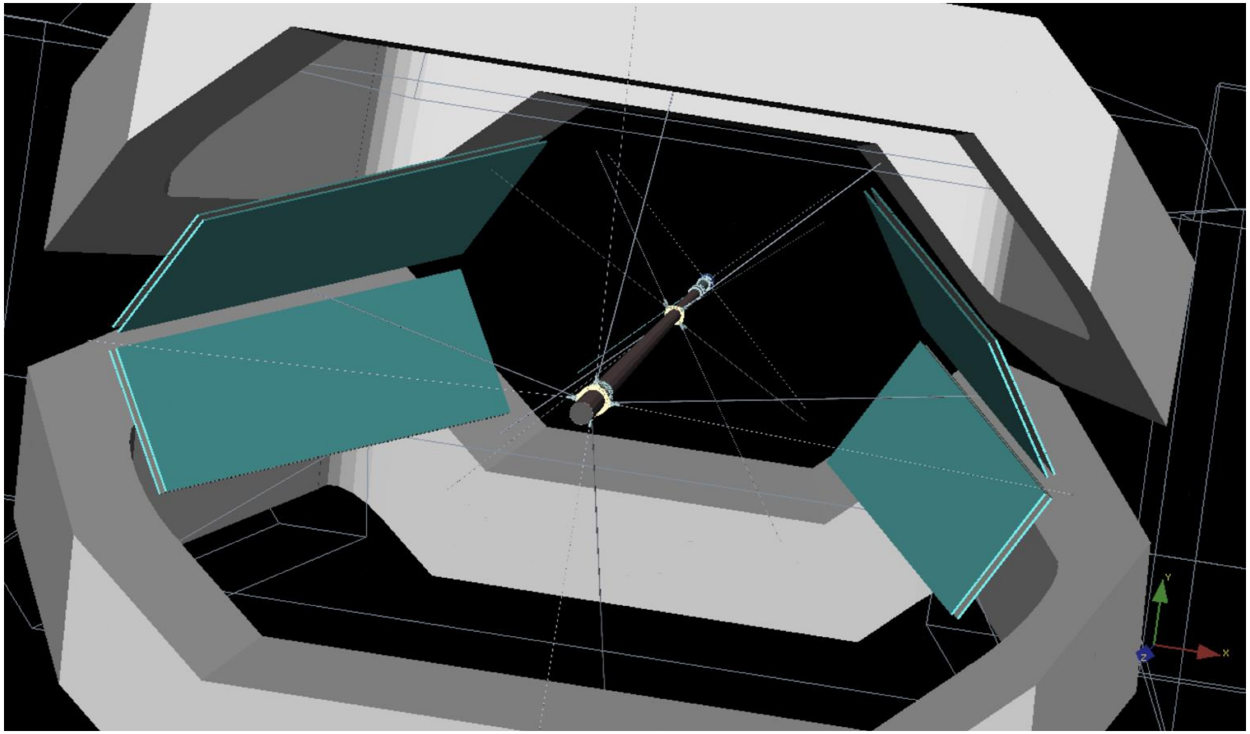
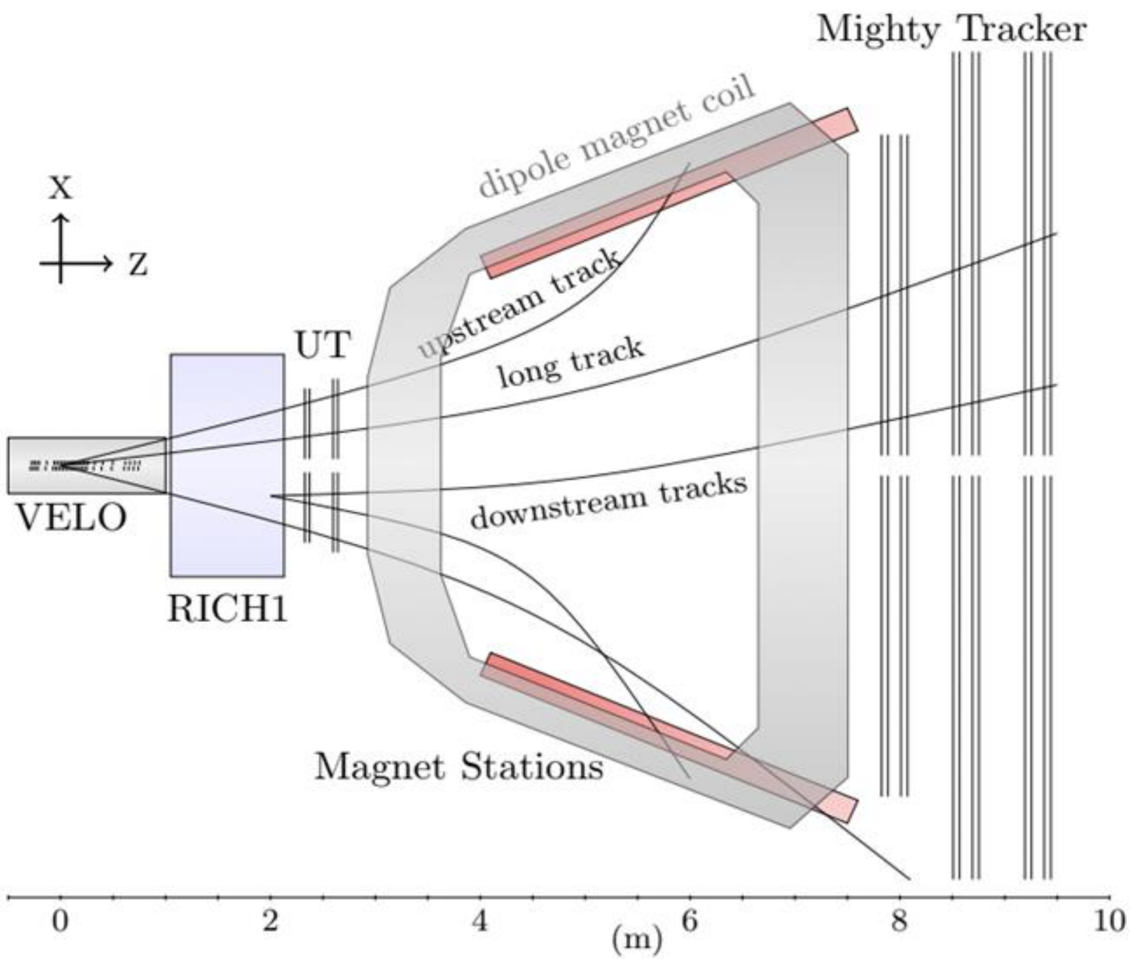
