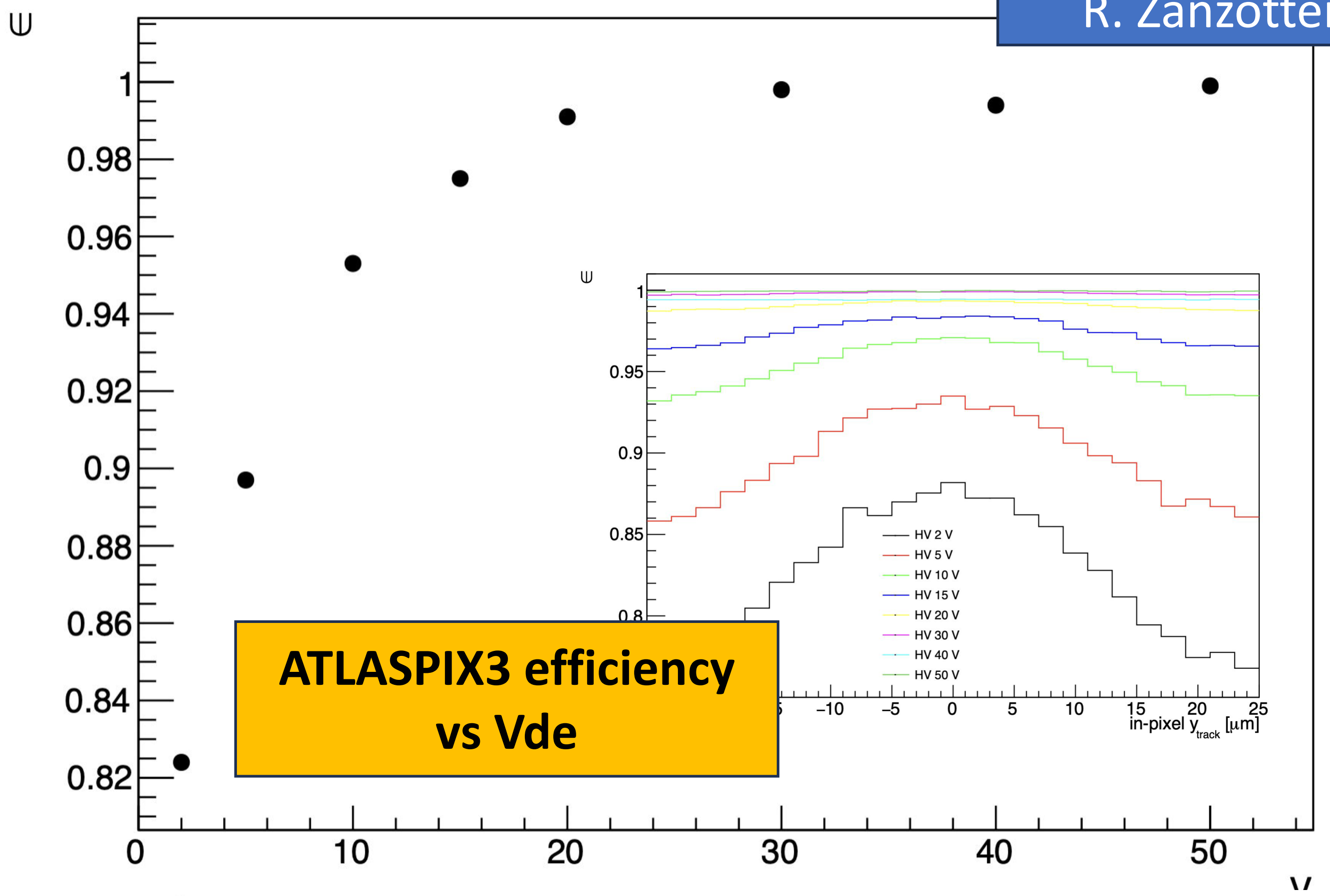
- New interesting testbeam results:
  - learning details of detector features
  - efficiency and resolution within target for vertex and tracker

Z. Liang

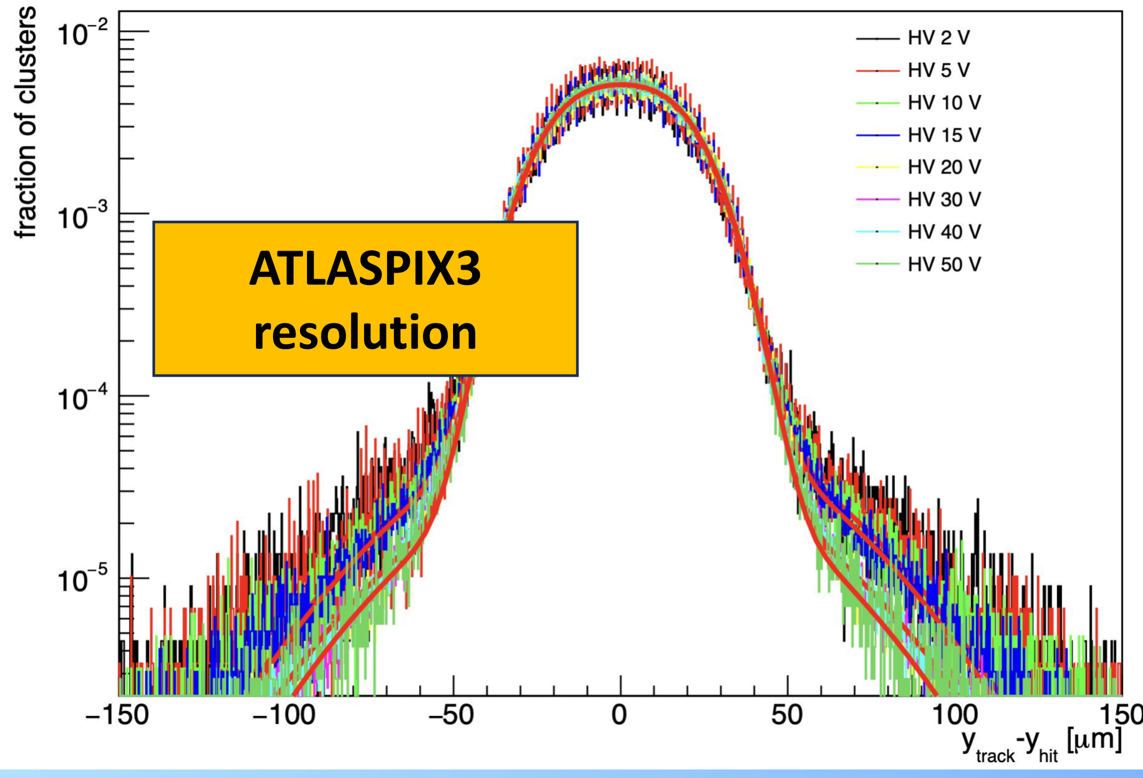


Taichupix3 position resolution

R. Zanzottera

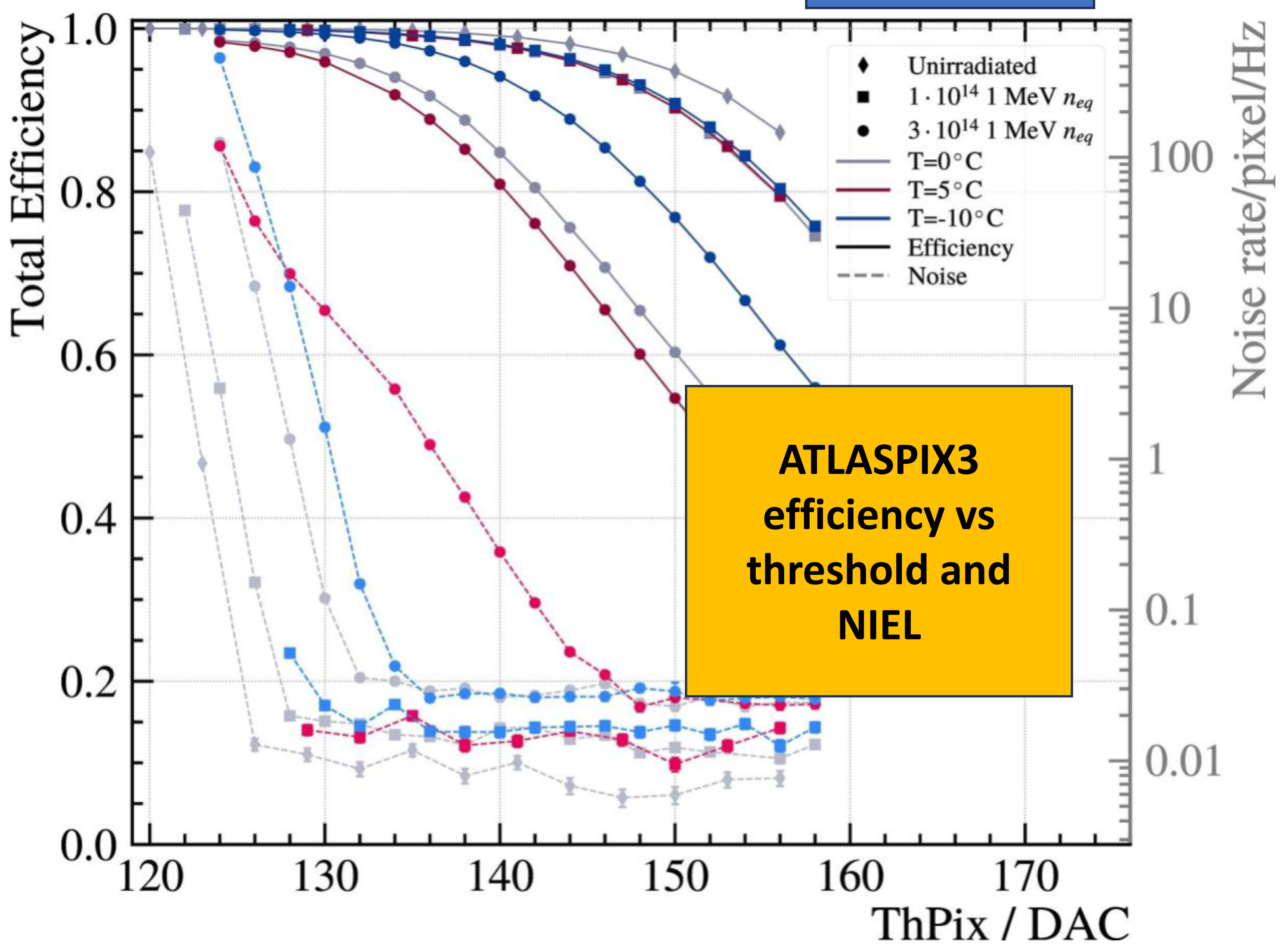


ATLASPIX3 efficiency vs Vde

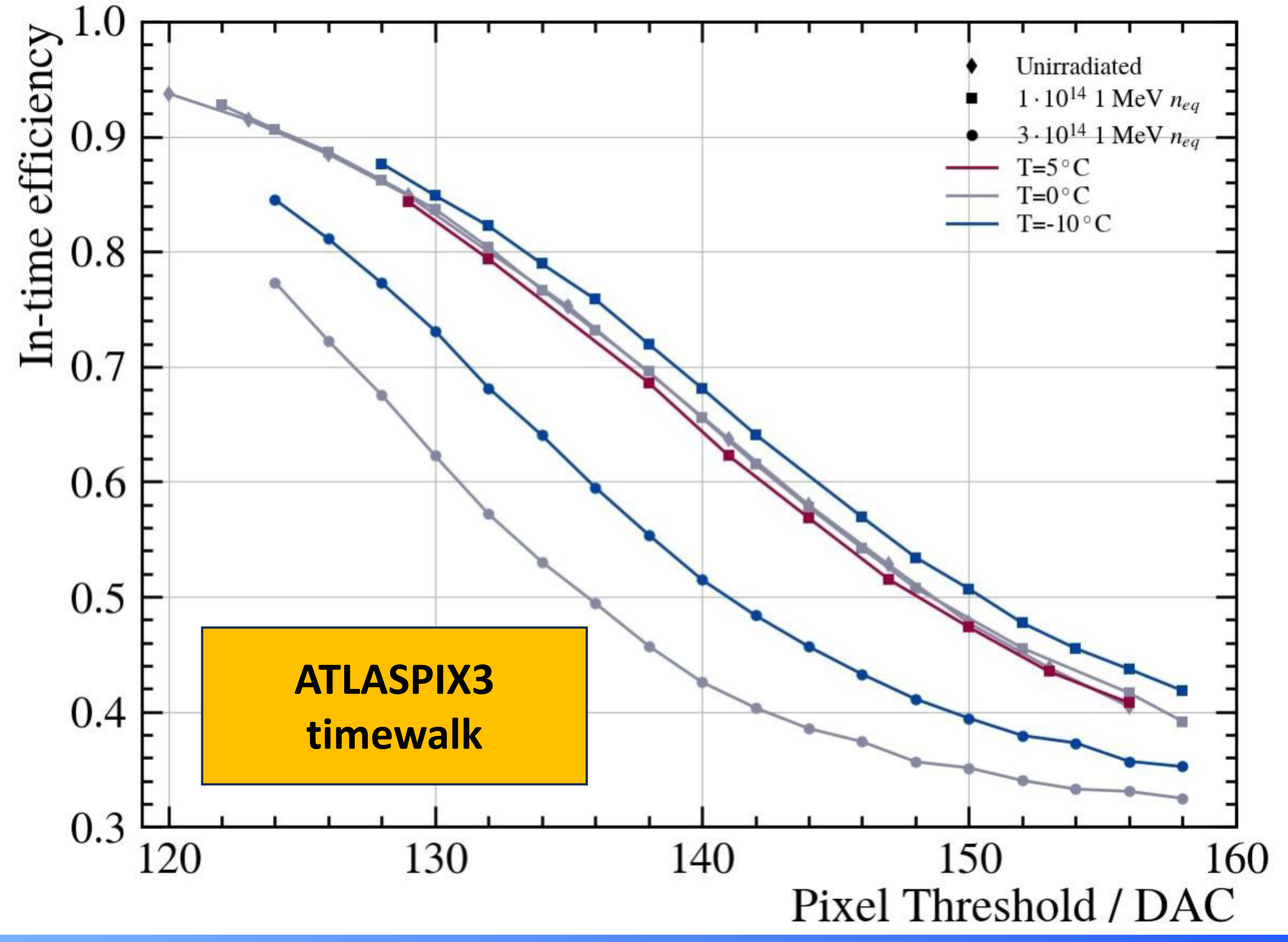


ATLASPIX3 resolution

E. Vilella



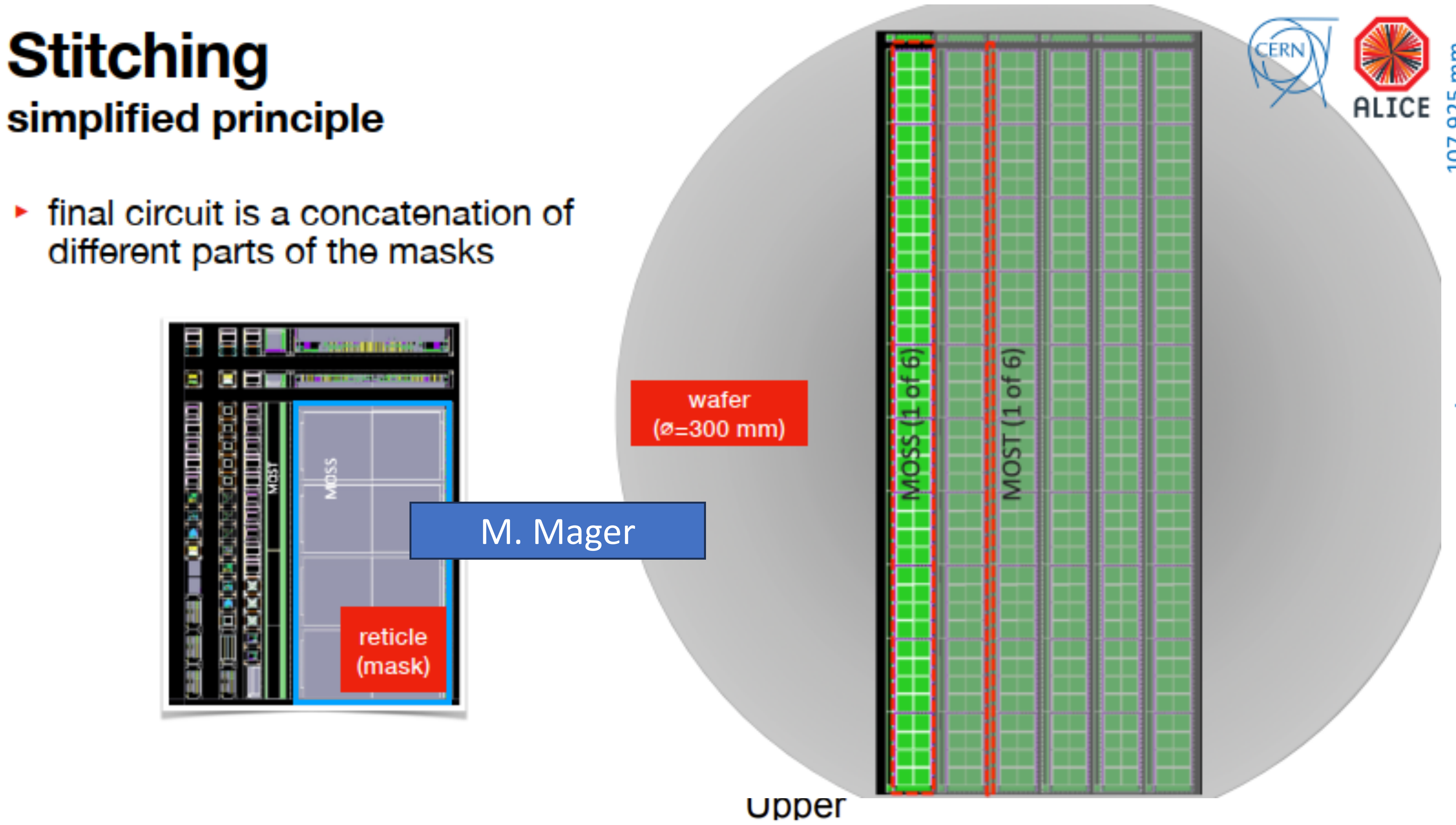
ATLASPIX3 efficiency vs threshold and NIEL

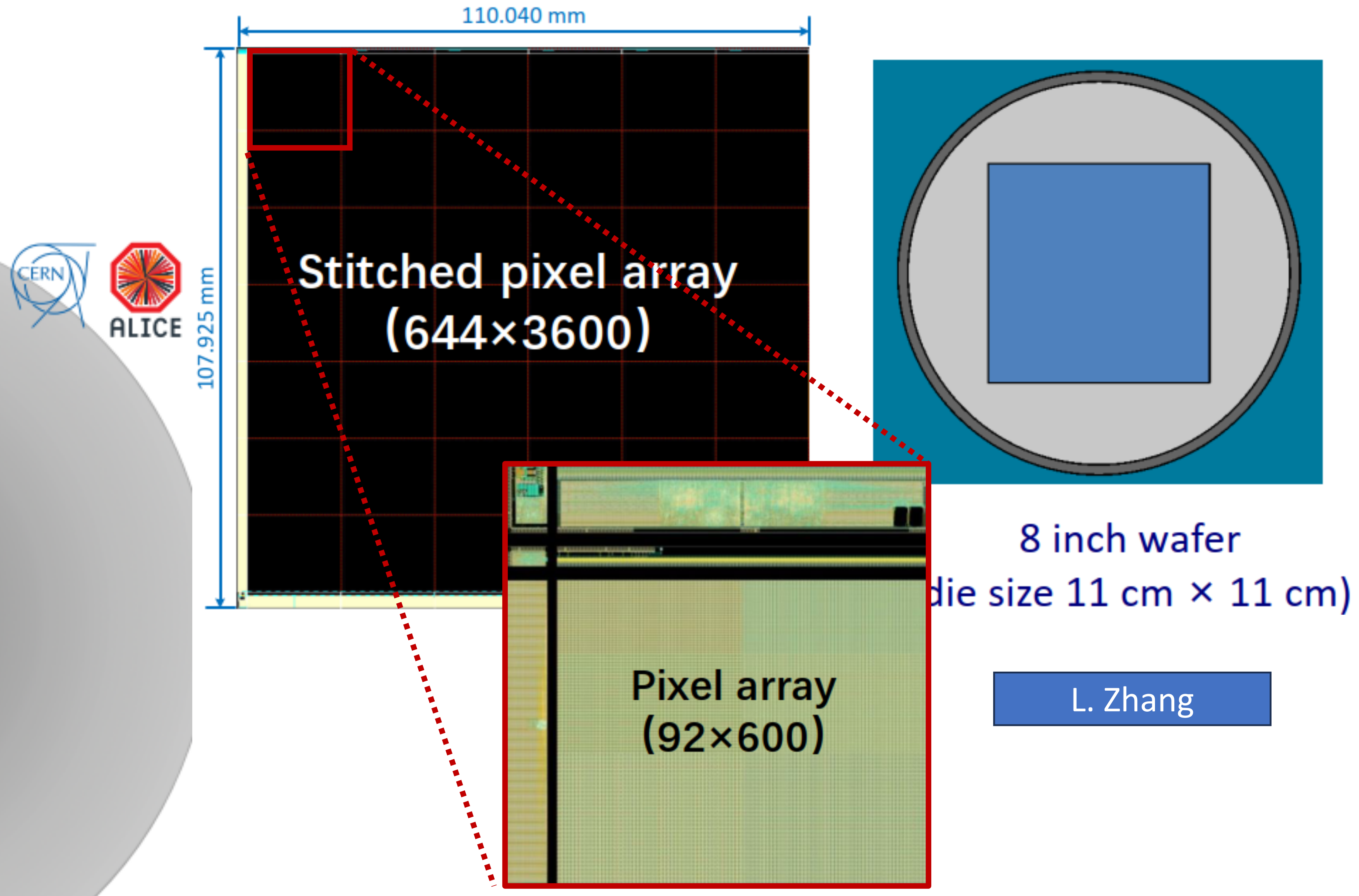


ATLASPIX3 timewalk

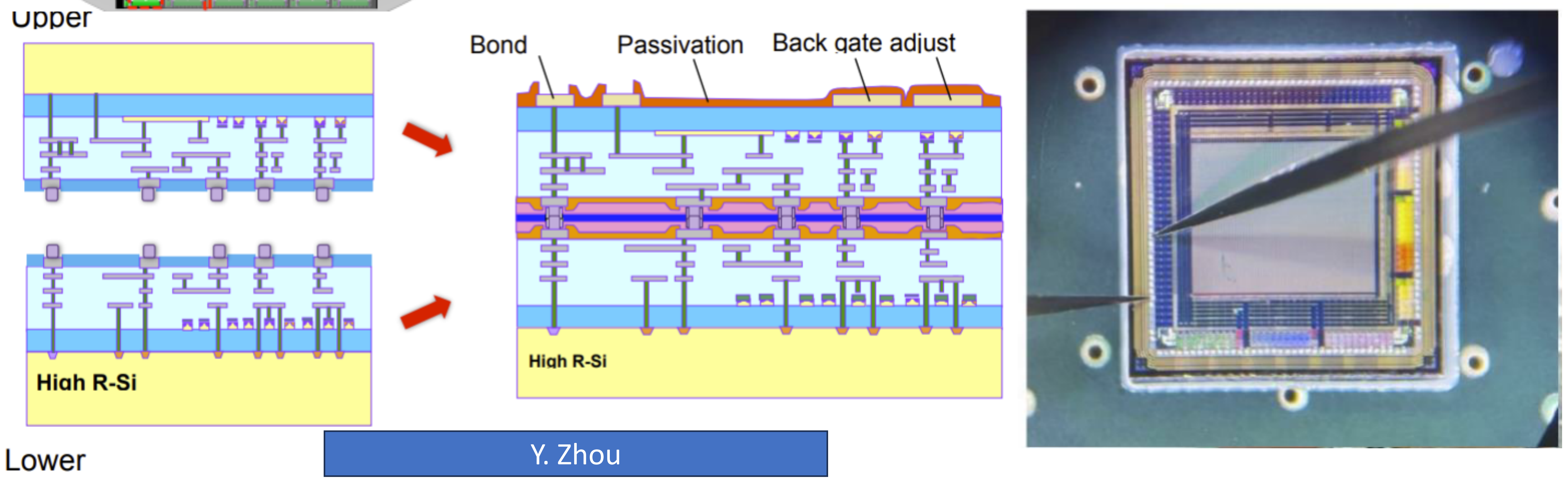
Silicon Tracker: advanced technologies

- Full-wafer size detector are possible using stitching
  - prototypes built to get experience with the process
  - aspect ratio differs depending on applications (vertex or large area tracker)