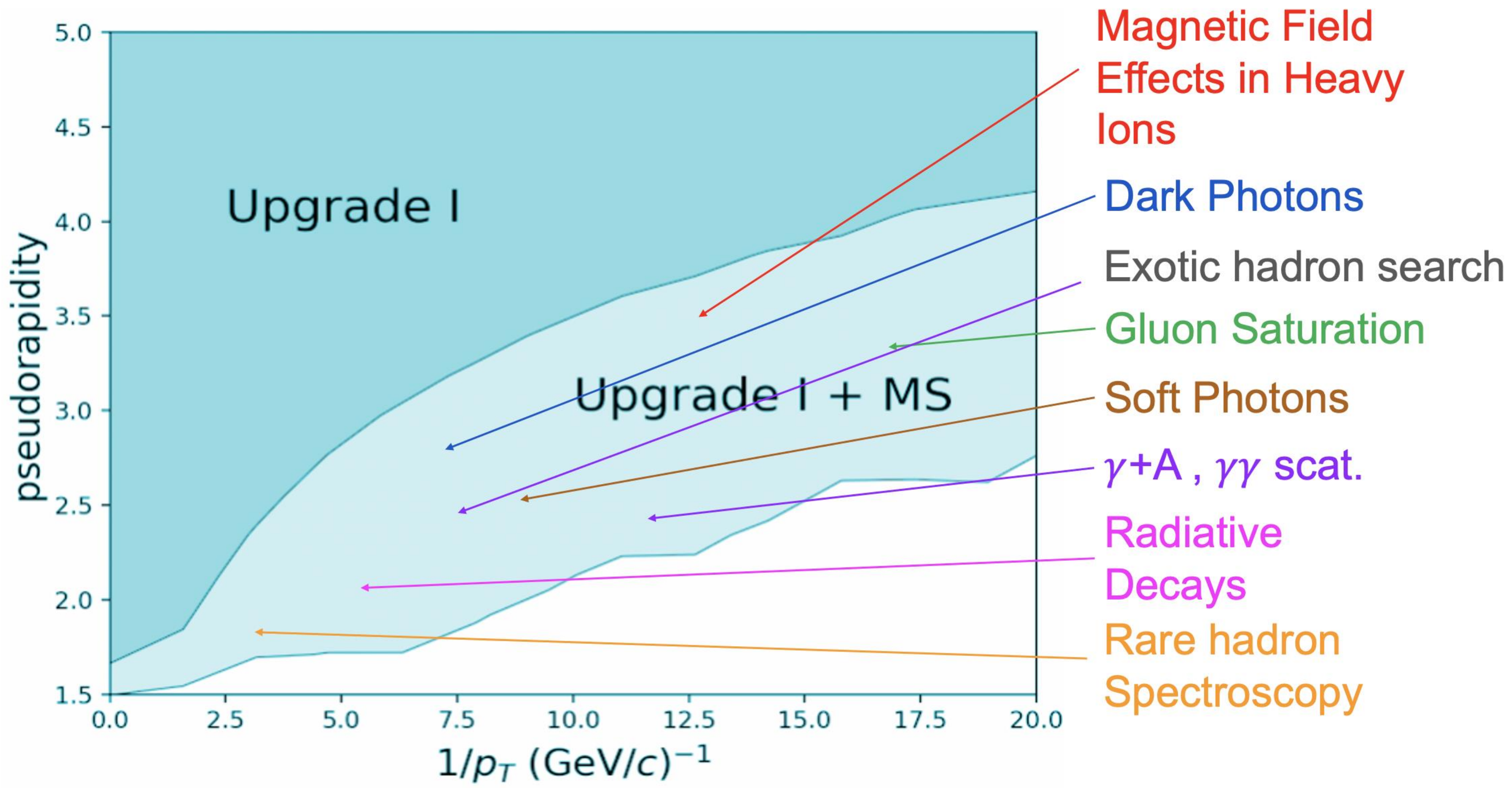
Magnet Station Updates