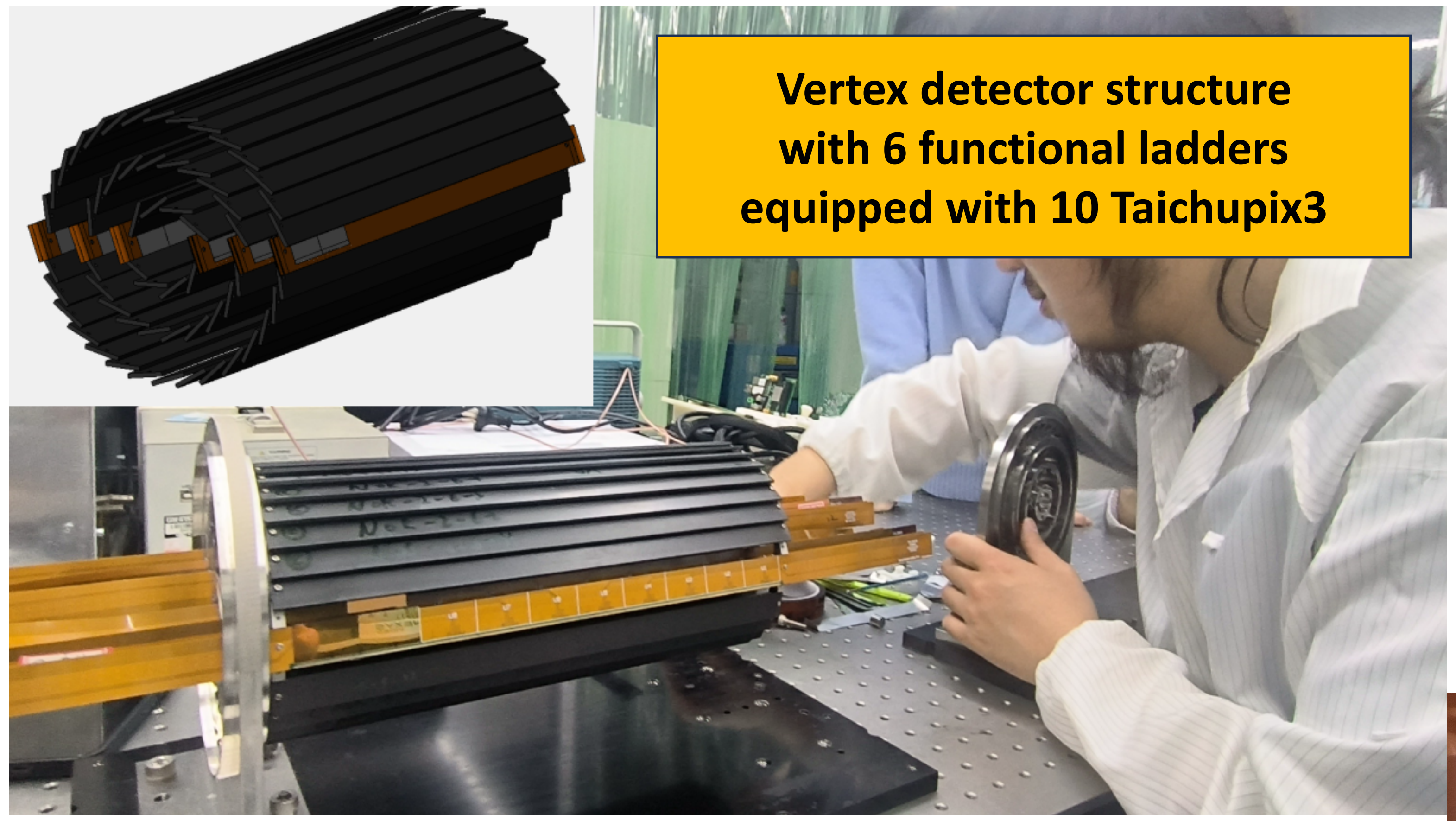


- 3D integration now available at commercial vendors
  - very interesting opportunity
  - encouraging results on the CPV-4 chip
  - still at the beginning of the learning curve



Silicon Tracker mechanics

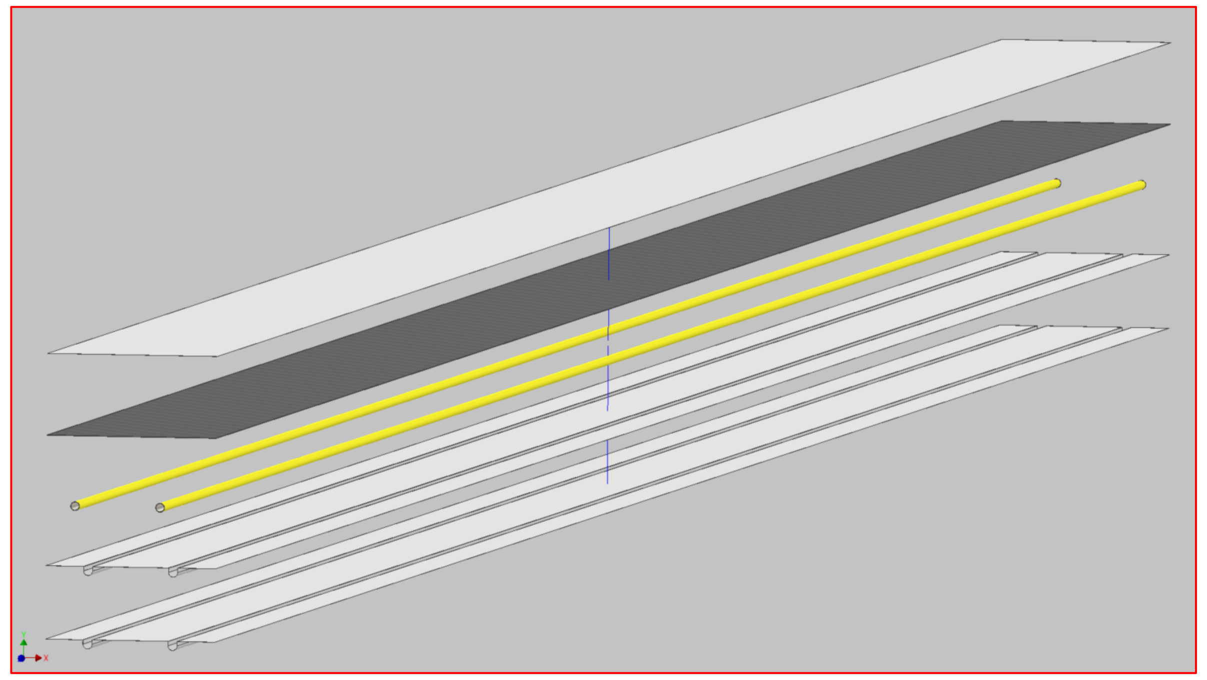
- Prototypes of mechanical structures are being developed, following the baseline CEPC detector design
- important steps towards demonstrating the detector feasibility
- but also keep in mind innovative solutions which may become mature in the CEPC timescale



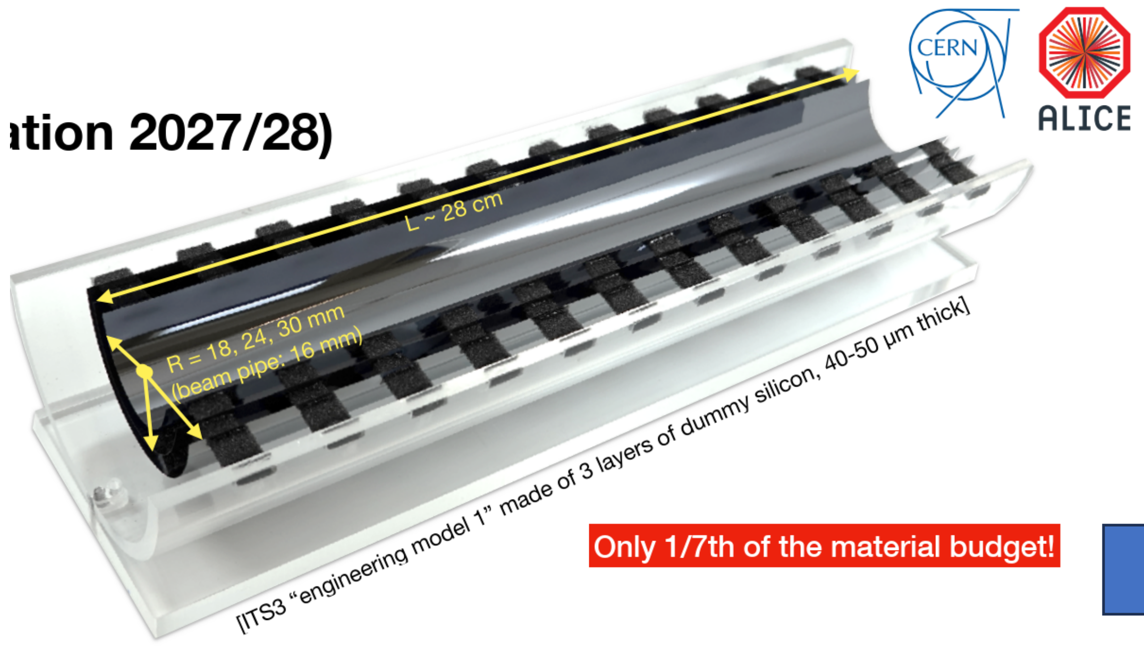
Z. Liang

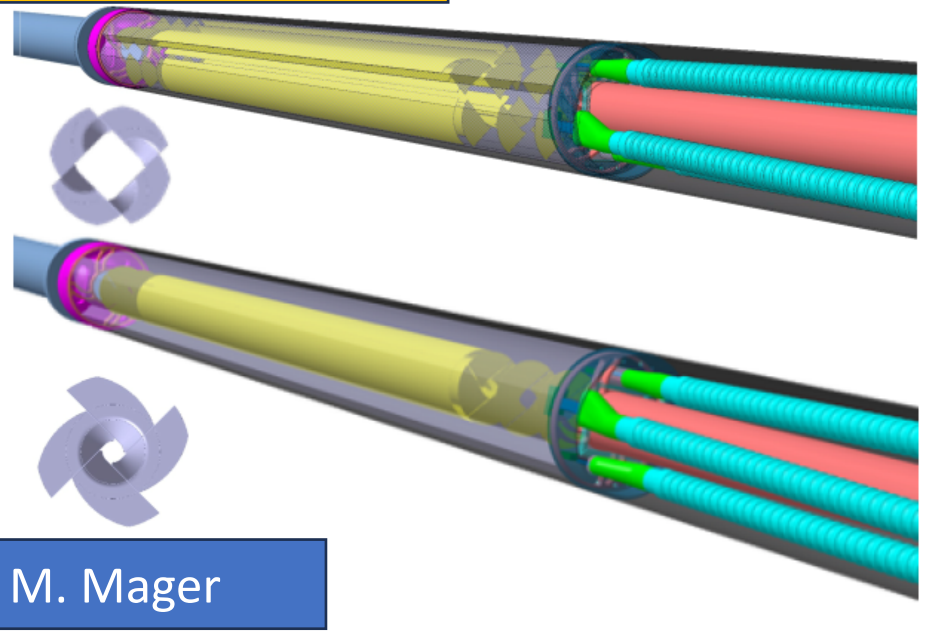
1300 mm long stave for CDR SIT

F. Bosi



Curved detector for HL-LHC upgrades

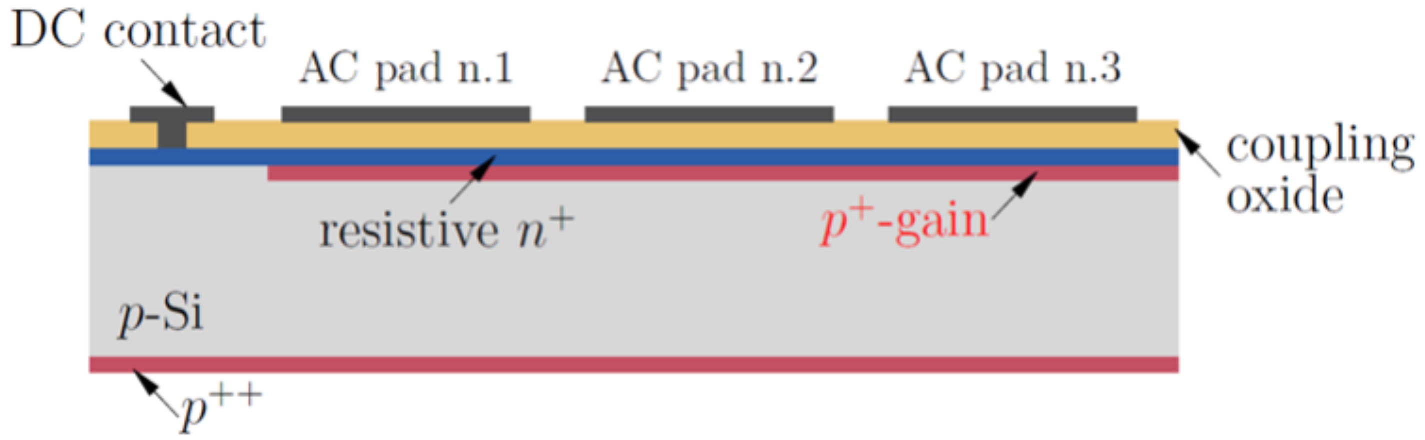




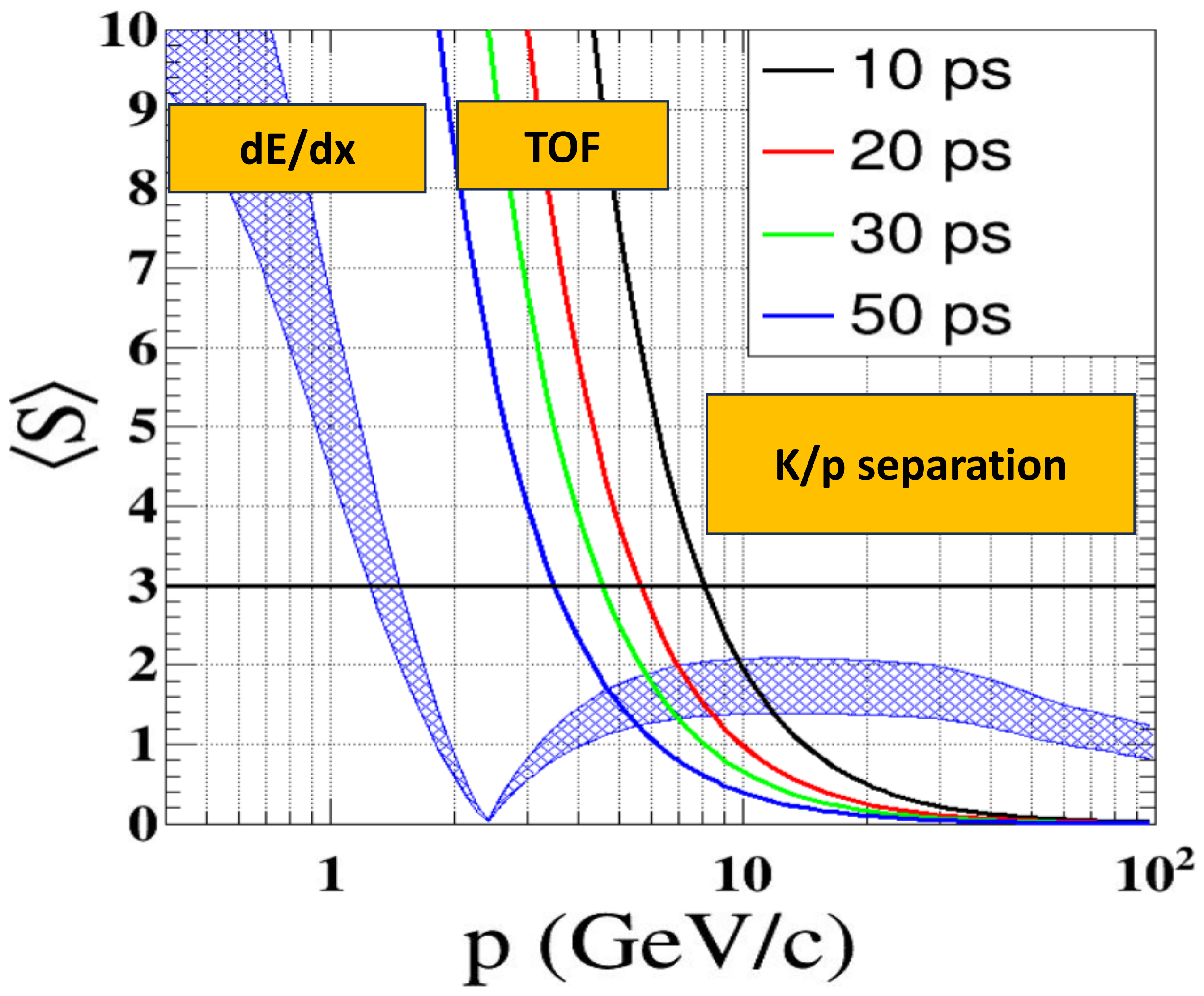
M. Mager

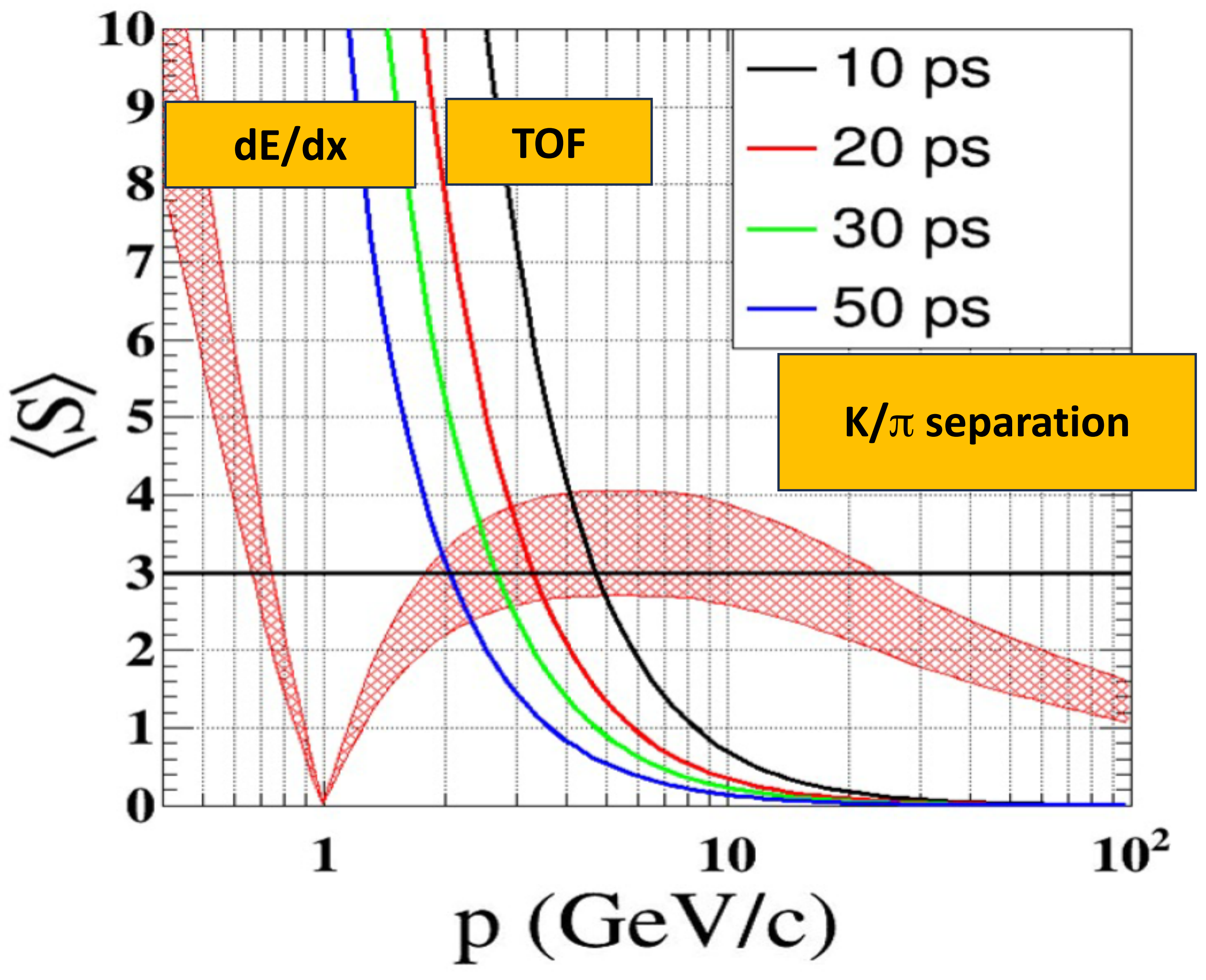
Silicon tracker: TOF layer

- Timing layer at SET radius (1.8 m) complements dE/dx for particle identification
- AC-LGAD:

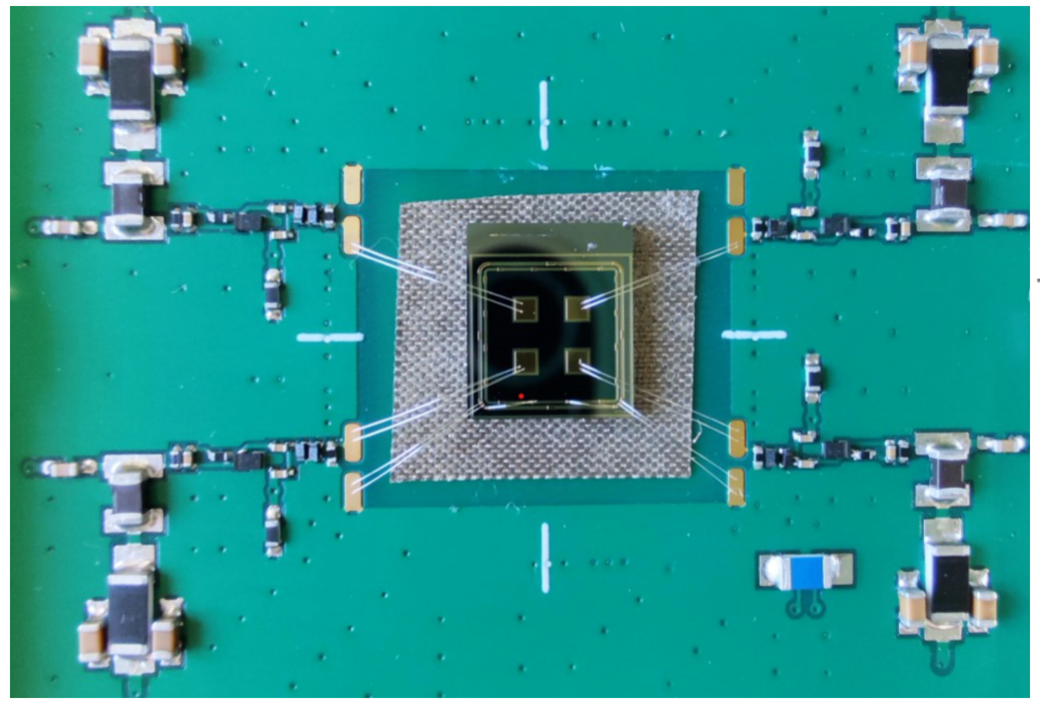


  - excellent time resolution of LGADs
  - tracking precision by charge interpolation, even with a large pitch size
  - promising results from the IHEP-IME prototypes