Los Alamos National Lab (LANL):
Cesar da Silva, Matt Durham, Eliane Epple, Bade Sayki, Hubert van Hecke
Krakow Institute of Nuclear Physics (PAN) :
Marcin Chrzaszcz, Jakub Malczewski,
Krakow University of Science and Technology (AGH) :
Marek Idzik, Jakub Moron, Krzysztof O´slizło
Krakow University of Technology (PK) :
Piotr Duda, Łukasz Felkowski



Framework TDR



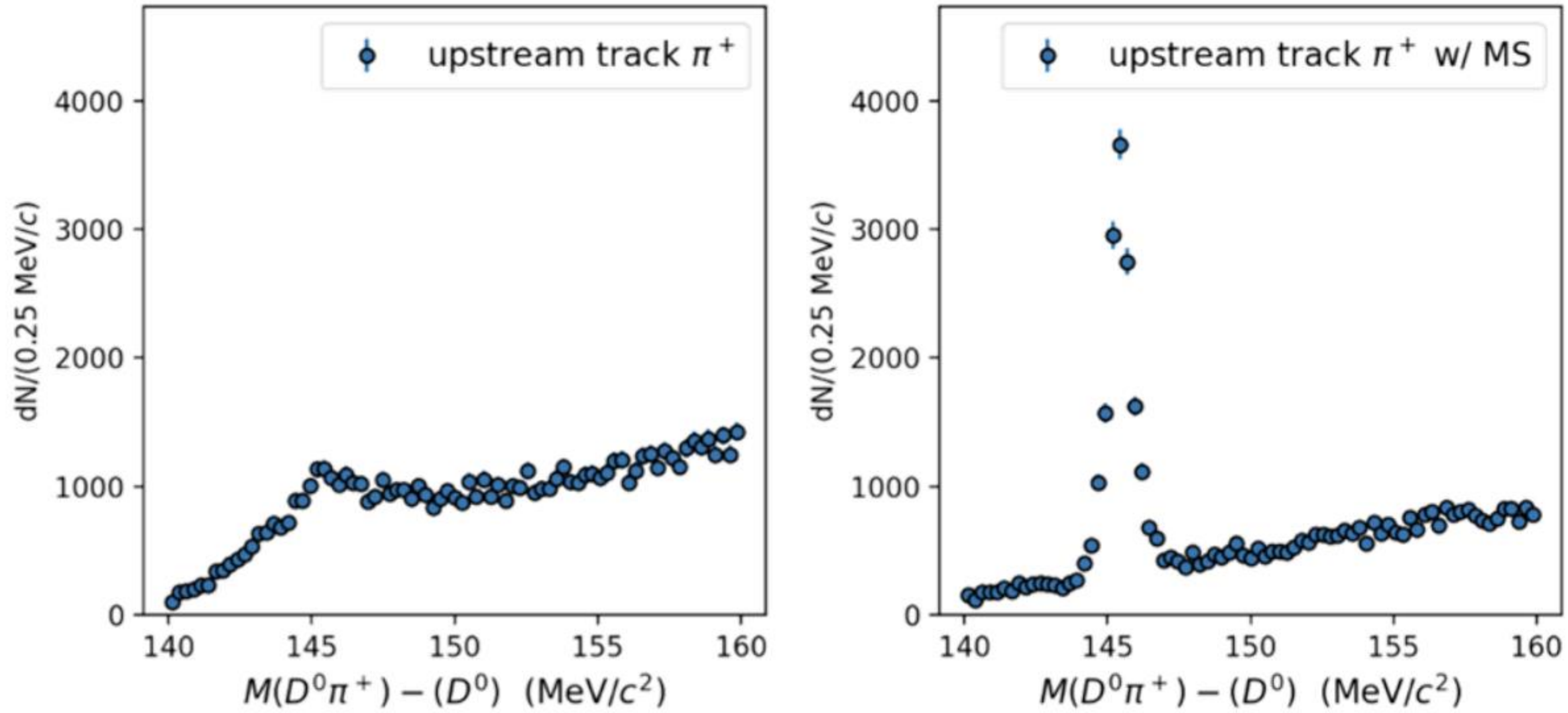
- Growing physics topics which can benefit from Magnet Station...
- Recurring requests from theorists on a technical and physics paper to guide their calculations.

Table 3.1: Track efficiency relative to the condition where the particle produce two hits in UT.

channel	≥8 SciFi hits	SciFi+MS hits	gain
$\gamma \to e^+e^-$ ($p_{T,\gamma}$ >10 MeV/c)	0.245	0.98	4.1
$\rho^0 \to \pi^+\pi^-$	0.530	0.780	1.5
$K^0_S \to \pi^+\pi^-$	0.384	0.720	1.9
$K^{*0} \to K^\pm\pi^\mp$	0.479	0.704	1.5
$D^\pm \to D^0\pi^\pm$(from triggered D^0)	0.74	0.91	1.2
$D^{*+} \to D^0\pi^\pm$ (from triggered D^0)	0.33	0.67	2.0
$D^{*0} \to D^0 + e^+e^-$ (from triggered D^0)	0.22	0.66	3.0
$D_s^+ \to D^0K^+$ (from triggered D^0)	0.74	0.89	1.20
$\chi_{c1}(3872)$ (from triggered J/ψ)	0.51	0.73	1.43
$B^+ \to (J/\psi \to e^+e^-\gamma)\,K^+$	0.70	0.83	1.3
$\Omega_c^{*0}(3067) \to (\Xi_c^+ pK^-\pi^+)\,K^+$	0.63	0.80	1.27
$B^+ \to (\bar{D}^0 \to (K_S^0 \to \pi^+\pi^-)\,\pi^+\pi^-)\,K^+$	0.34	0.56	1.7
γ+pomeron $\to J/\psi \to e^+e^-$	0.57	0.69	1.18
γ+pomeron $\to \rho^0 \to \pi^+\pi^-$	0.39	0.58	1.49
$\gamma + \gamma \to e^+e^-$	0.008	0.03	3.8