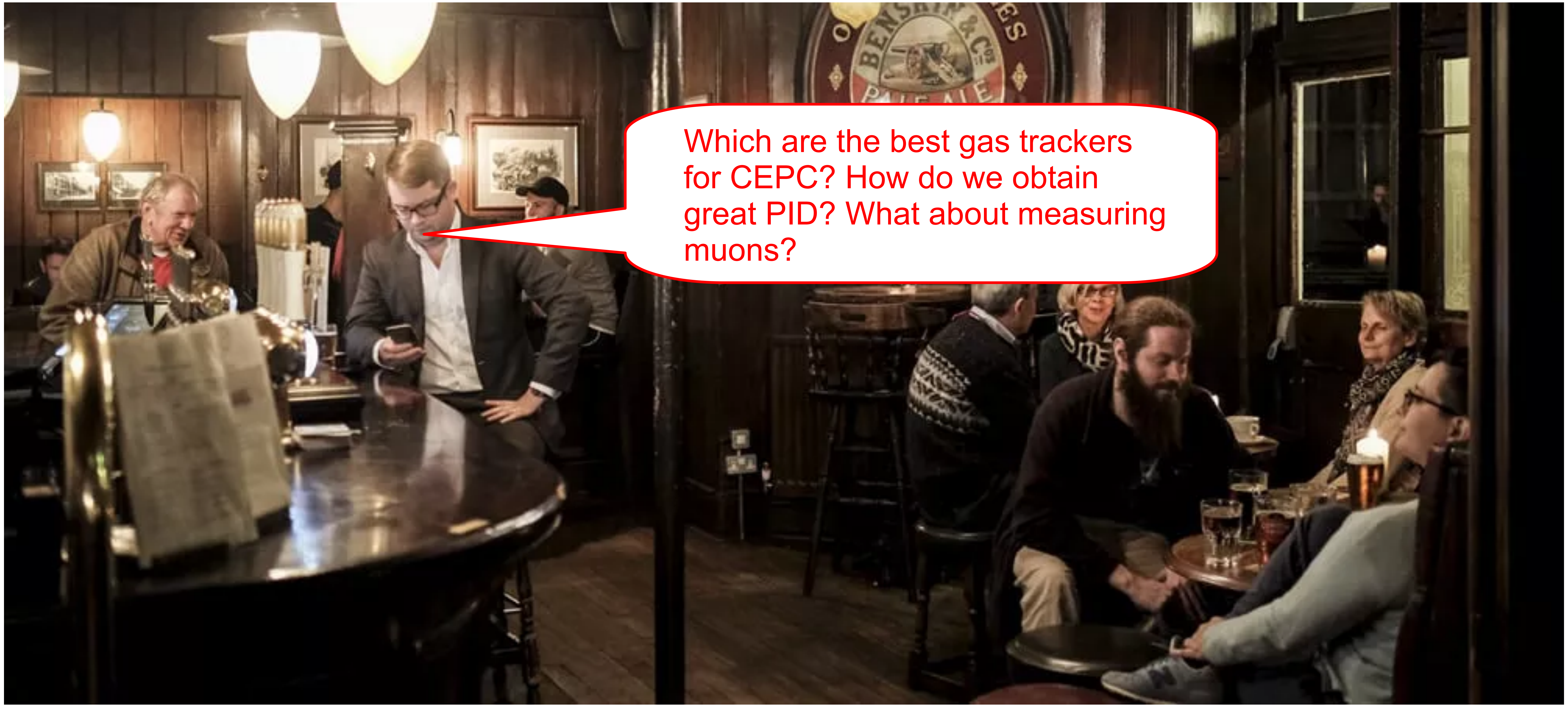


Y. Fan



Sensors	Pitch size [μm]	Spatial resolution [μm]	Time resolution [ps]
IHEP AC-LGAD	1000	15	22 （laser）
FBK AC-LGAD	500	11	32 （laser）
BNL AC-LGAD	100	-	45 （beta source）

Gas detectors - the pub perspective


Which are the best gas trackers for CEPC? How do we obtain great PID? What about measuring muons?
BENSKIN & Co
PALE ALE

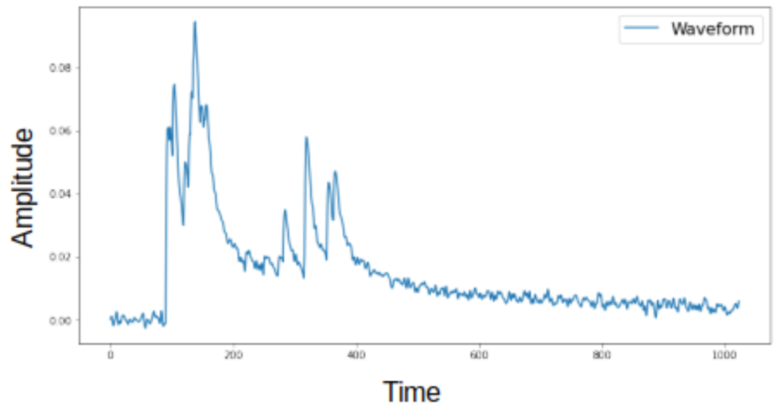
Large drift chambers

PID with Cluster Counting of the CEPC Drift Chamber

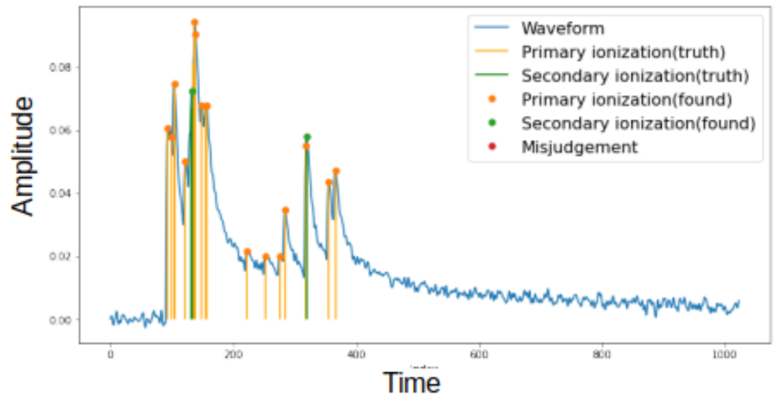
Linghui Wu
For the DC-PID group of CEPC the 4th conceptual detector

The 2023 International Workshop on Circular Electron Positron Collider (European Edition), Jul 6, 2023, University of Edinburgh

Two-step reconstruction algorithm



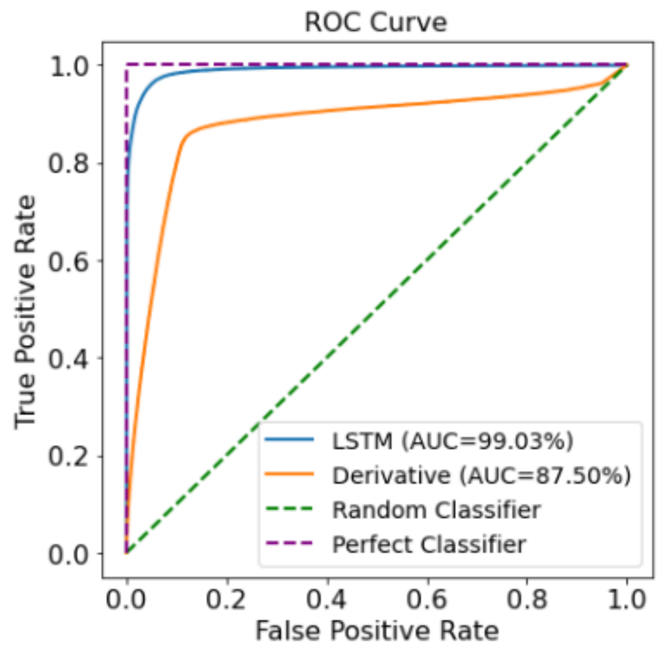
Step1. Peak Finding
Discriminate peaks (both primary and secondary) from the noises (classification problem)



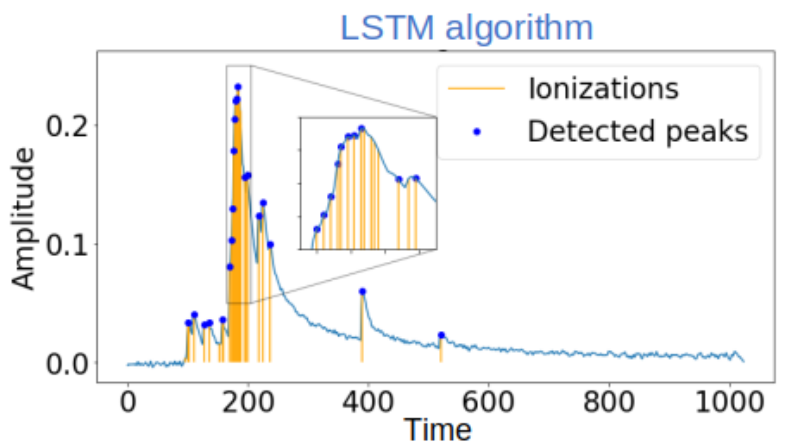
Step2. Clusterization:
Determine the number of clusters (from the detected peaks (regression problem)

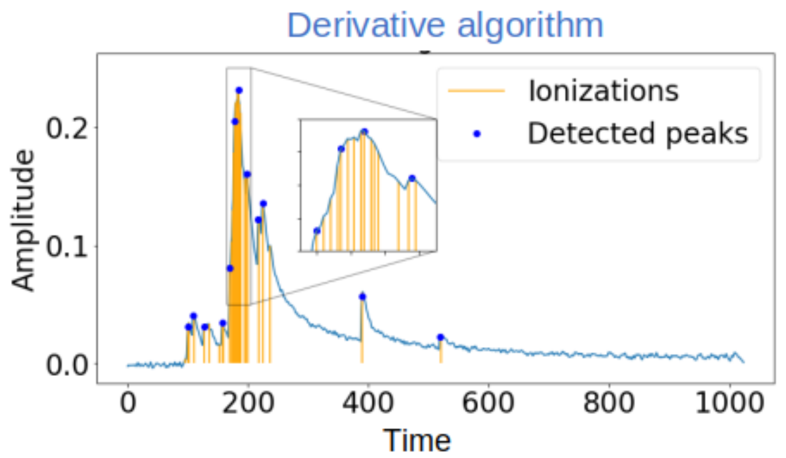
10

Comparison between LSTM and derivative model



Better AUC for LSTM, due to the better pile-up recovery ability of the LSTM model

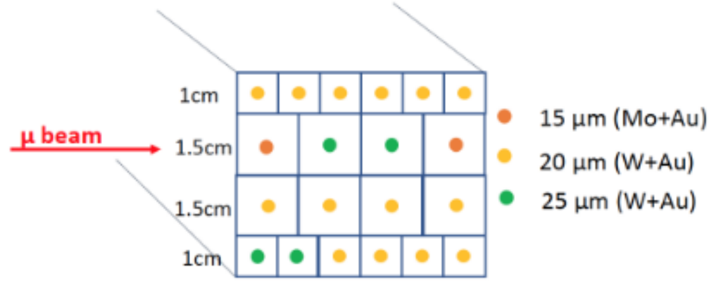


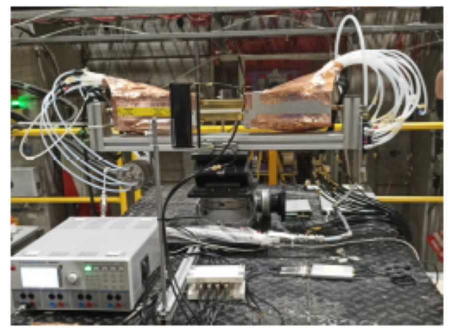


15

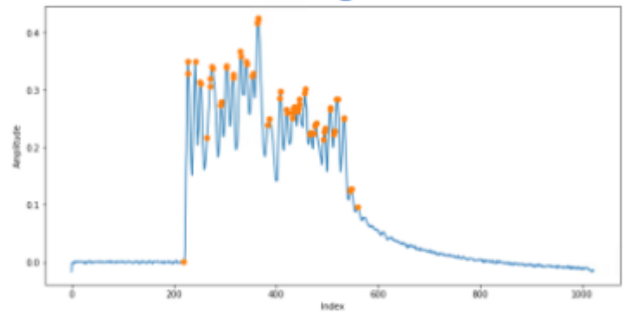
Beam test of DC prototype

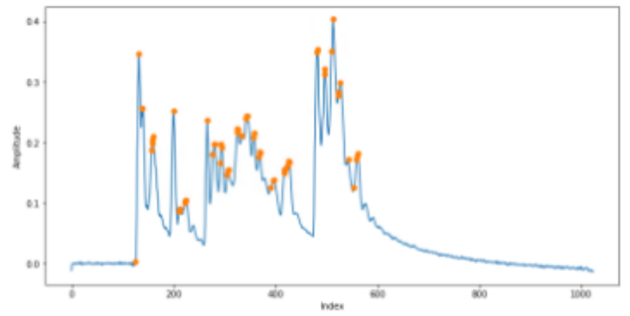
- Beam tests organized by INFN group
- Joint efforts of INFN and Chinese groups
  - Data taking
  - Data analysis
  - Optimizing DC simulation
  - Plan to apply ML algorithm on online FPGA





Preliminary results of peak finding with ML algorithm





- Clusterization under optimization

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IDEA's drift chamber

Update of the IDEA drift chamber

Nicola De Filippis
Politecnico and INFN Bari
on behalf of the DCH community

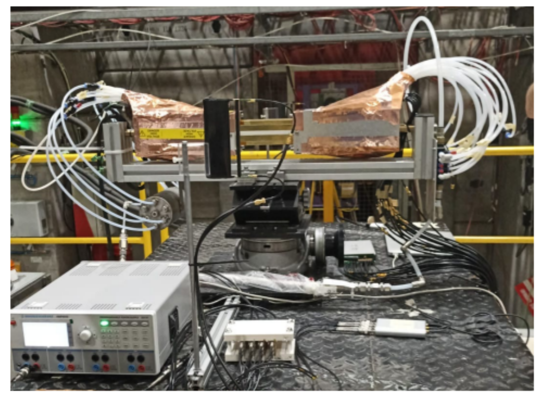
The 2023 International Workshop on Circular Electron Positron Collider (European Edition)

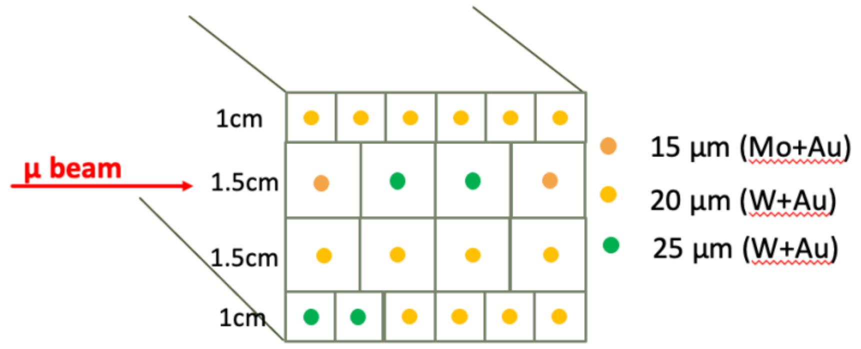
University of Edinburgh, July 3-6 2023

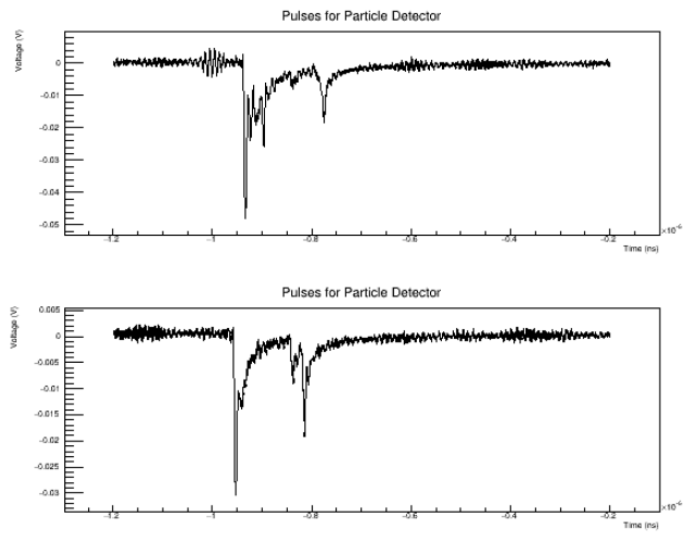
N. De Filippis 1

Beam test setup at T10/CERN in 2023

- 20 tubes with different wires (different material and diameter) and different cell size.
- 1 16-channel DRS
- 2 4-channel DRS
- custom PCBs for the 2 trigger scintillators.
- two external hard disk to store the data collected







- Data to be collected at different percentages of helium and isobutane: 90-10. , 85-15, 80-20.
- Data to be collected with muon beam momentum between 1 and 12 GeV

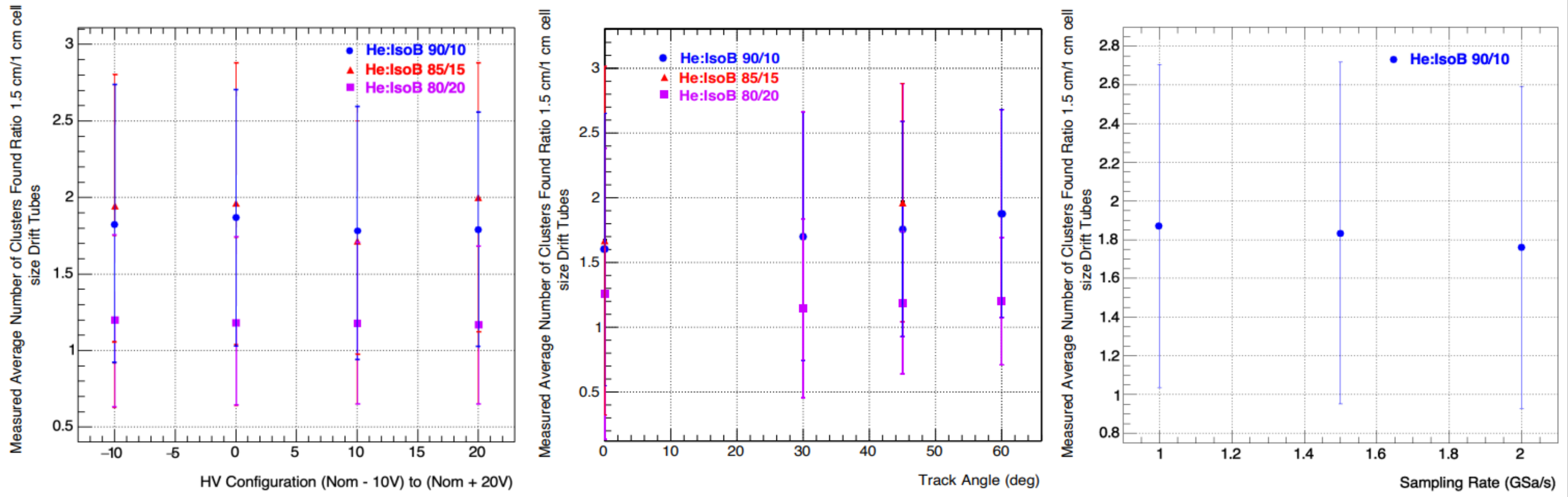
N. De Filippis

Beam test results: recombination and attachment

Efficiency w.r.t. Expected Number of Electrons (Clusters) above ~85%. What about being independent from theoretical assumptions?

in Ratios

Expected number of cluster= δ cluster/cm (MIP) x drift tube size [cm] x 1.3 (relativistic rise) x 1/cos(α)



Space charge + attachment + recombination effects affect the experimental CC efficiency!

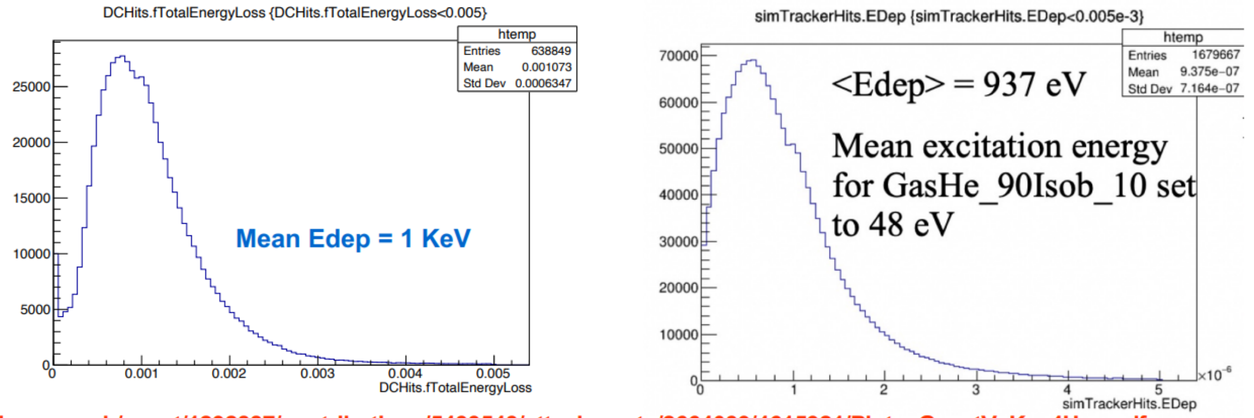
- The **loss of efficiency at small angles** is due to the partial shielding of the electric field due to the space charge.
- The **loss of efficiency at large angles** is partially due to the fact that increasing the number of clusters in the same drift time, increases the probability of pileup, then decreasing the counting efficiency.
- The **lower counting efficiency in 2cm** tubes compared to 1cm ones is only partially explained by the effects of recombination and attachment; other possible effects under investigation

N. De Filippis

Geant4 vs DD4HEP: comparison

- **Goal: to validate the implementation of the IDEA drift chamber (DC) geometry and its reconstruction in the DD4hep by doing a comparison with the Geant4 framework. Muons at 10 GeV are used for the validation. Good agreement is observed between the results from the two frameworks.**

Geant 4 Framework **DD4HEP in Key4Hep Framework**



https://indico.cern.ch/event/1292887/contributions/5433543/attachments/2664039/4615921/Plots_GeantVsKey4Hep.pdf

N. De Filippis

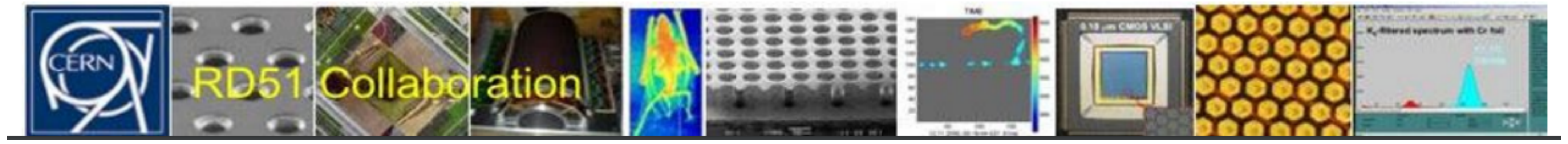
µRWELL detectors

The micro-RWELL technology for application in future facilities

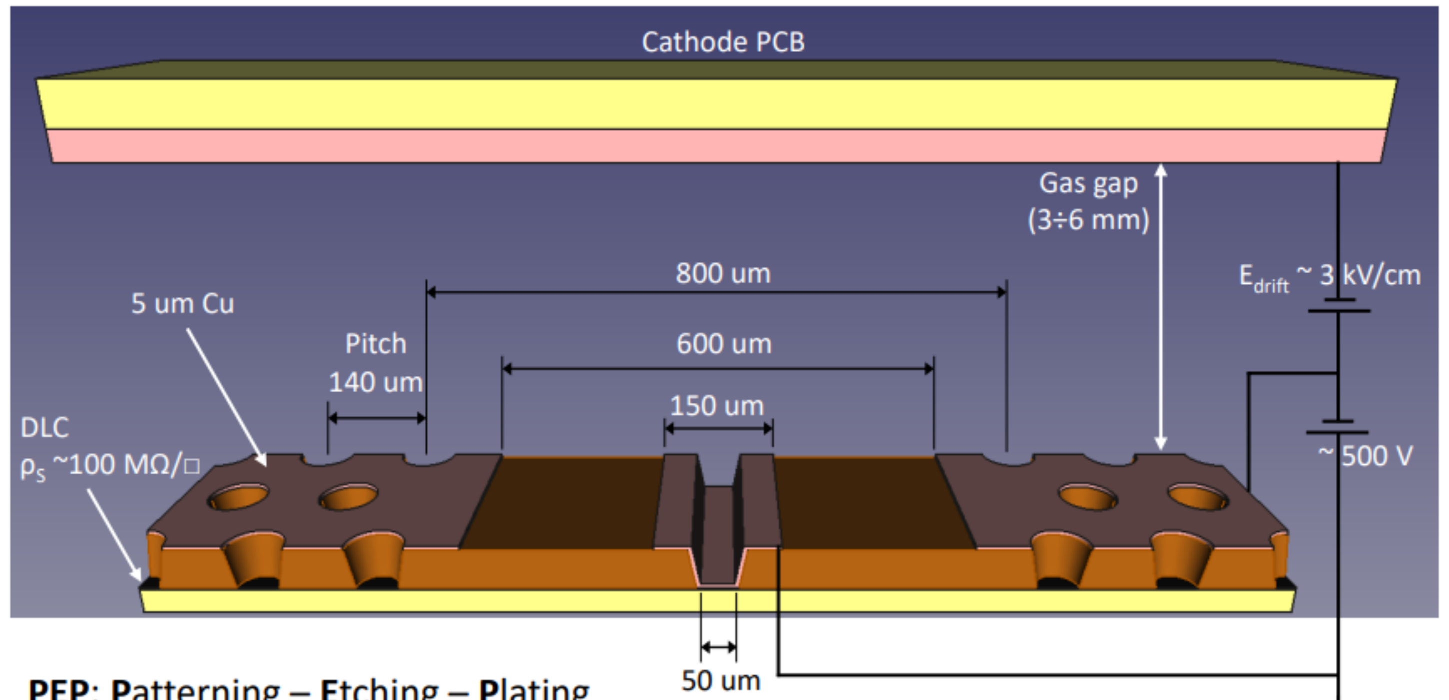
G. Morello[LNF-INFN]