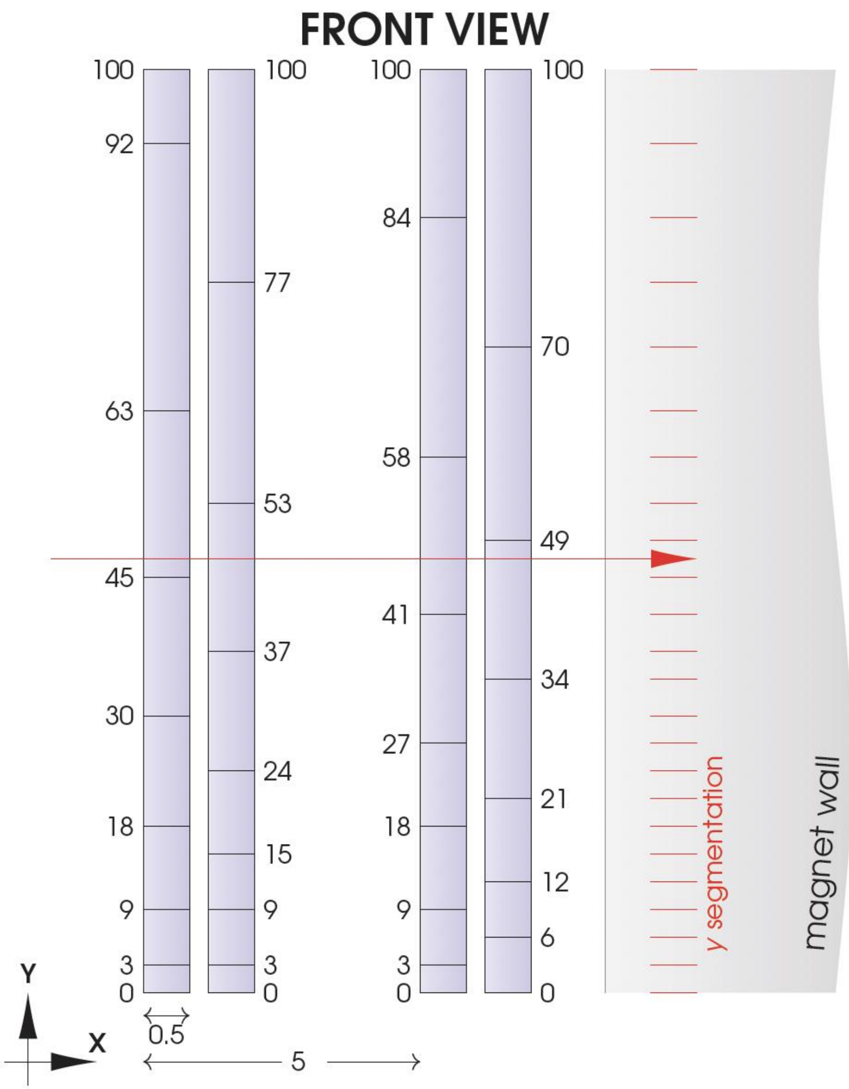
- Growing physics topics which can benefit from Magnet Station...
- Recurring requests from theorists on a technical and physics paper to guide their calculations.