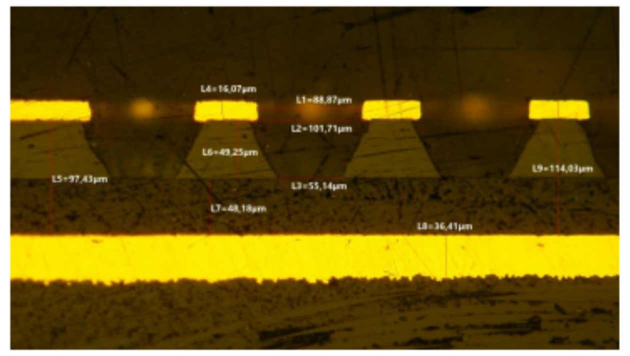
on behalf of
LNF-INFN (leading group)
Bologna-Ferrara INFN teams
R. De Oliveira - CERN-EP-DT-MPT Workshop

The 2023 International Workshop on Circular Electron Positron Collider, Edinburgh, July 3rd 2023



The µ-RWELL technology: the evolution



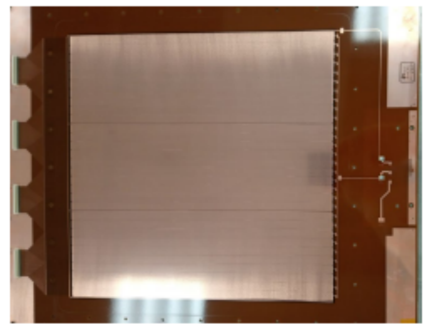


Geometrical PARAMETERS

Layout	GND pitch [mm]	Dead Area [mm]	DOCA [mm]	Geom. Acceptance
PEP1	6 // 8	1	0.475	66%
PEP2.1	8.9	0.8	0.375	91%
PEP2.2	17.8	0.8	0.375	95.5%

PEP: Patterning – Etching – Plating
- Single DLC layer
- Grounding from top by Cu and kapton etching and plating
- No alignment problems
- Scalable to larger sizes

Present prototype: 30 x 30 cm²
In construction 50 x 50 and 150 x 50 cm²



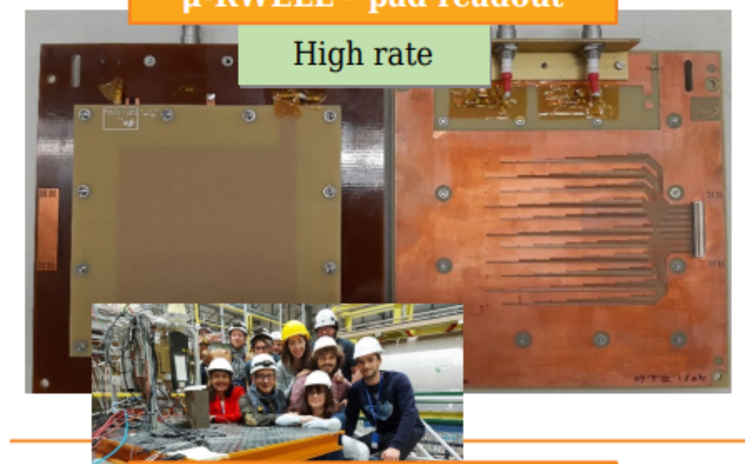
ACTIVE AREA
30 x 30 cm²

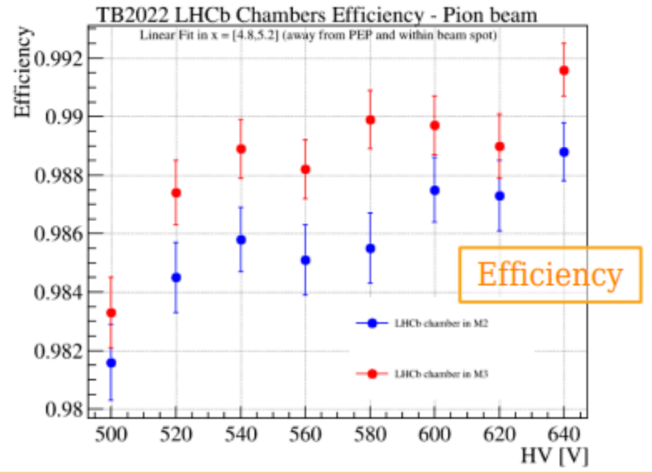
DOCA (Distance of Closest Approach): the minimum distance between a grounding line and an amplification channel.

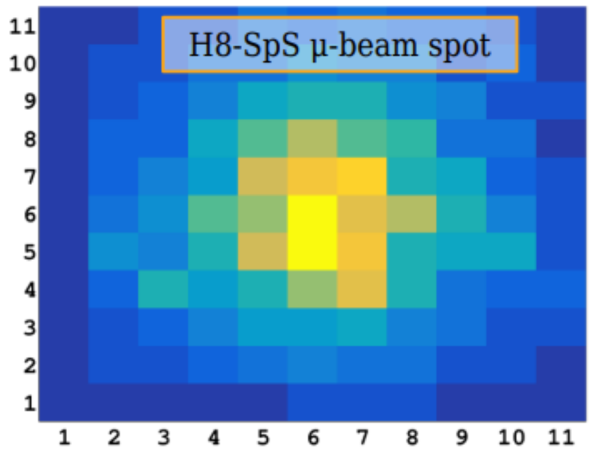
Suitable for large size apparatuses

The µ-RWELL technology: beam tests measurements

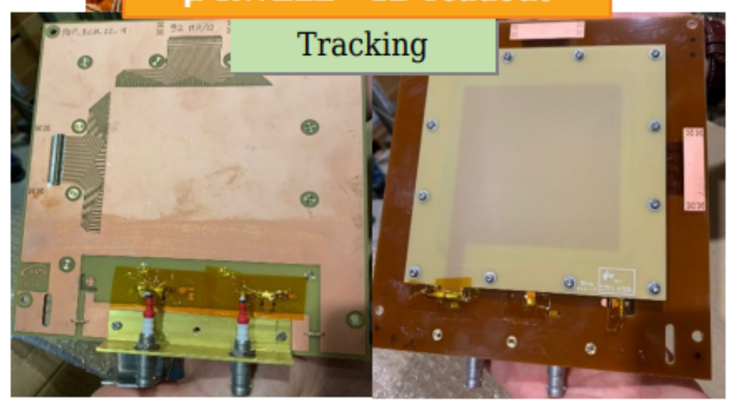
µ-RWELL - pad readout
High rate

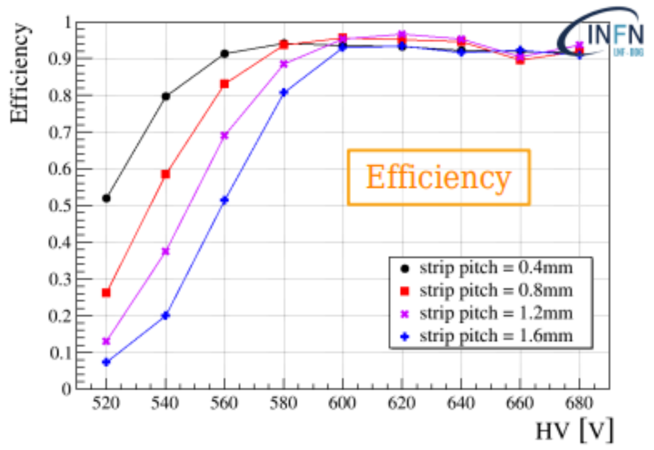


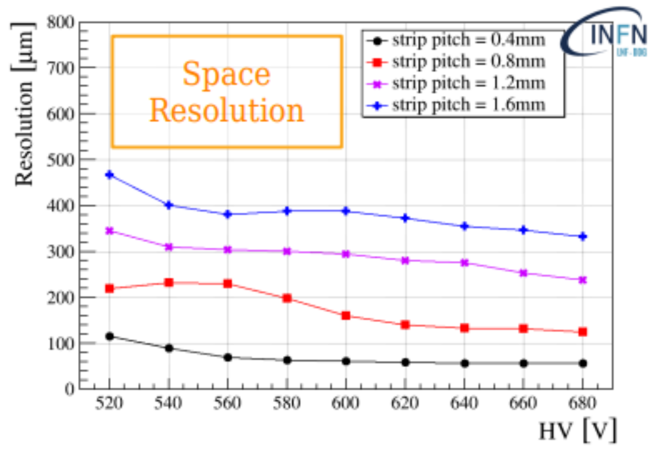




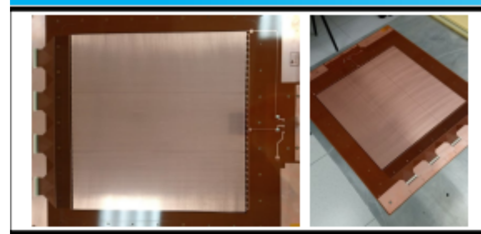
µ-RWELL - 1D readout
Tracking







The µ-RWELL technology: TT



Need for industry!!!

The three stages are embedded in a single PCB, produced by **standard ridig-flex PCB manufacturing (even involving mixed multi-layer).**

MEMENTO:
Amplification stage +
Resistive stage +
Readout plane =
µ-RWELL_PCB

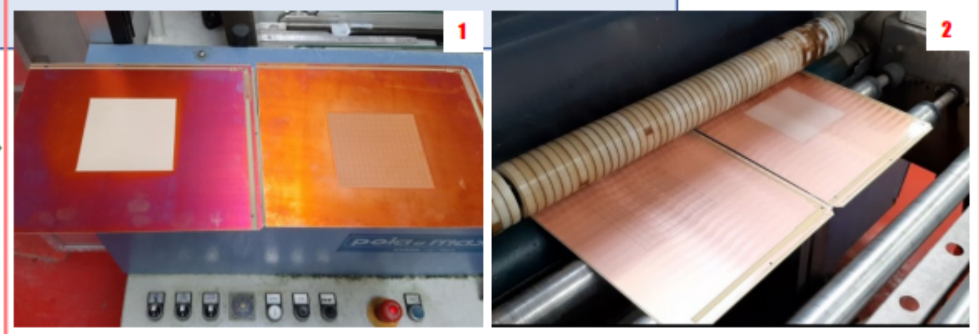
Start!

INFN LNF – Istituto Nazionale di Fisica Nucleare

AIDA innova EU-project;

µ-RWELL techn. transf.

ELTOS – PCB production



DLC sputtering know-how

DCL foil prod.*

CERN – INFN

Detector manufacturing

Completed µ-RWELL_PCB shipping

PCB shipping

***DLC Magnetron Sputtering machine co-funded by INFN-CSN1**

TPC

Status of Pixelated and Pad Readout TPC Technology R&D at CEPC

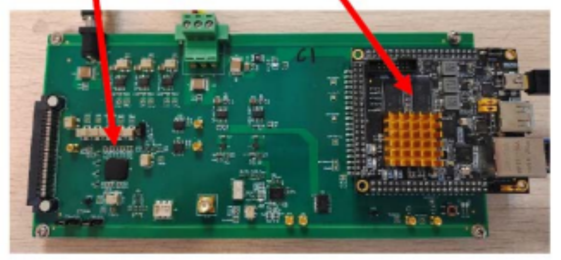
Huirong Qi
Yue Chang, Xin She, Liwen Yu, Zhi Deng, Jian Zhang, Jinxian Zhang
Linghui Wu, Guang Zhao, Gang Li, Manqi Ruan, Jianchun Wang

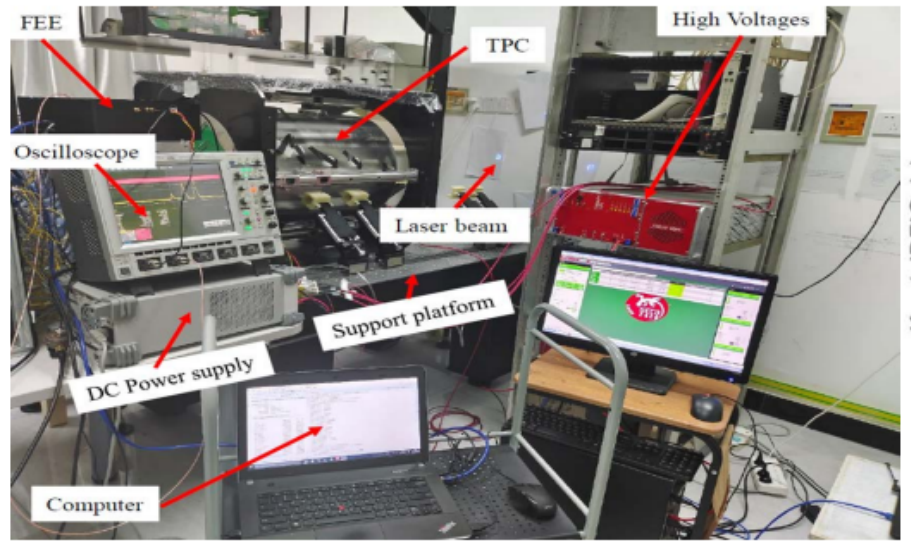
On behalf of CEPC TPC study group and Special thanks to LCTPC collaboration

2023 international workshop on CEPC, 3-6 July, 2023, Edinburgh

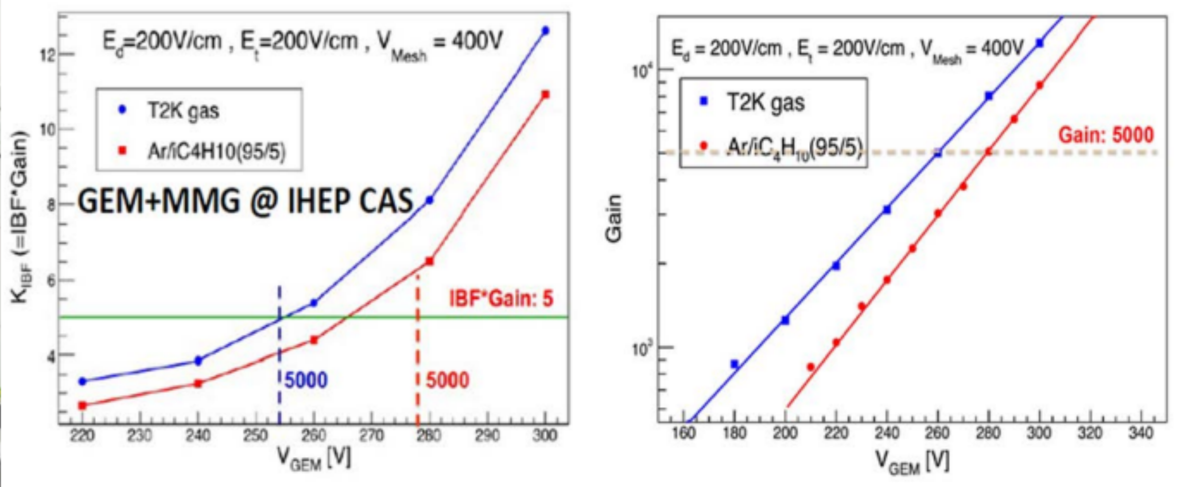
CEPC TPC detector prototyping roadmap

- From TPC module to TPC prototype R&D for beam test
  - Low power consumption FEE ASIC (**reach <5mW/ch** including ADC)
- Achievement by far:
  - Supression ions hybrid GEM+Micromegas module
    - IBF × Gain **~1 at Gain=2000** validation with GEM/MM readout
  - Spatial resolution of **$\sigma_{r\varphi} \leq 100$ μm** by TPC prototype
  - dE/dx for PID: <4% (as expected for CEPC baseline detector concept)





Low power consumption readout

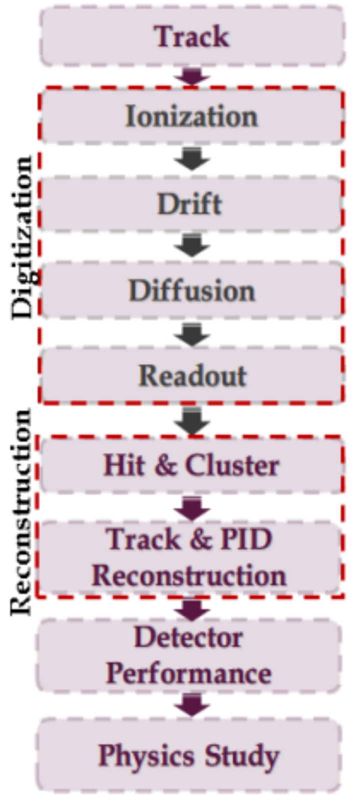


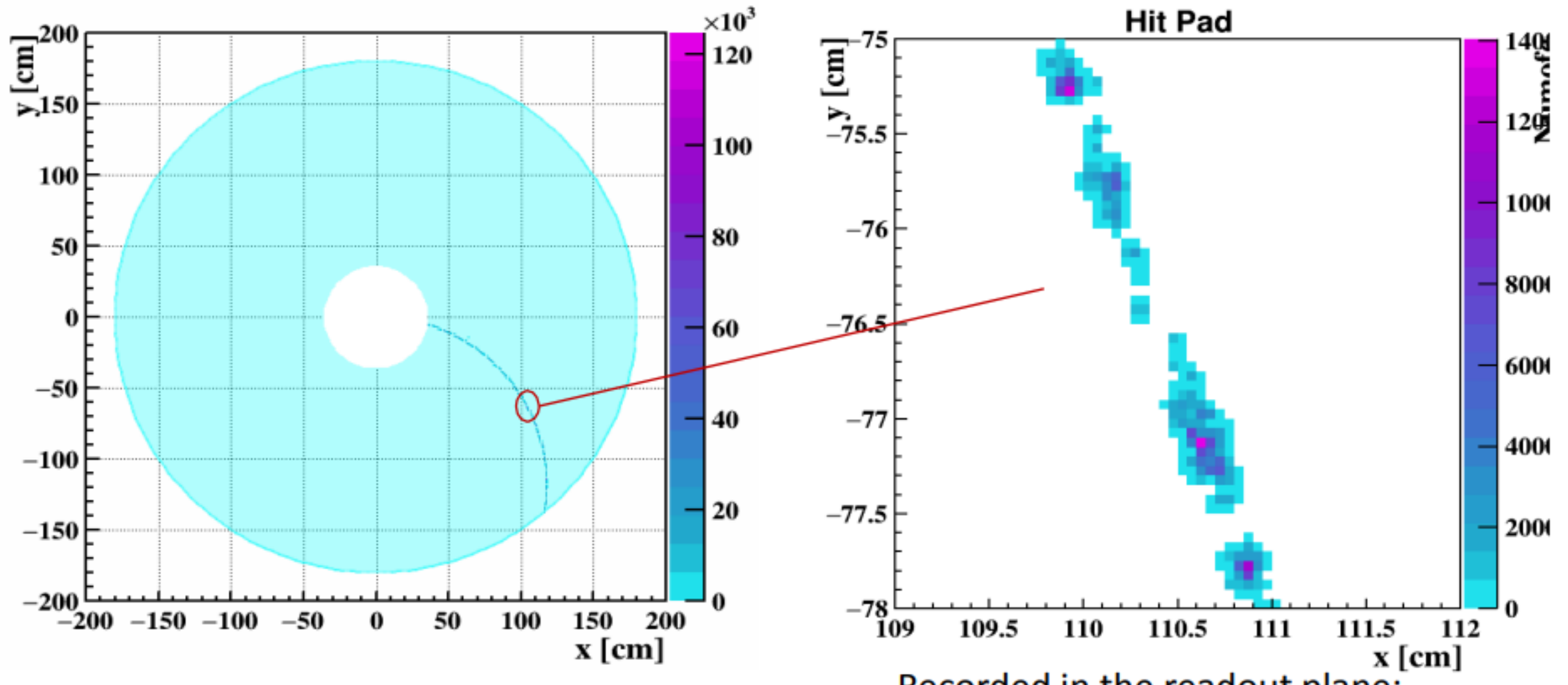
GEM+Micromegas module R&D

Simulation of the pixelated TPC - ongoing

Yue Chang, Guang Zhao, Linghui Wu, Gang Li

- All detailed simulation **starting** at IHEP using Garfield++ and Geant4
  - Setup the new simulation framework
  - TPC detecror module simulated **under 2T and T2K gas** from CEPC CDR
  - Progress presentaion will be prepared soon





Recorded in the readout plane:
Drift distance = 150mm
Pixel size: 500μm × 500 μm

Same goal: Low power consumption pixelated TPC technology IHEP/LCTPC

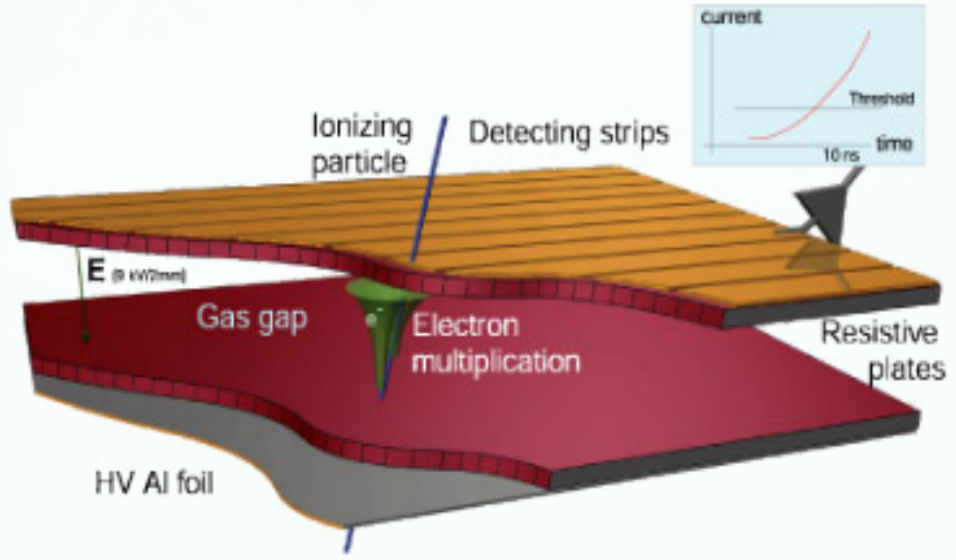
- R&D @ IHEP based on **0.5 × 0.5 mm² pixels and electronics uses a power of <0.2mW/channel**.
  - For all the active area of 160 000 cm² one has 64 M channels and **<1.2 kW** power consumption
  - > 89% coverage in the endplate
- Current TPX3 chip has 256 × 256 channels and a surface of 1.41 × 1.41 cm²
- Power consumption ~2W/chip; this means 30 mW/channel
- A full pixel TPC in the detector will have a total area 160 000 cm²
  - For full coverage one needs 80 000 chips
  - With the current TPX3 chip one reaches about 60% coverage
  - For the pixel TPC the total power is 160 kW (so 80 kW per endcap)
- Low power consumption **is the first requirement** for the pixelated TPC technology to LCTPC
  - TPX3 Gridpixes in low power mode reduces the power consumption for a pixel TPC to **8 kW per endcap** at the cost of a worse time resolution.

■ Ref1 https://iopscience.iop.org/article/10.1088/1748-0221/14/01/C01024
■ Ref2 https://iopscience.iop.org/article/10.1088/1748-0221/14/01/C01001

RPCs

G. Pugliese

CEPC 2023



The RPC technology: current state of the art and future prospects

G. Pugliese
INFN & Polytechnic of Bari

The 2023 International Workshop on the Circular Electron Positron Collider European Edition Edinburgh 3td - 6th July 202

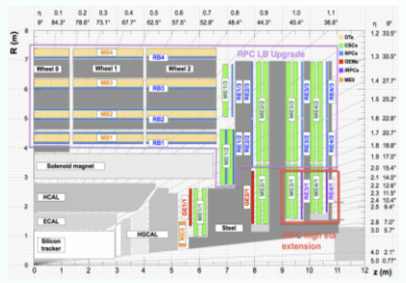
1

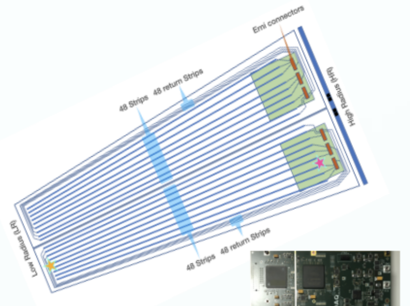
Improved RPCs for the CMS experiment

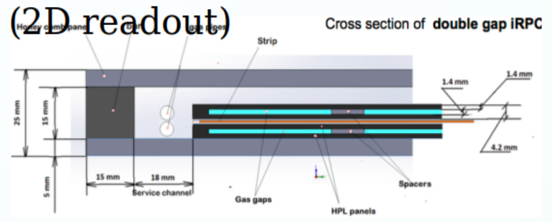
G. Pugliese

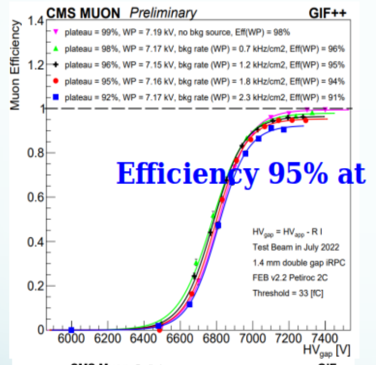
CEPC 2023

- New detector geometry, strips layout and Font-End Board electronics (2D readout)



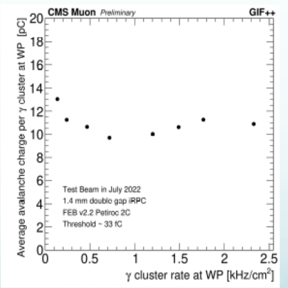


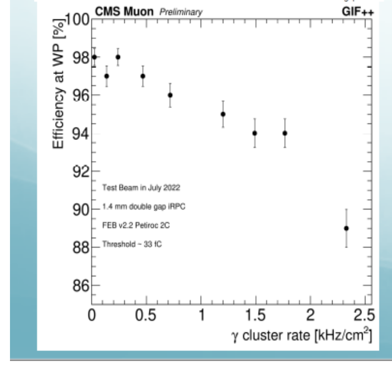




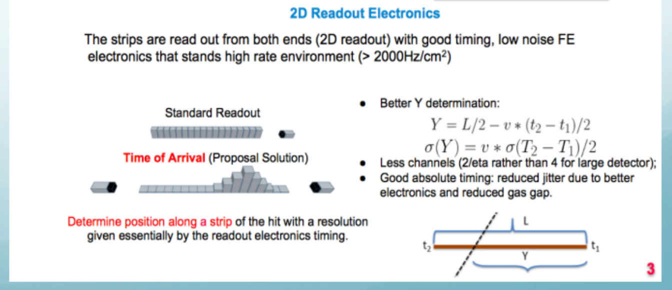
FEB: 6 ASICs PetiROC2C and 3 FPGAs CYCLONE V

	iRPC	RPC
HPL thickness	1.4 mm	2 mm
Num. of Gas Gap	2	2
Gas Gap width	1.4 mm	2 mm
Resistivity (cm)	0.9 - 3 10^{10}	1 - 6 10^{10}
Charge threshold	50 fC	150 fC
η segmentation	2D readout	3 η partitions





Average avalanche charge 10 pC (from 25-30 pC for the legacy CMS RPC)



8

New RPCs for the ATLAS experiment

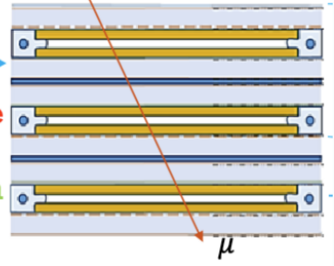
G. Pugliese

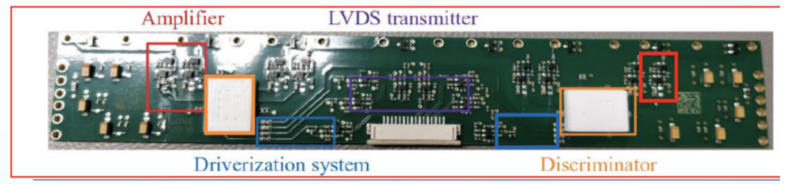
CEPC 2023

- New RPC with new detector geometry and electronics boards

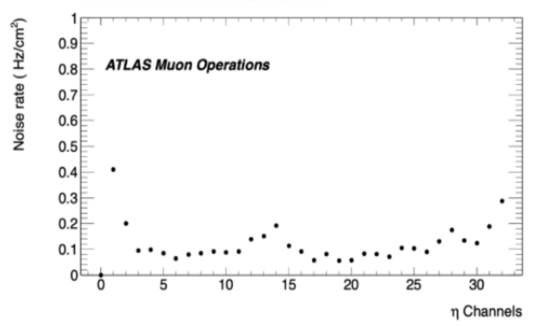
Detector parameters	ATLAS RPC	BIS78 RPC
Gas gap width	2 mm	1 mm
Electrode Thickness	1.8 mm	1.2 mm
Time Resolution	≈ 1 ns	≈ 0.4 ns
Space Resolution	≈ 6 mm	≈ 1 mm
Gaps per chamber	2	3
Gas Mixture	ATLAS Standard	ATLAS Standard
Readout	2D Orthogonal	2D Orthogonal
FE technology	GaAs	Si&Si-Ge
FE Effective Threshold	2-3 mV	0.2-0.3 mV
FE Power consumption	30 mW/ch	12 mW/ch

Triplet Structure

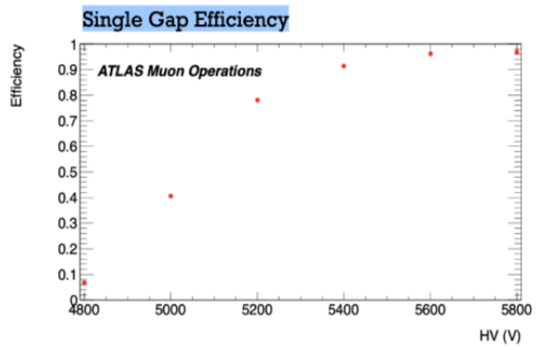


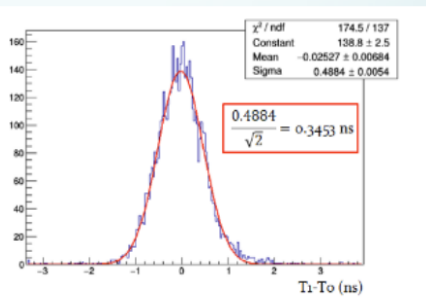


Noise rate of a single panel



Single Gap Efficiency





9

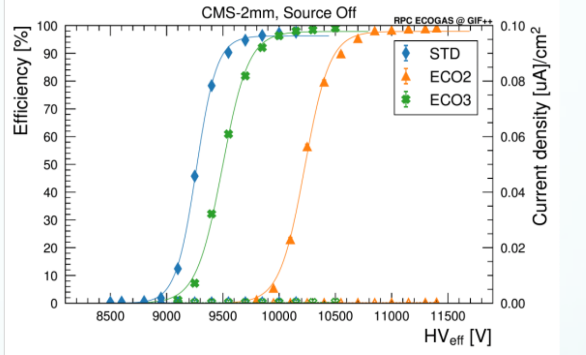
R&D with eco-gas mixtures

G. Pugliese

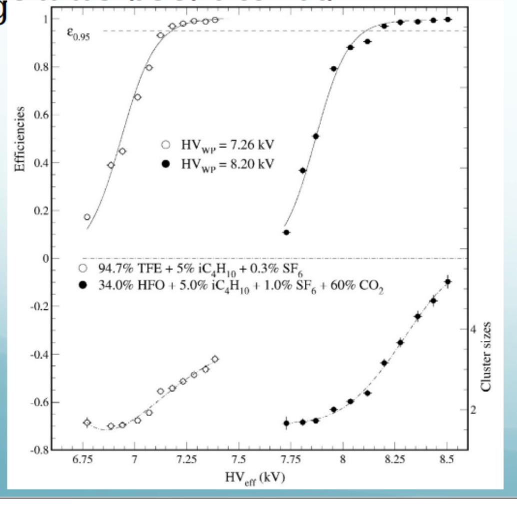
CEPC 2023

Gas mixture	$C_2H_2F_4$	HFO-1234ze	CO_2	$I\text{-}C_4H_{10}$	SF_6
STD	95.2	0	0	4.5	0.3
ECO1	0	45	50	4	1
ECO2	0	35	60	4	1
ECO3	0	25	69	5	1

- Several HFO based gas mixtures tested
- A fraction of CO_2 is needed to lower the HV working point



- **Comparable efficiency plateau and slightly higher WP (1kV)** between standard and HFO based mixtures measured with a CMS RPC and without g...



- Comparable efficiency plateau with a 1.4 mm double gap RPC
- Small increase of cluster size
  - <C_s> for the std. TFE gas = 2.78
  - <C_s> for 60% CO2 + HFO = 3.67

15

Calorimeters - the pub perspective

Calorimeters - the pub perspective

Calorimeters - the pub perspective

Calorimetry - W and Sci based ECAL /HCAL

- Lots of amazing progress all over the board, with many hardware and software developments (and lots of data from test beams!)

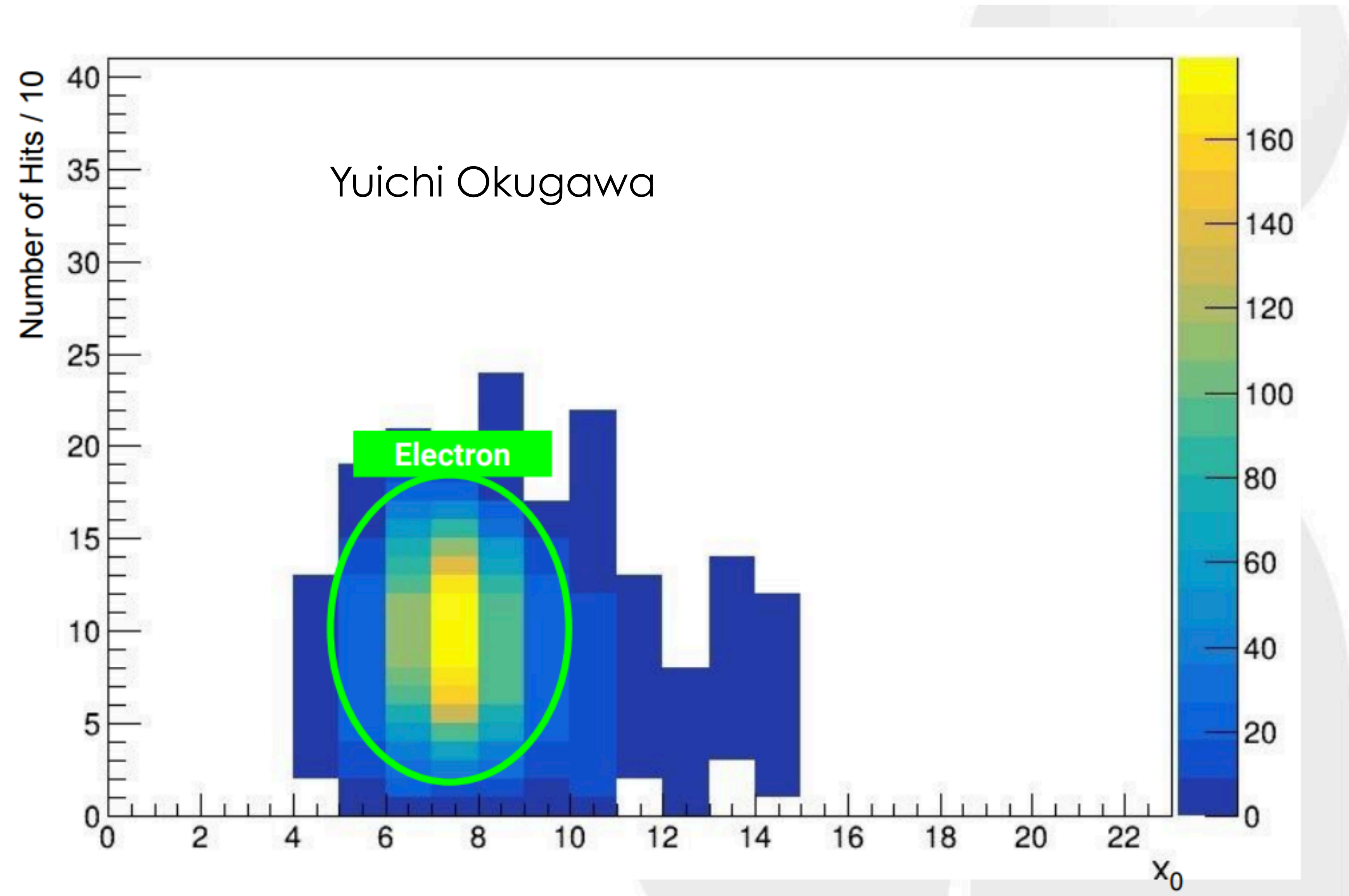
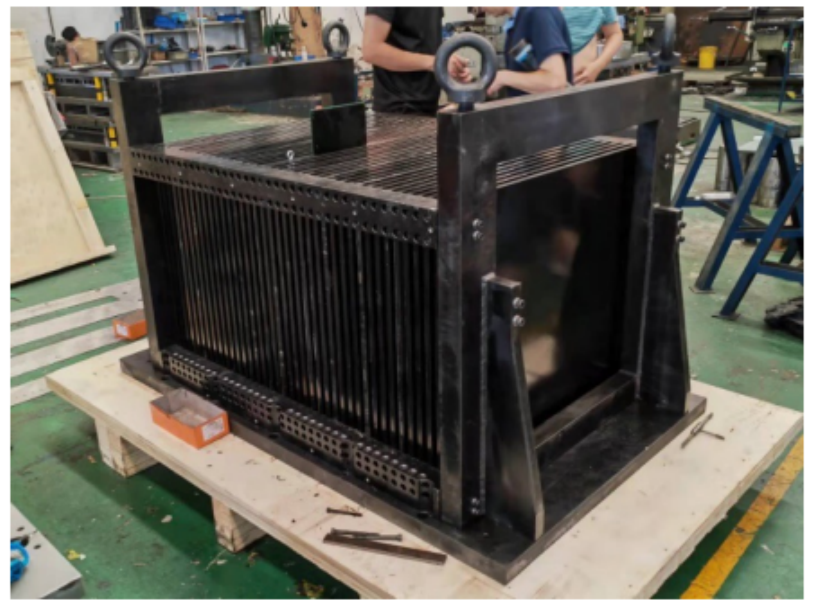
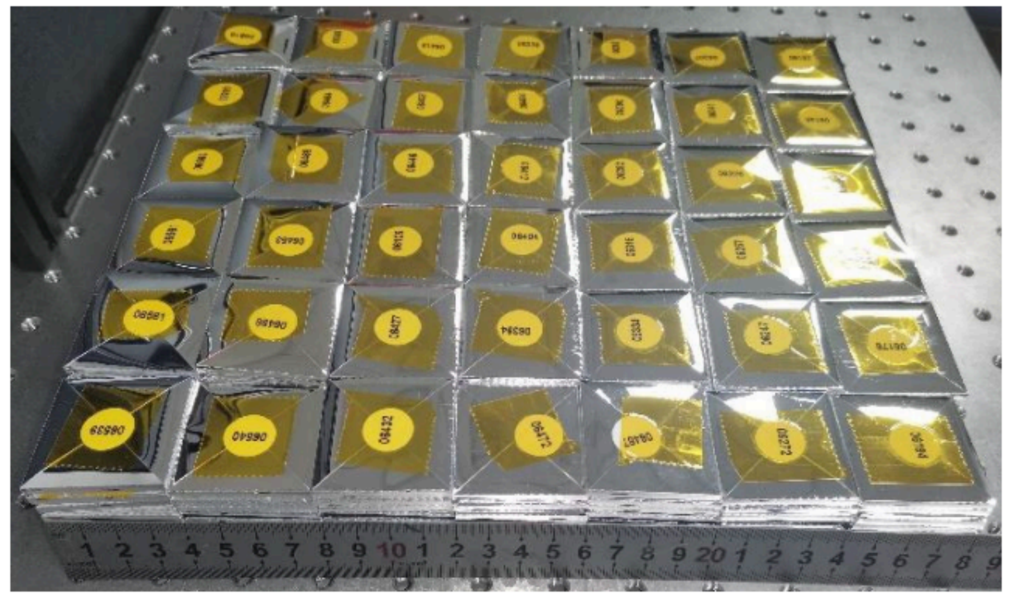
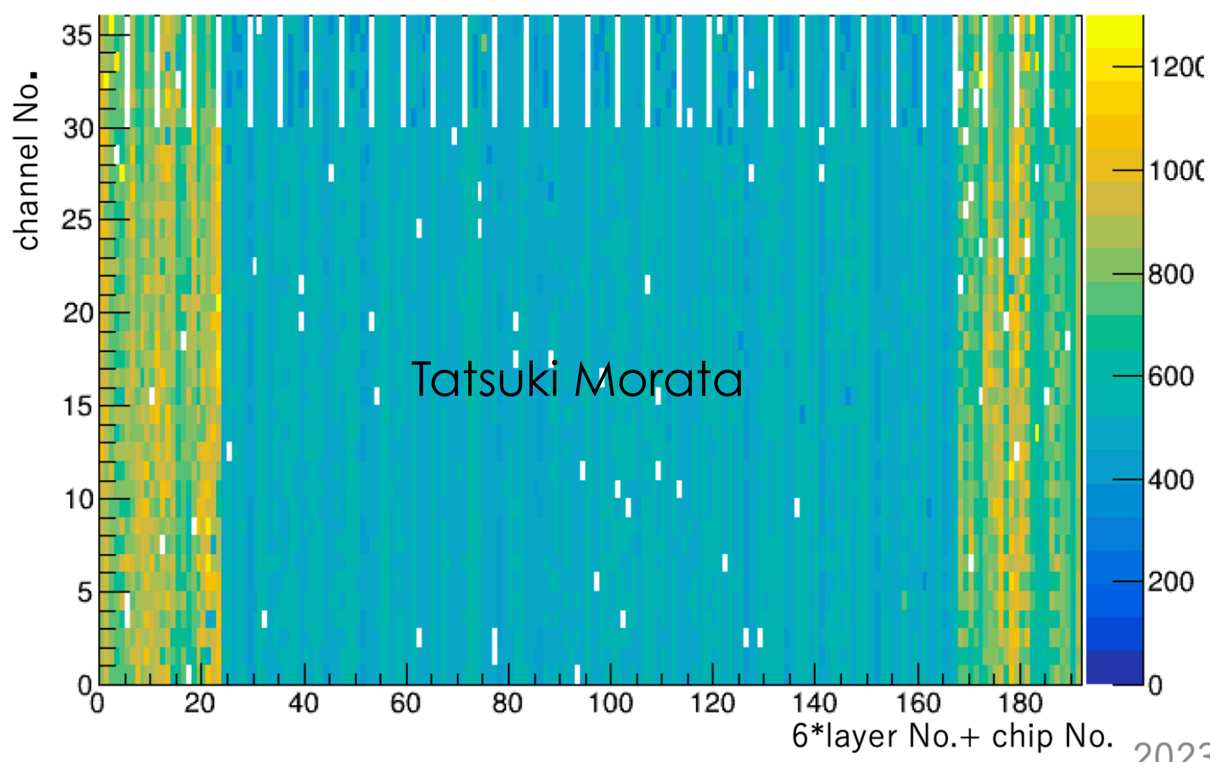


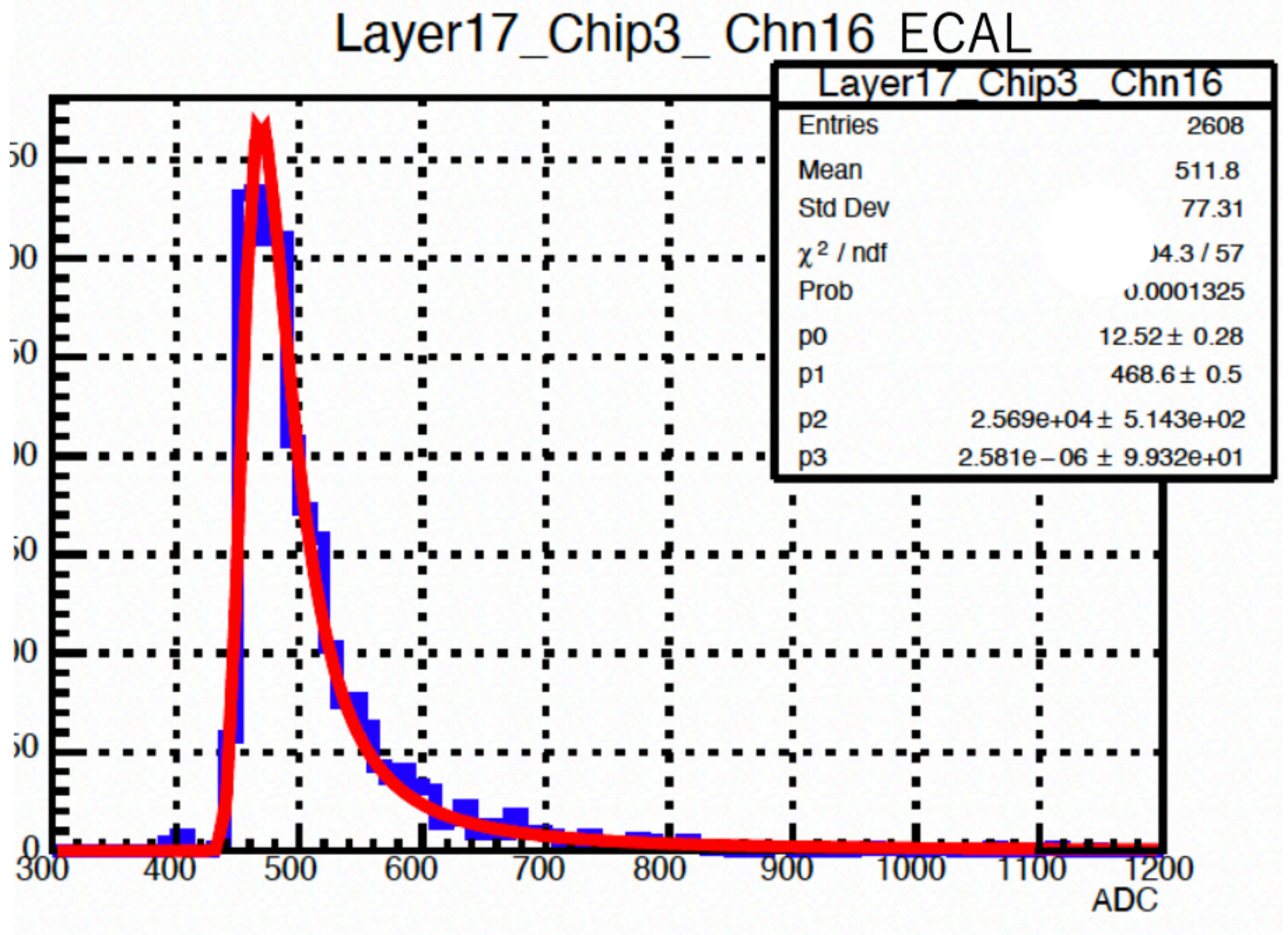
Fig. SiWECAL Electron 150 GeV

CALICE ECAL (SiW ~ 21 X_0 read out with different generations of FEV and COB boards) + AHCAL - Results on quality check + PID + MIP energy deposits