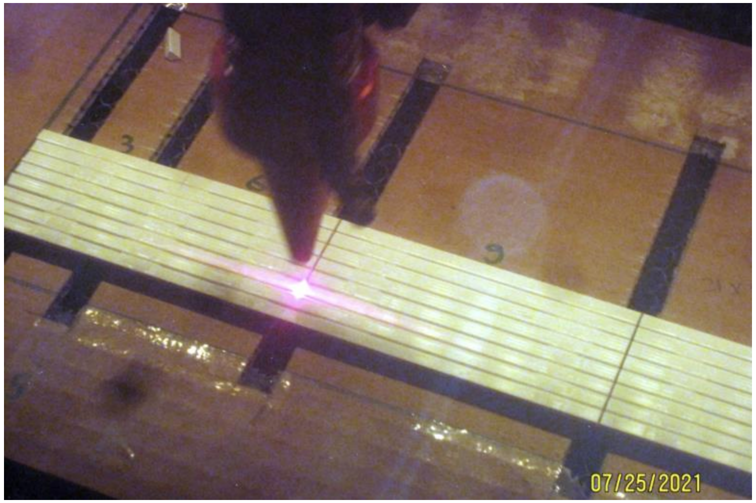
Just one example of what can be done with Magnet Station



- May need more of these examples to illustrate physics reach …
- Cannot wait for a final version of the full U2 simulation, that may not happen in years