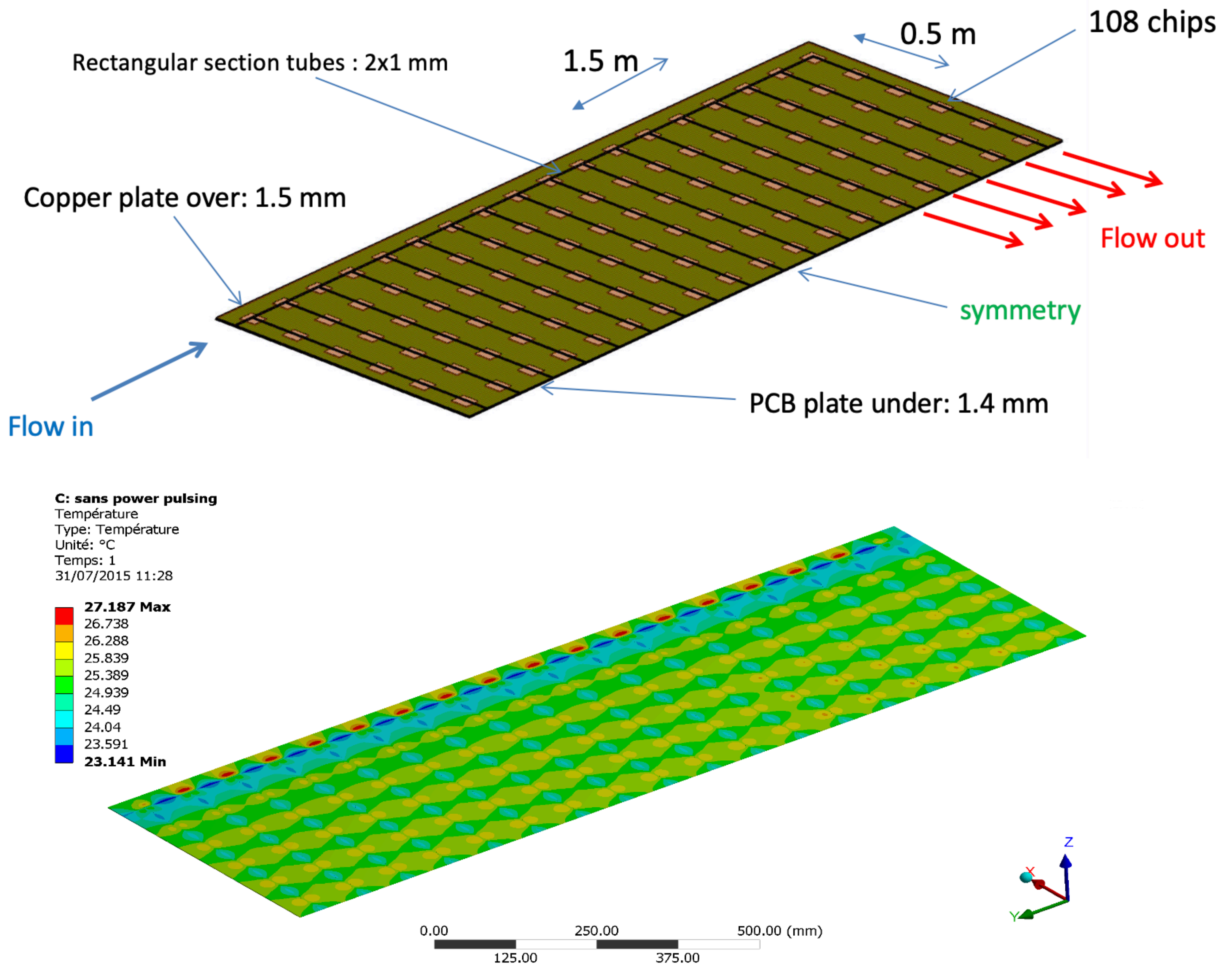


Scintillator based (Sc-ECAL, W absorber read out with SiPM - 23.3 X_0) + AHCAL

Calorimeters - the pub perspective

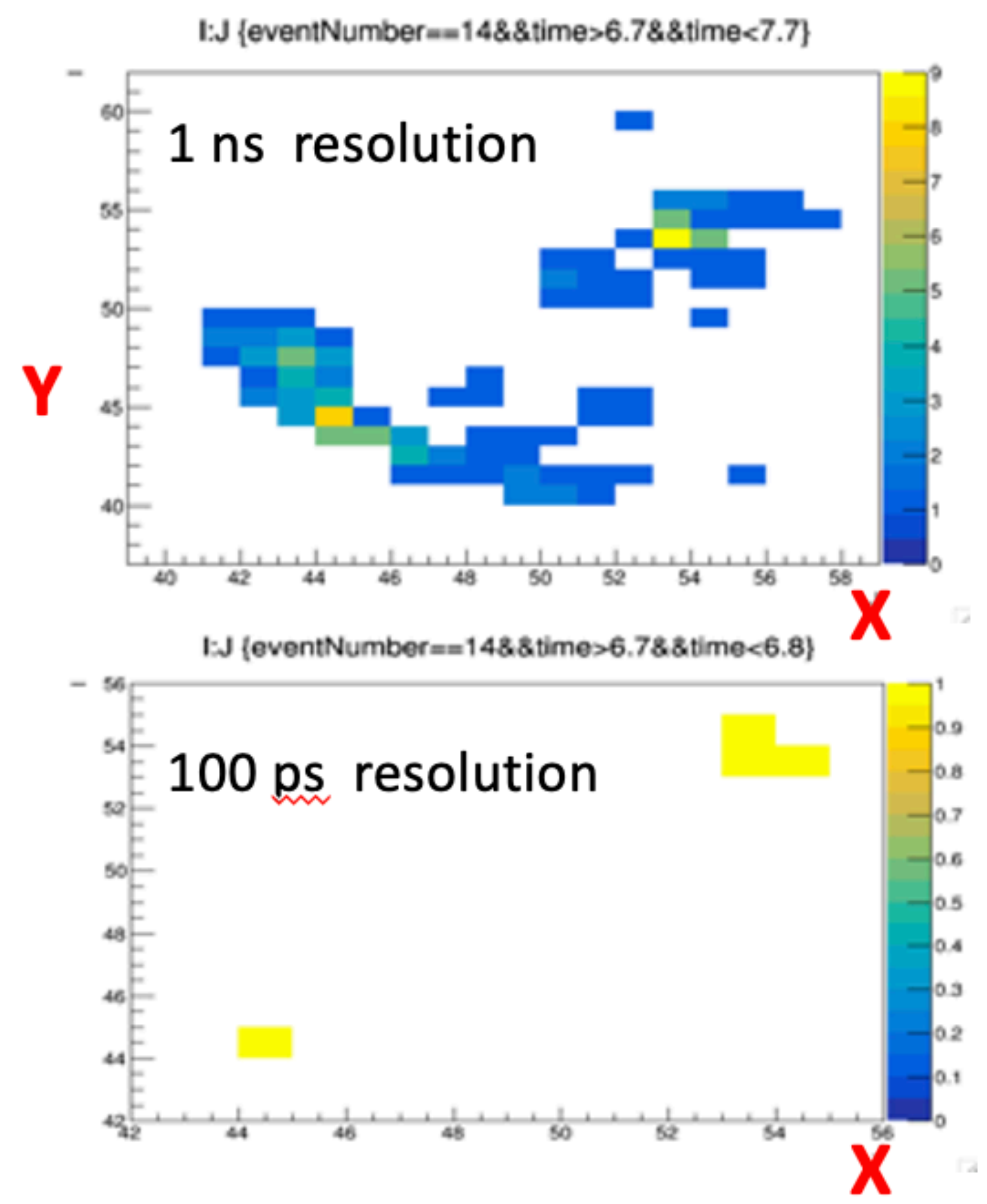
Calorimetry - SDHCAL

- SemiDigital hadronic calorimeter (using Glass Resistive plate chambers - originally designed for ILC, now adapted to circular colliders (CC). No power-pulsing at CC $\Rightarrow$ Need for cooling.



Water cooling circulation obtaining uniform temperatures on the board

Imad Laktineh

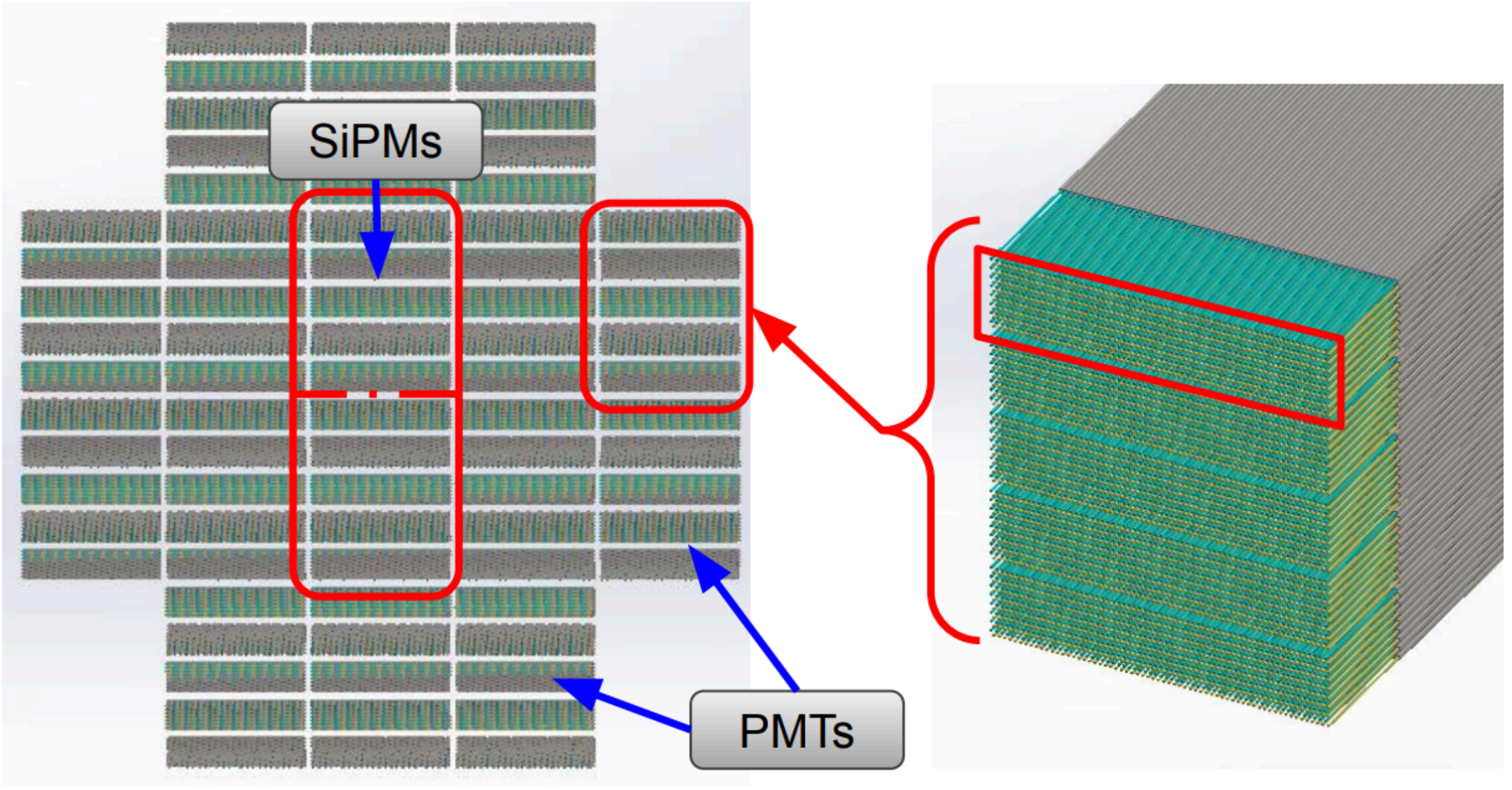


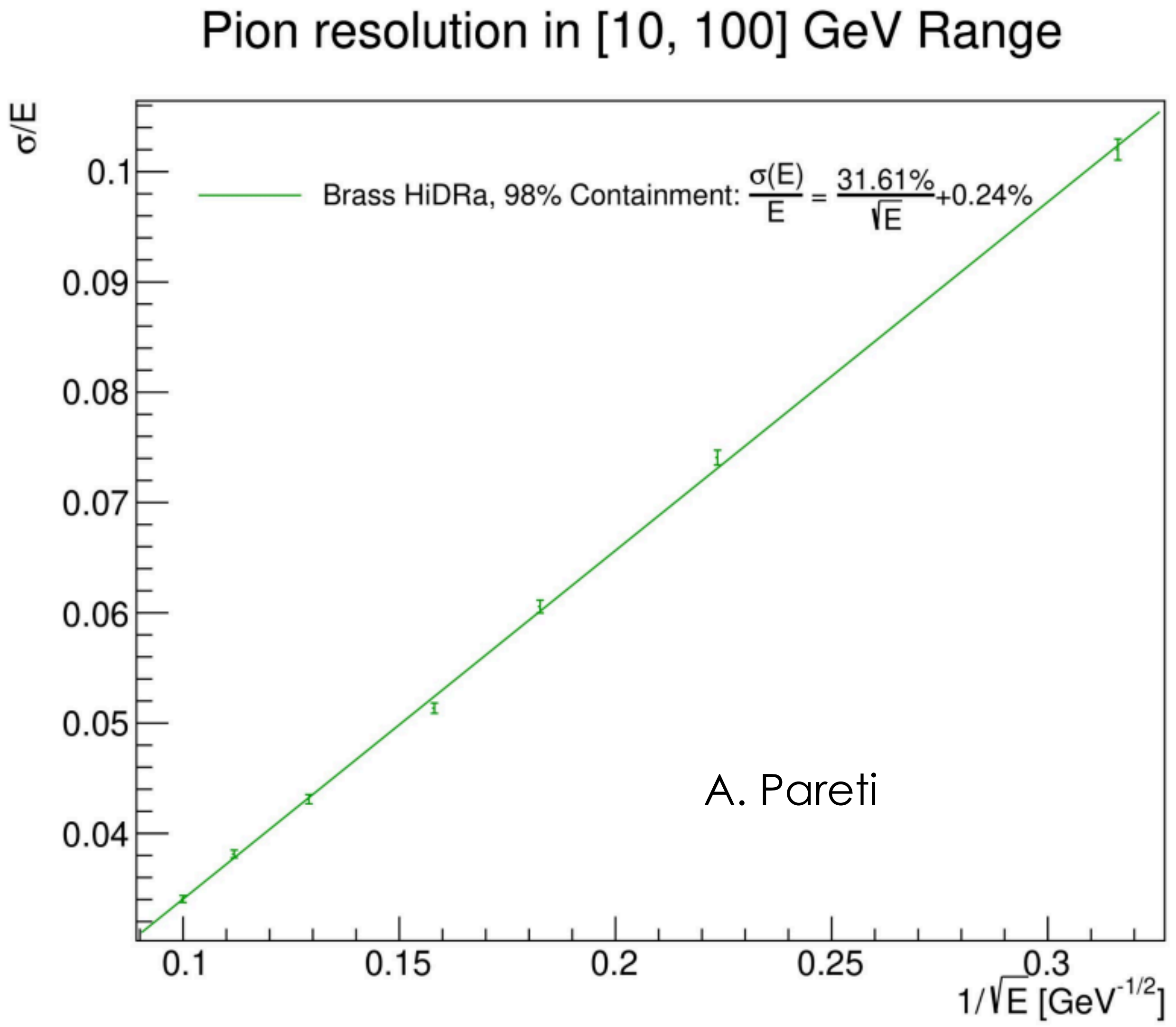
Towards 5-D calorimeter. Timing improves cluster separation. Studies ongoing with MultiGAP RPC + PETIROC promising

Dedicated studies on the use of glass doped with nanoparticles to improve rate capabilities of detector

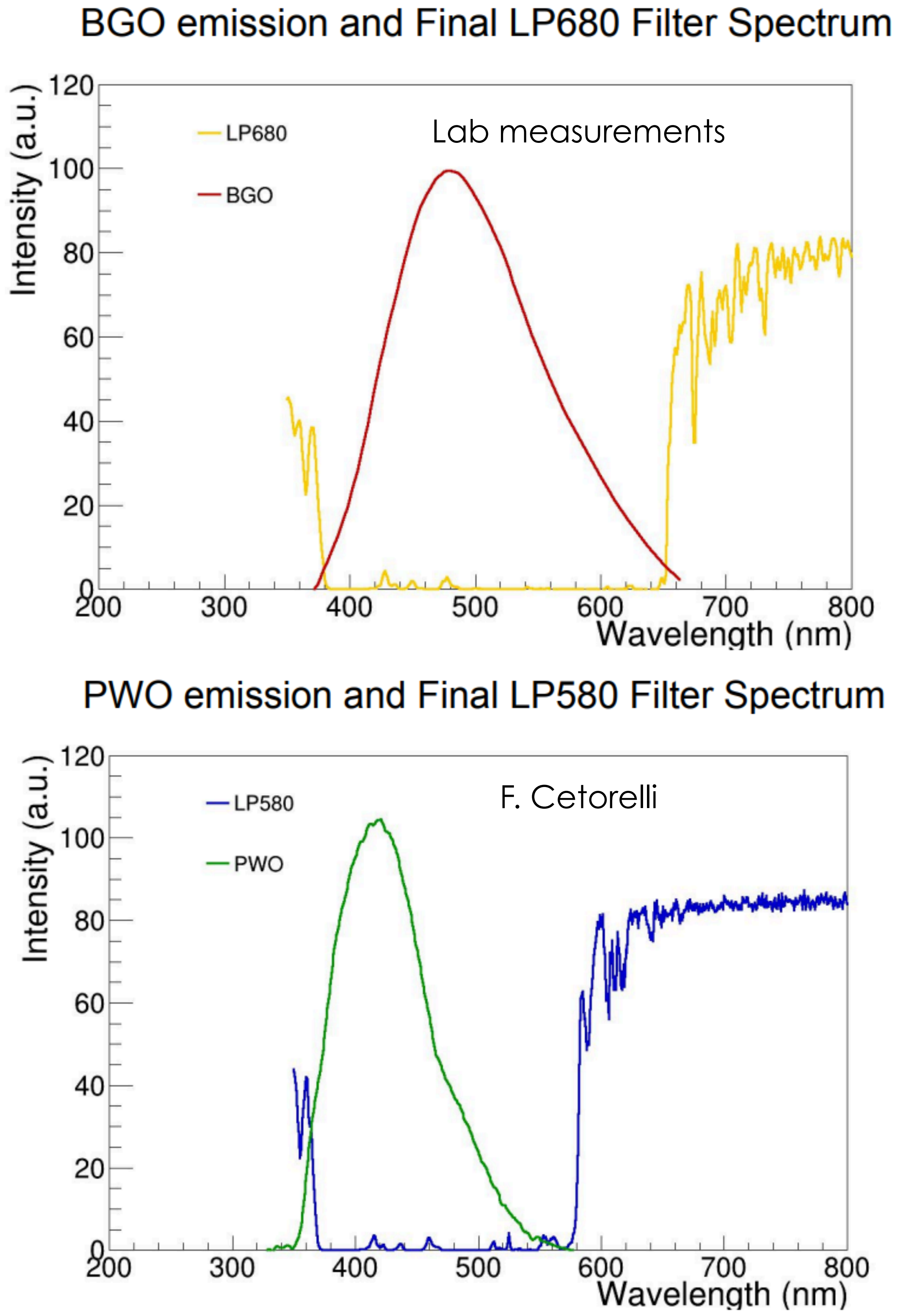
Calorimetry - dual readout

- Fiber calorimeter aiming at hadronic-size prototype (next two years)





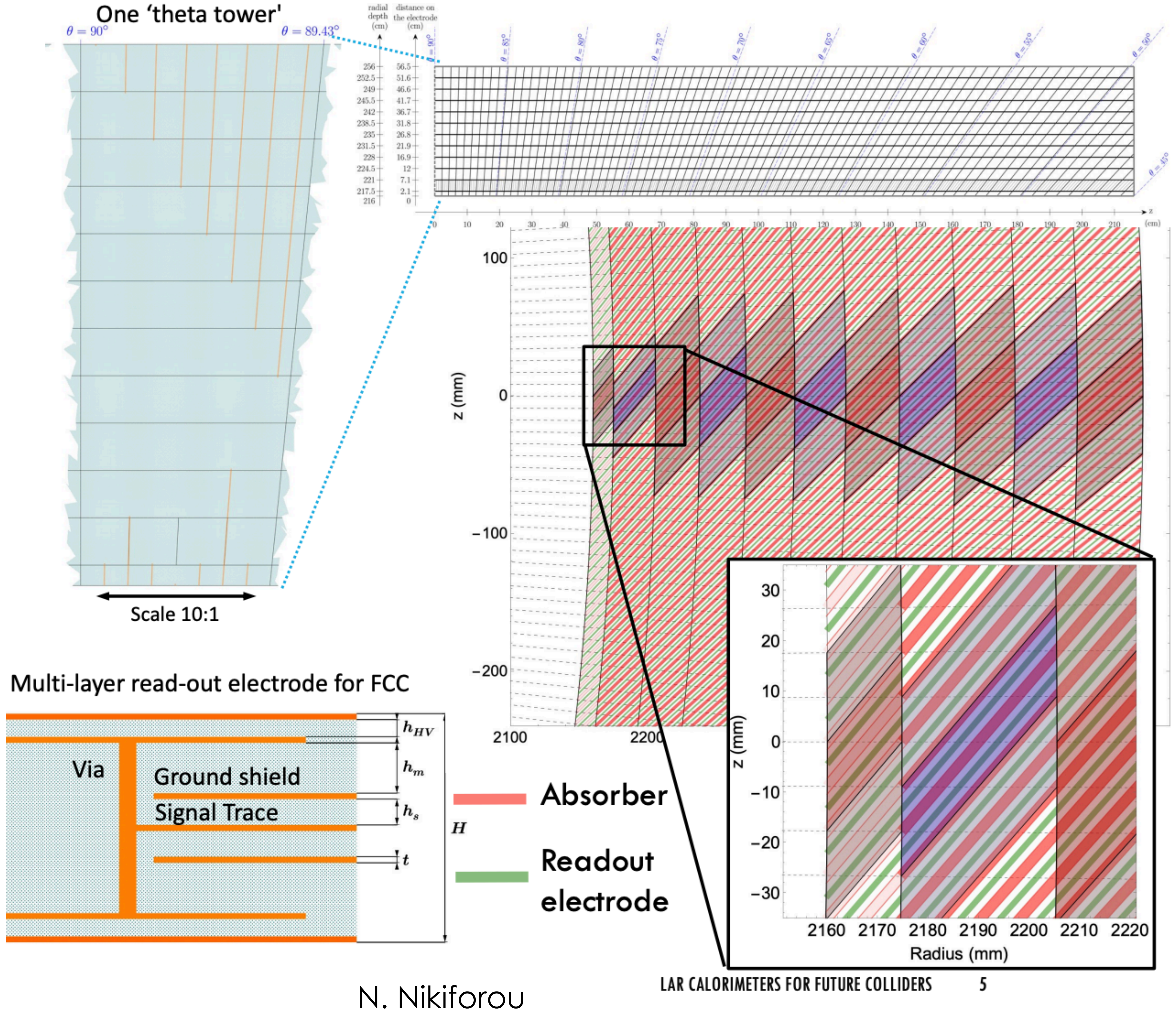
- Crystal-based EM section proposed - working on the choice of crystals and filters to separate (in frequency) Cherenkov from scintillation light.