Panel Design and Construction

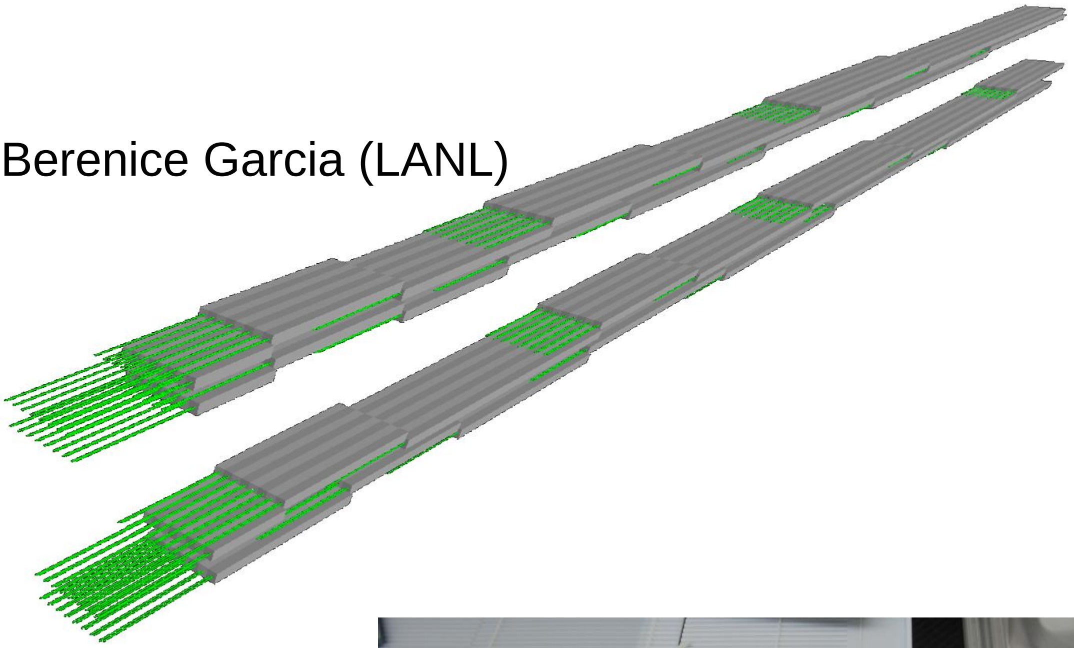


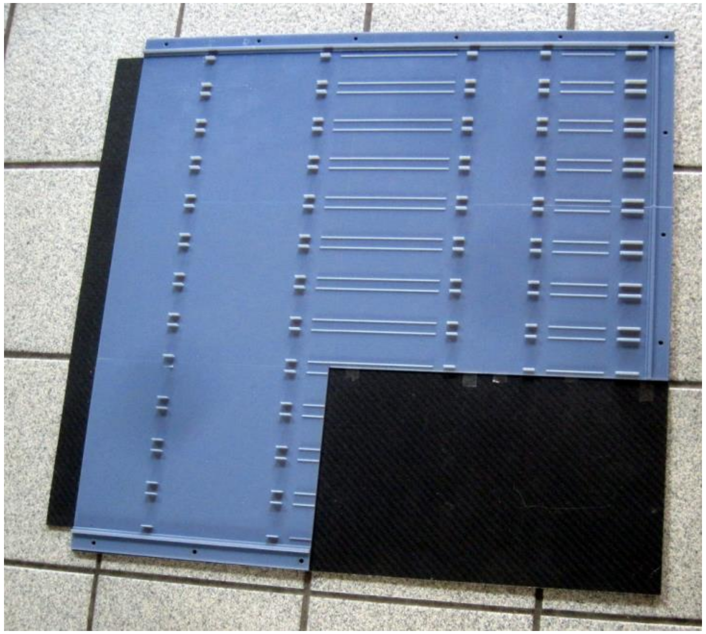


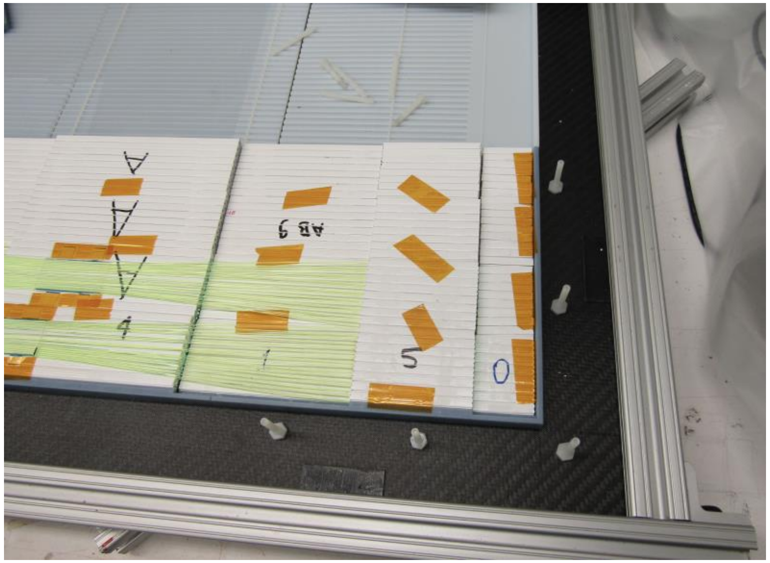