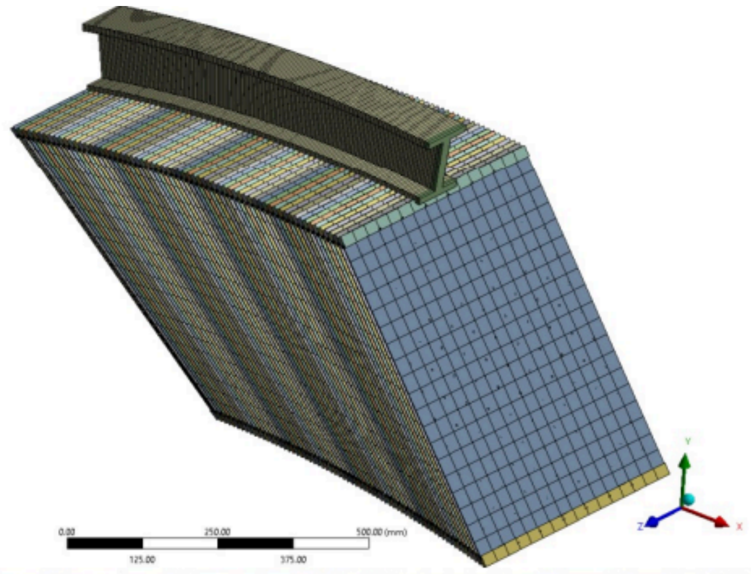
20

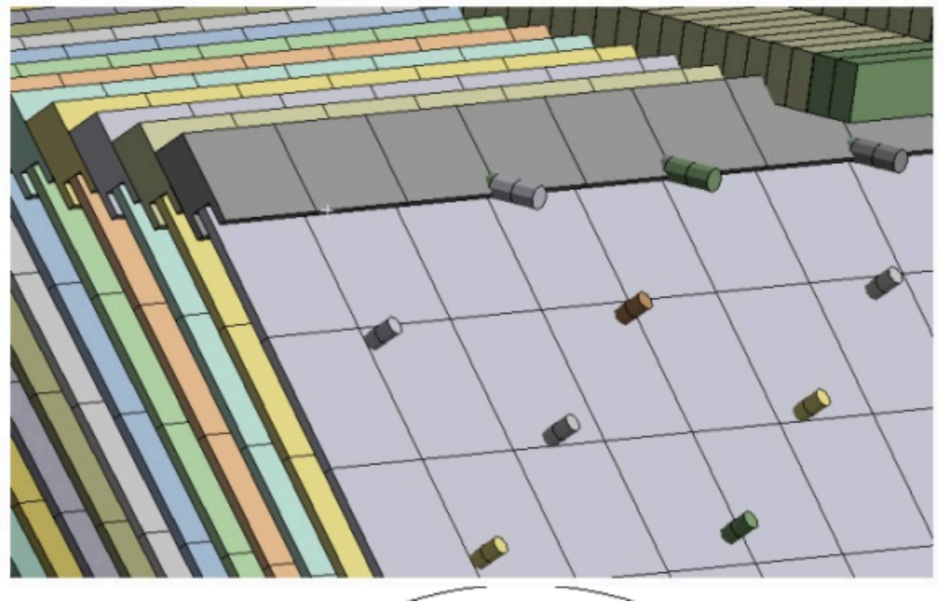
Noble gas calorimeters for lepton colliders

- Successfully used in ATLAS (and other experiments before).
- Being reoptimised for lepton collider.
  - Optimisation of geometry, electrodes design, electronics (cold or warm?), absorber and gas



N. Nikiforou





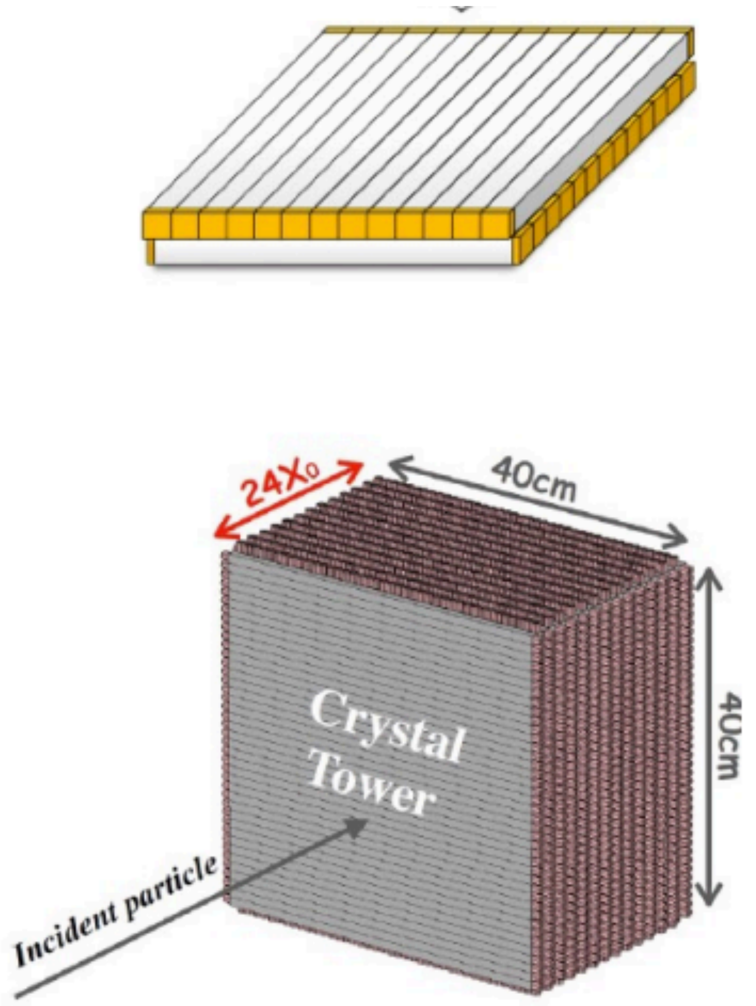
- Mechanical challenge to support electrodes while maintaining structure light being also investigated.

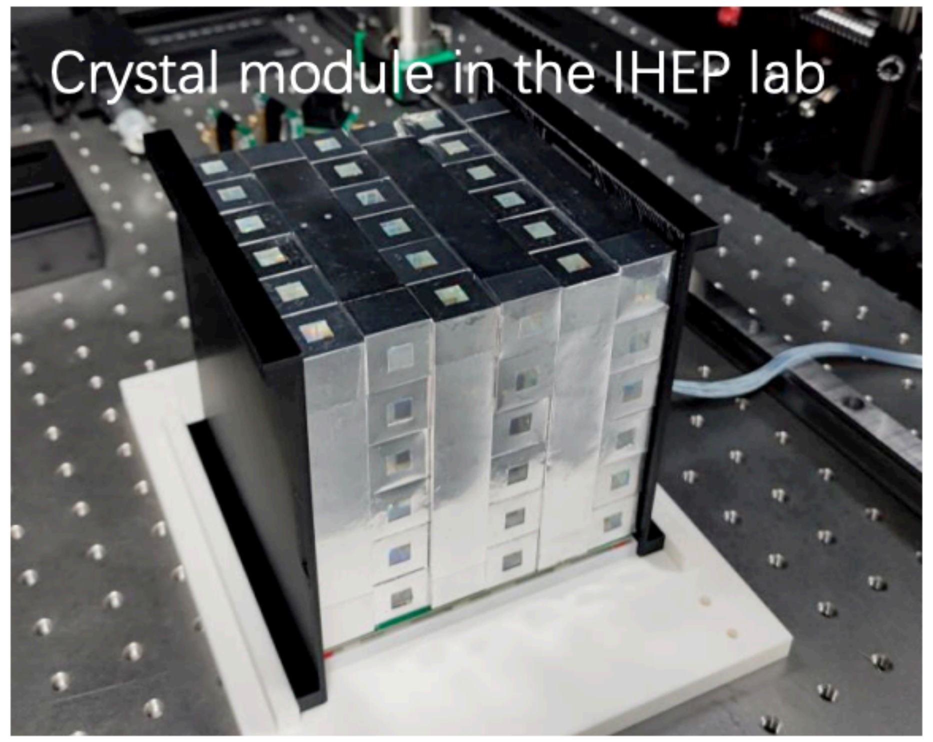
21

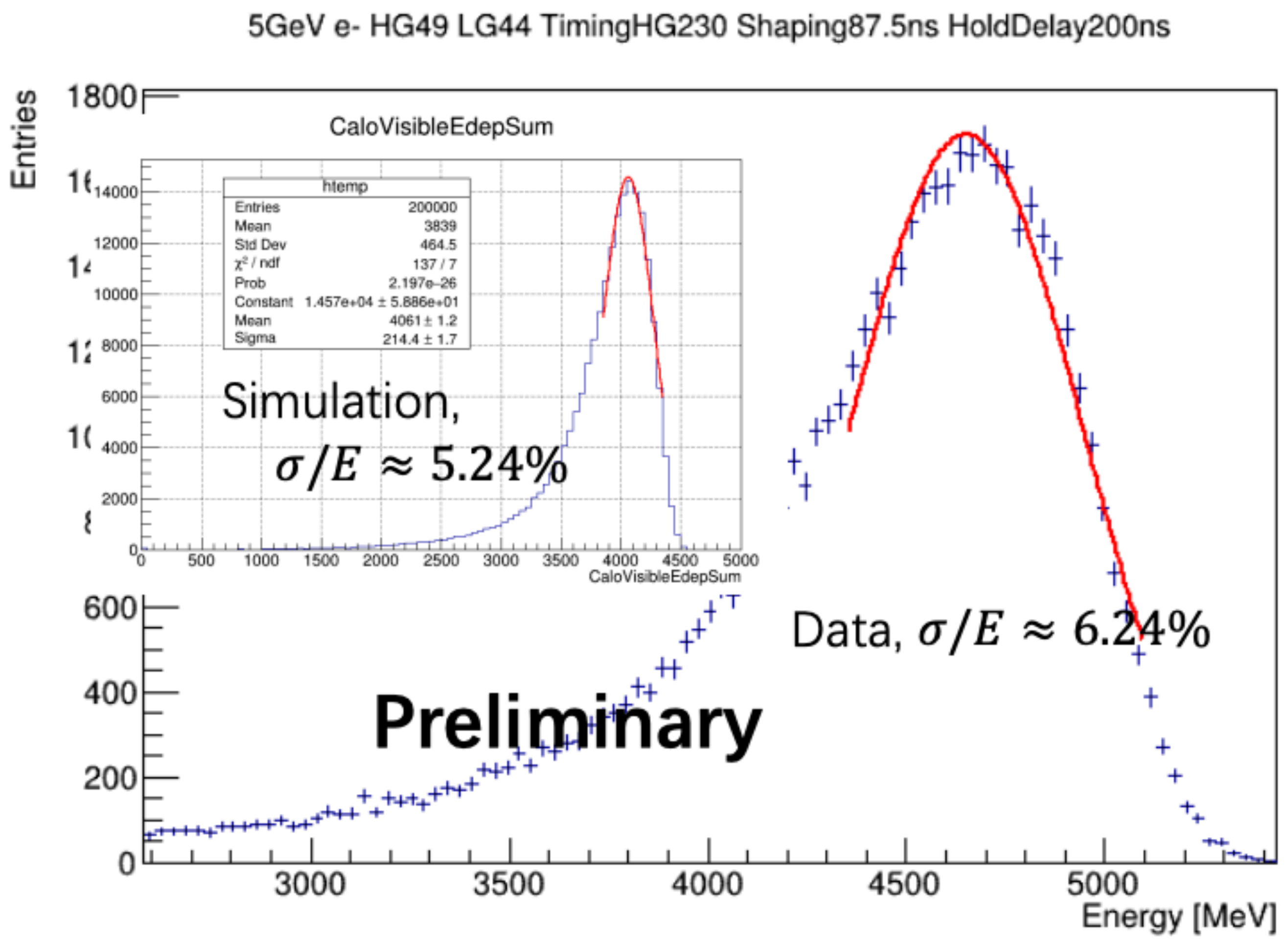
Fangyi Guo, Zhang Yang

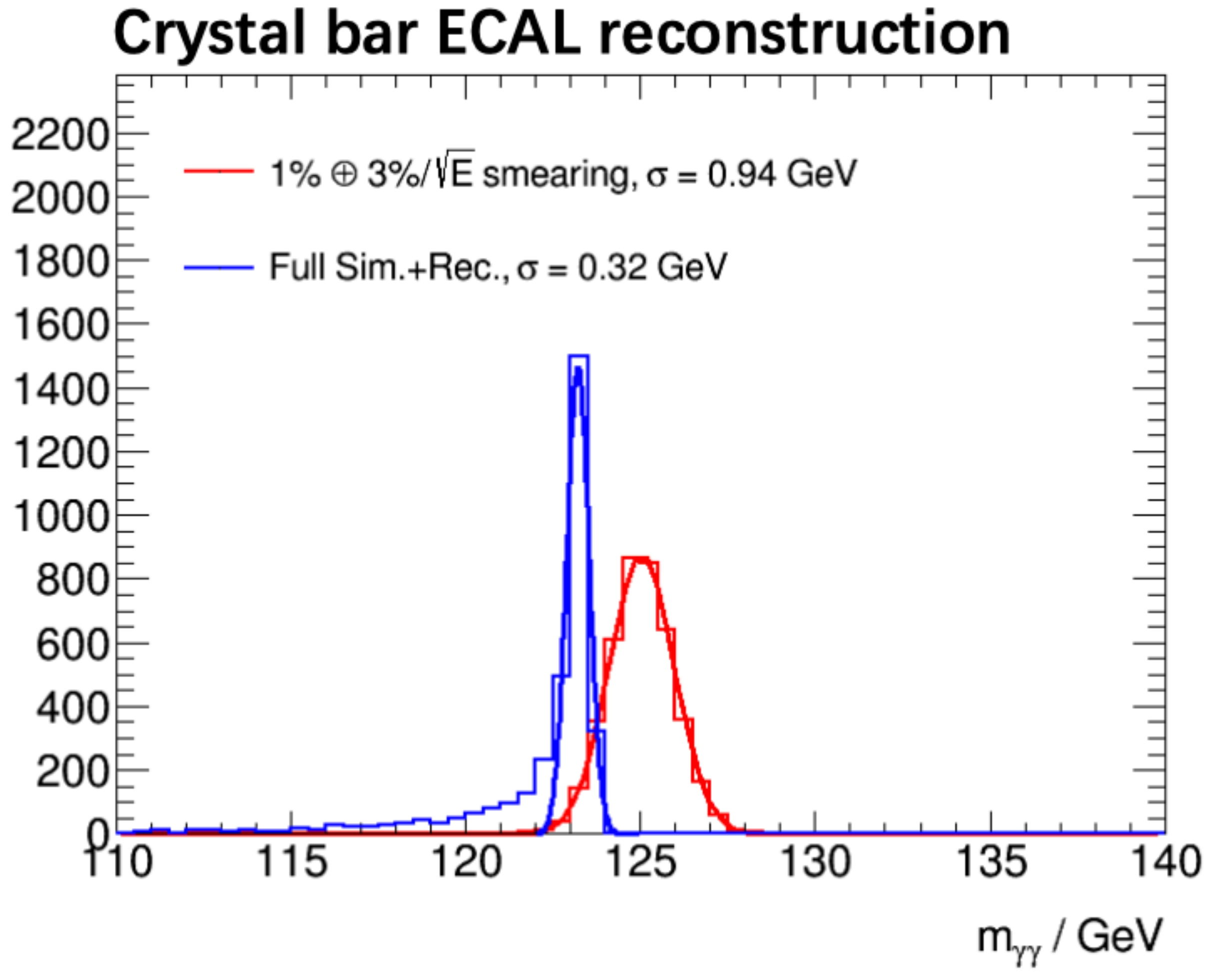
HGC-ECAL

- Impressive progress: module developed and put on beam at CERN.
- Software challenges connected with Ambiguity problem being tackled





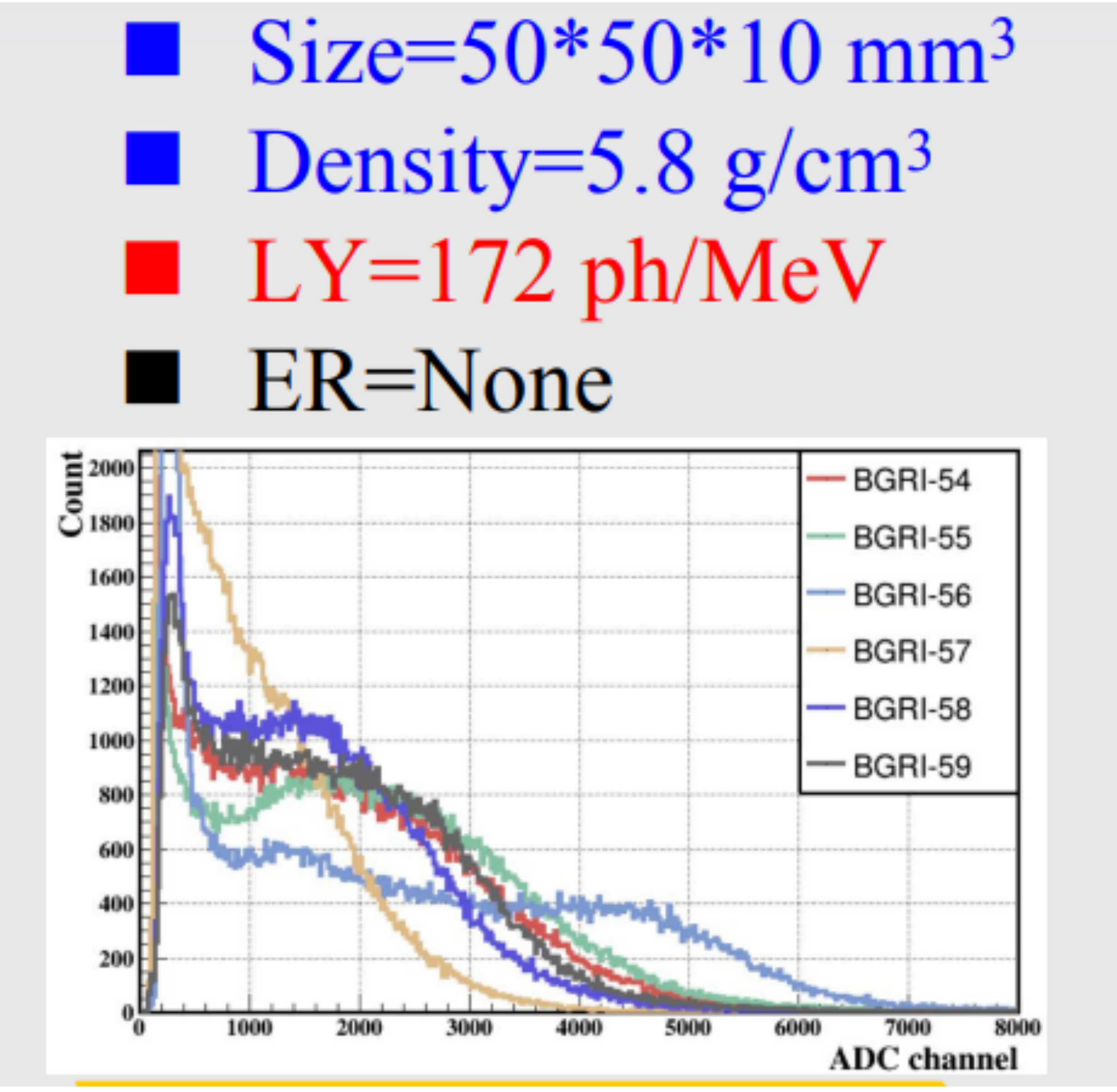


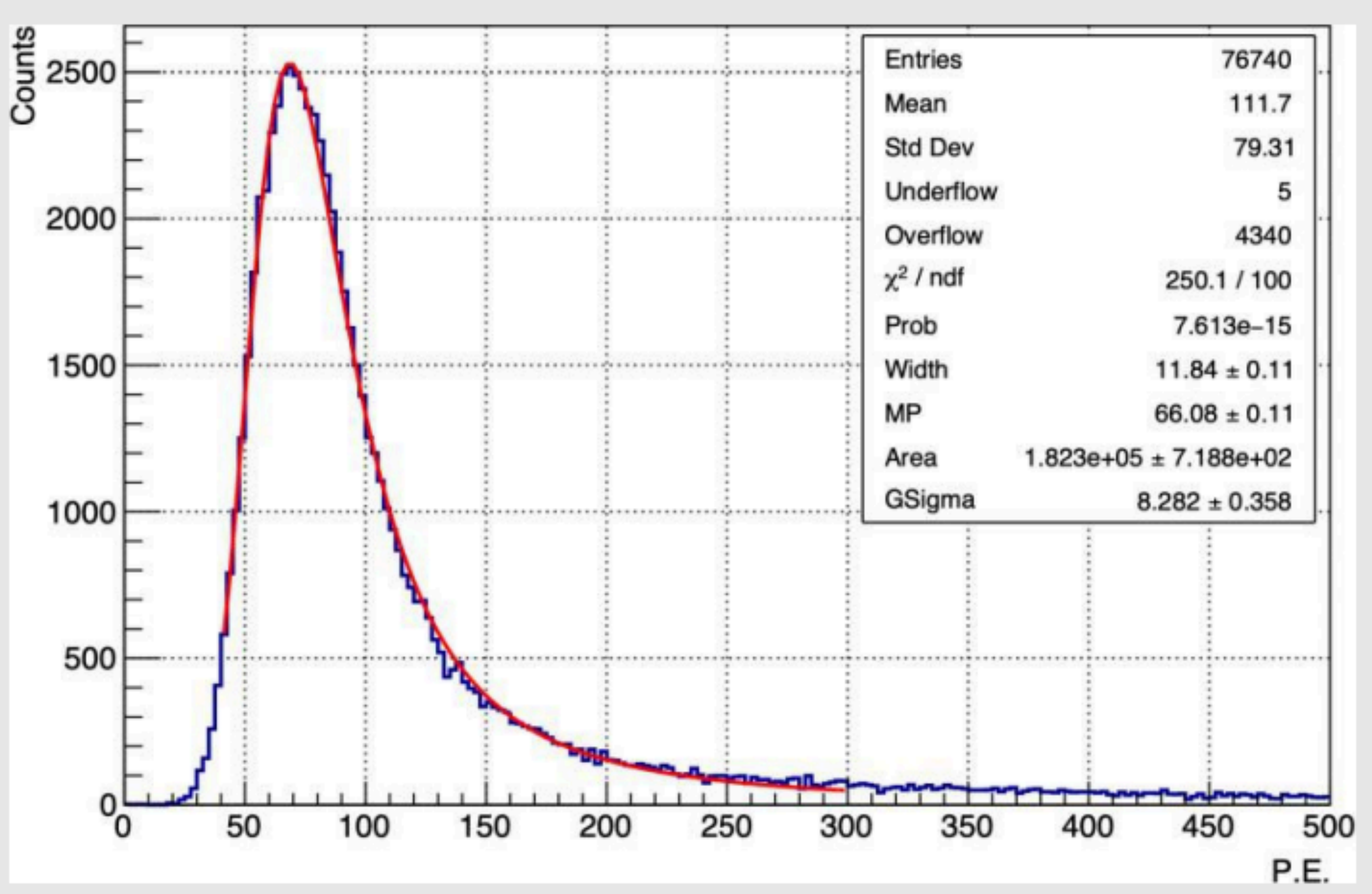


22

Glass Scintillator calorimeter

- Inspired to the AHCAL (scintillator/steel), replace plastic with glass (higher light yield, more compact)
- Prototype built and tested at CERN in 2022
- Understanding how to scale up from lab production is key





Glass scintillator (#3): 66 p.e./MIP ($29.8 \times 28.1 \times 10.2$ mm^3)

The 10 B€/$ question - the pub perspective

The 10 B€/$ question - the pub perspective

The 10 B€/$ question - the pub perspective

All that follows is my own personal opinion!

Higgs factory - the pub perspective

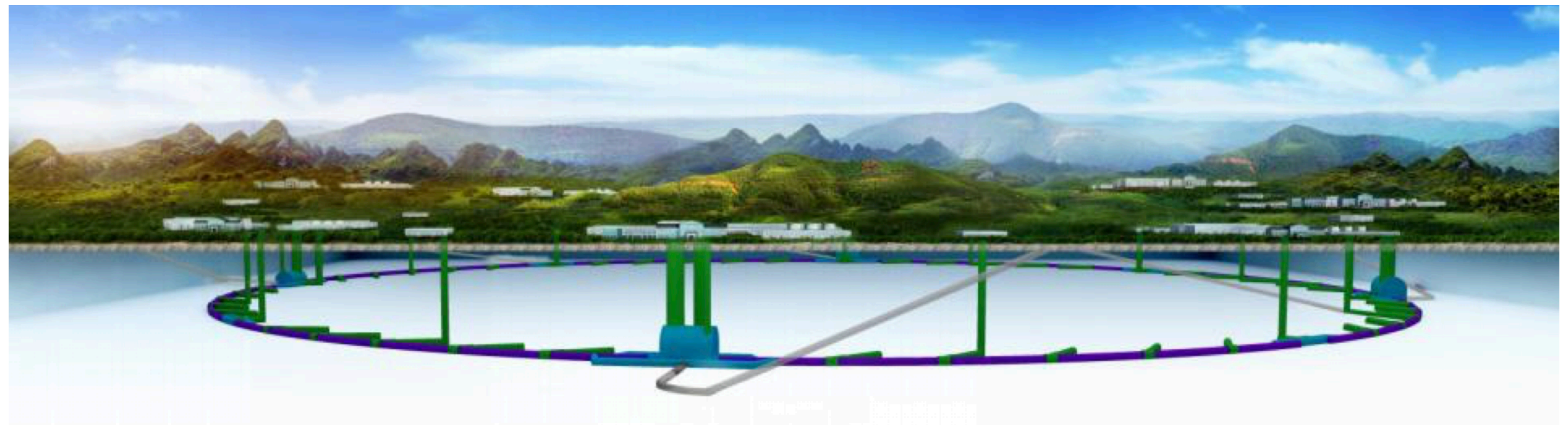
Options being discussed

Higgs factory - the pub perspective

Options being discussed

Circular	Linear

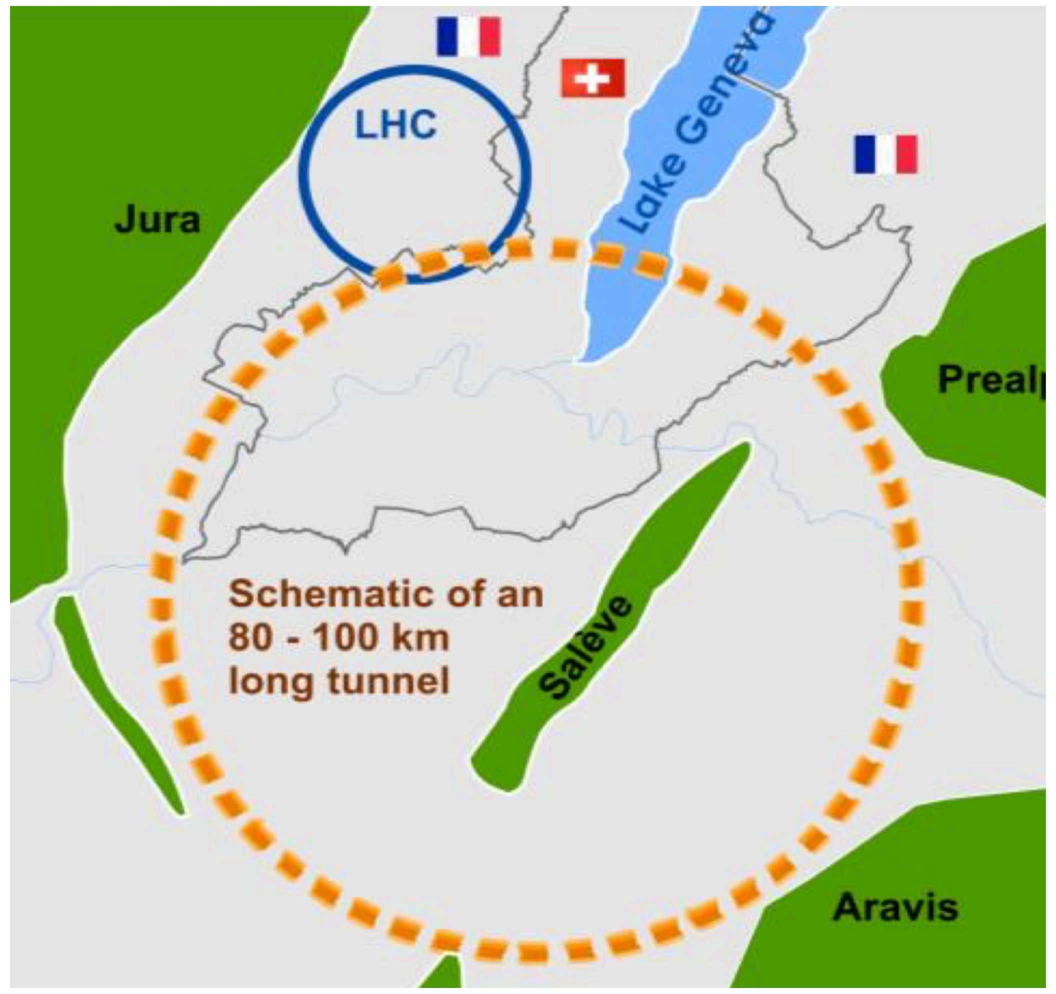
China



CERN

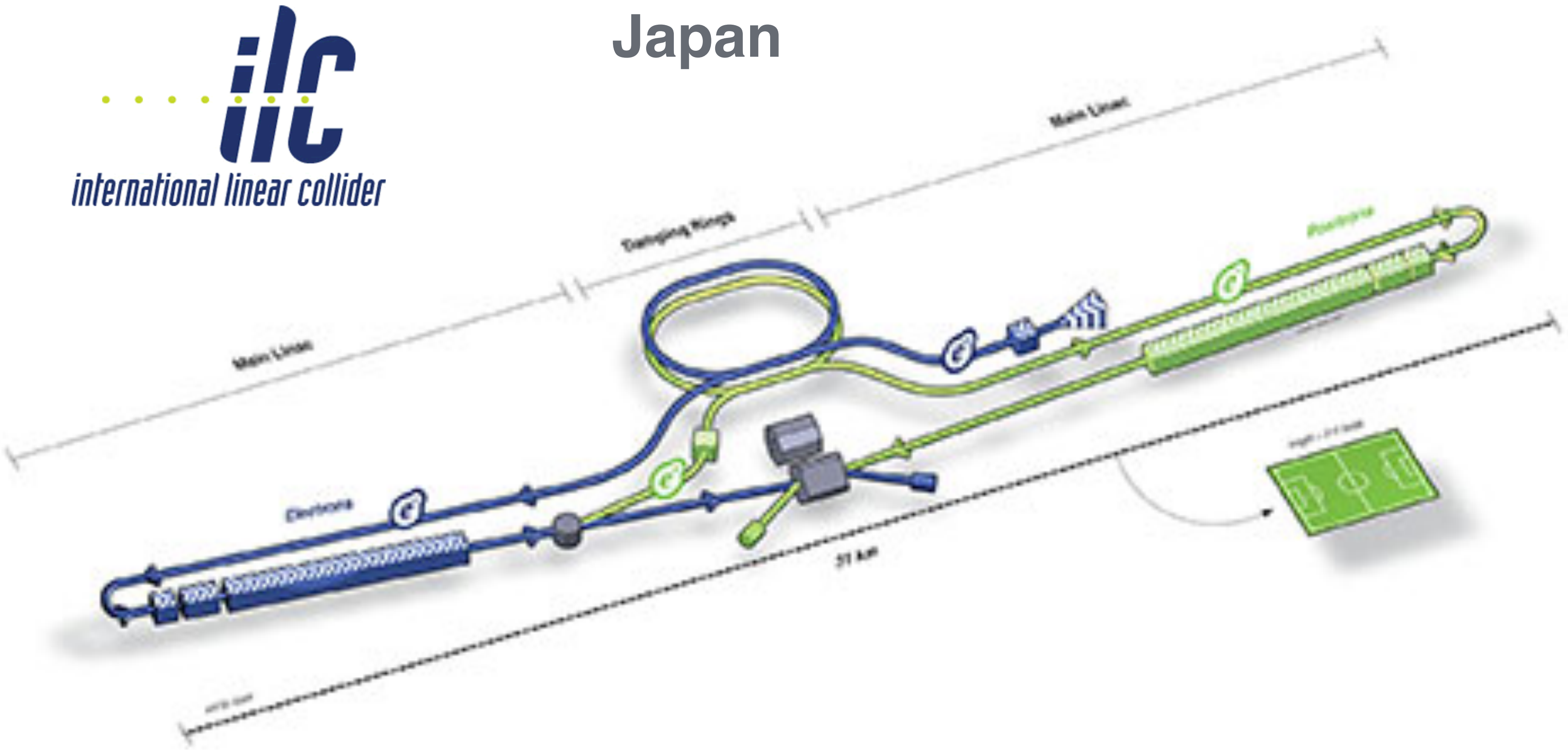
CERN

$\sqrt{s}$ = 90 – 375 GeV



international linear collider

Japan



Higgs factory - the pub perspective

Options being discussed

Circular	Linear

(Too) Many options on the table.

To the ones listed here you should also add:

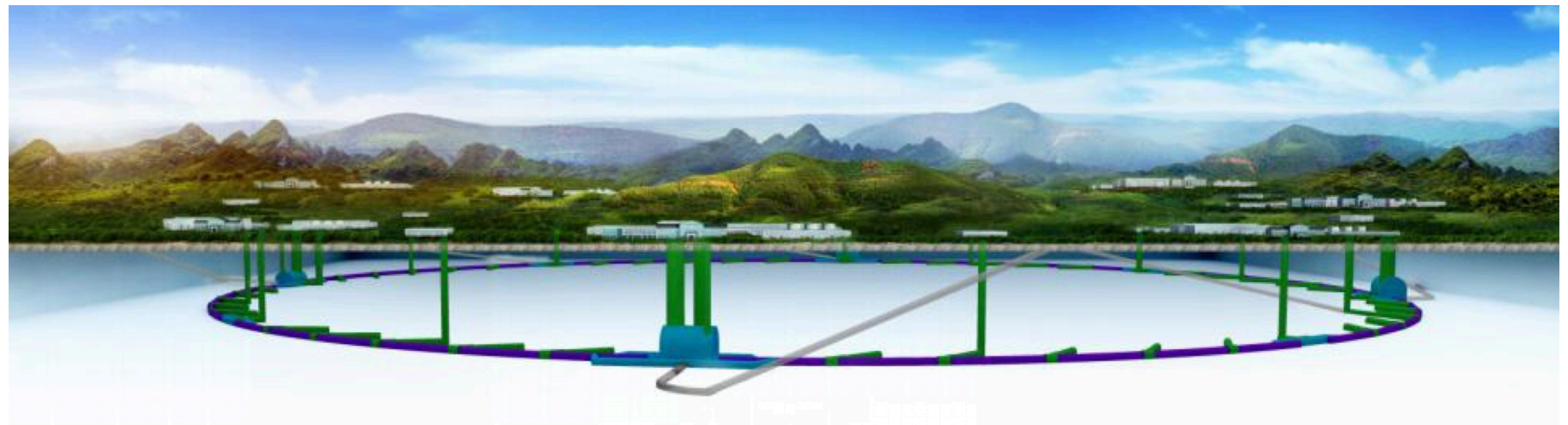
Muon Collider

C[3]

HEP can afford only 1 very large project.

It has to be truly **worldwide**.

China



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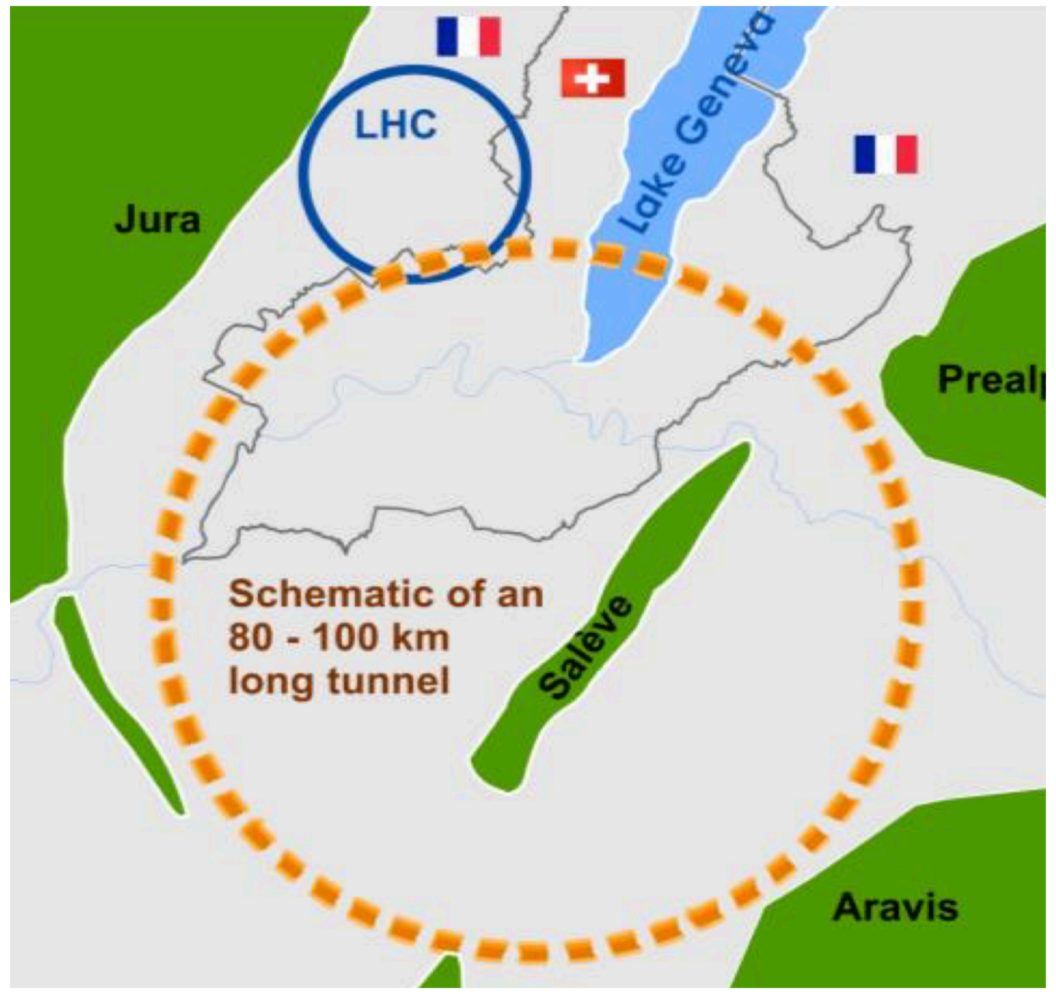
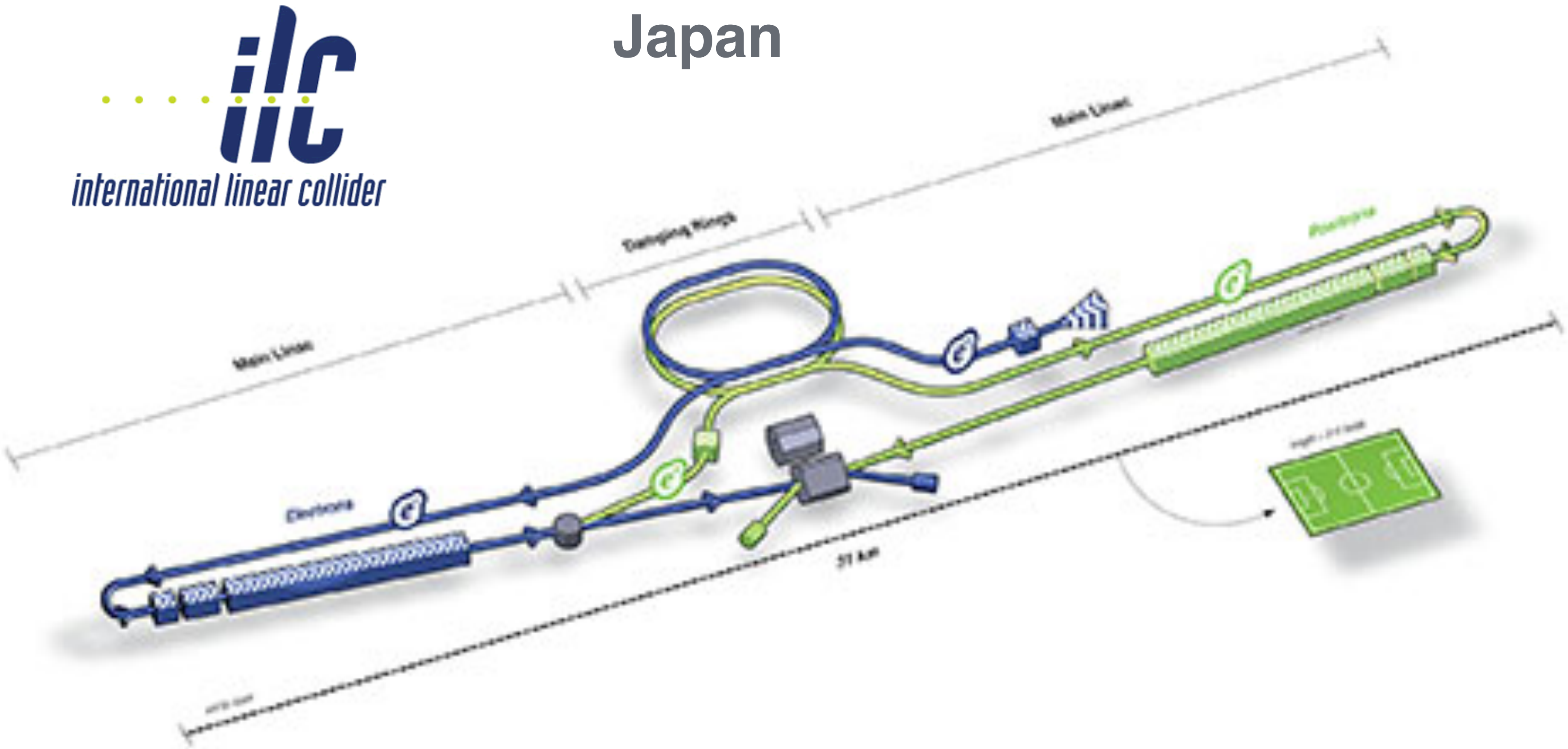


Japan



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  - **Other machine components**

Conclusions

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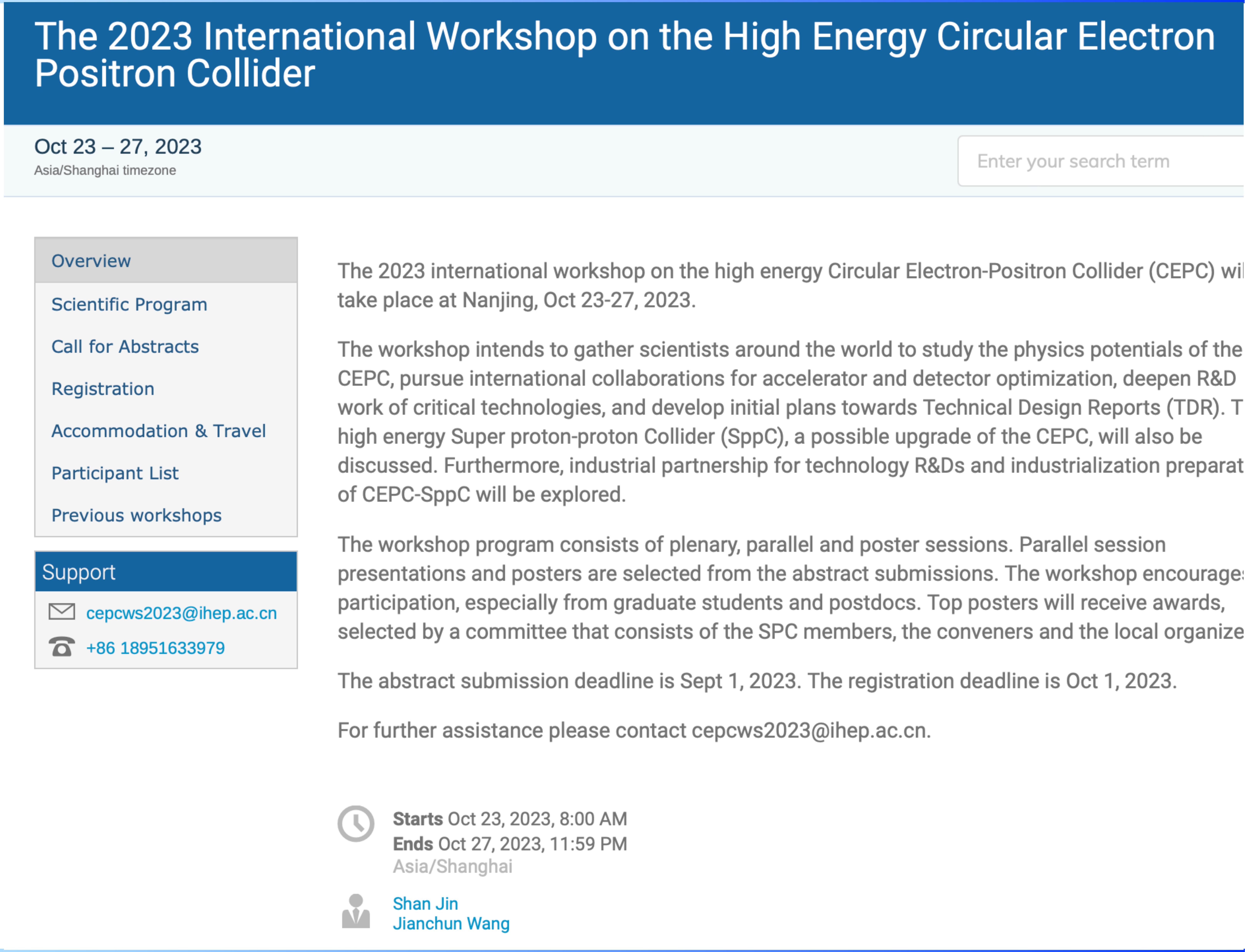
Let's make sure we get at least one collider approved between FCC and CEPC!

Nanjing, October 23-27/10/2023:

https://indico.ihep.ac.cn/event/19316/

The workshop will be with in-person participation



The 2023 International Workshop on the High Energy Circular Electron Positron Collider

Oct 23 – 27, 2023
Asia/Shanghai timezone

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The 2023 international workshop on the high energy Circular Electron-Positron Collider (CEPC) wi take place at Nanjing, Oct 23-27, 2023.

The workshop intends to gather scientists around the world to study the physics potentials of the CEPC, pursue international collaborations for accelerator and detector optimization, deepen R&D work of critical technologies, and develop initial plans towards Technical Design Reports (TDR). T high energy Super proton-proton Collider (SppC), a possible upgrade of the CEPC, will also be discussed. Furthermore, industrial partnership for technology R&Ds and industrialization preparat of CEPC-SppC will be explored.

The workshop program consists of plenary, parallel and poster sessions. Parallel session presentations and posters are selected from the abstract submissions. The workshop encourage participation, especially from graduate students and postdocs. Top posters will receive awards, selected by a committee that consists of the SPC members, the conveners and the local organize

The abstract submission deadline is Sept 1, 2023. The registration deadline is Oct 1, 2023.

For further assistance please contact cepcws2023@ihep.ac.cn.

Starts Oct 23, 2023, 8:00 AM
Ends Oct 27, 2023, 11:59 PM
Asia/Shanghai

Shan Jin
Jianchun Wang

Have a nice flight back home!