Hubert van Hecke (LANL)

Bar holders and WS fiber guide inside panel.

Berenice Garcia (LANL)

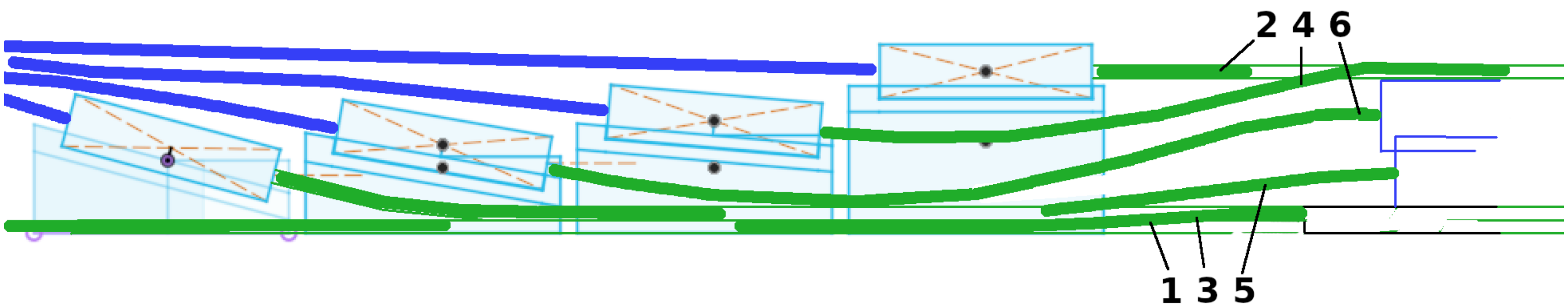


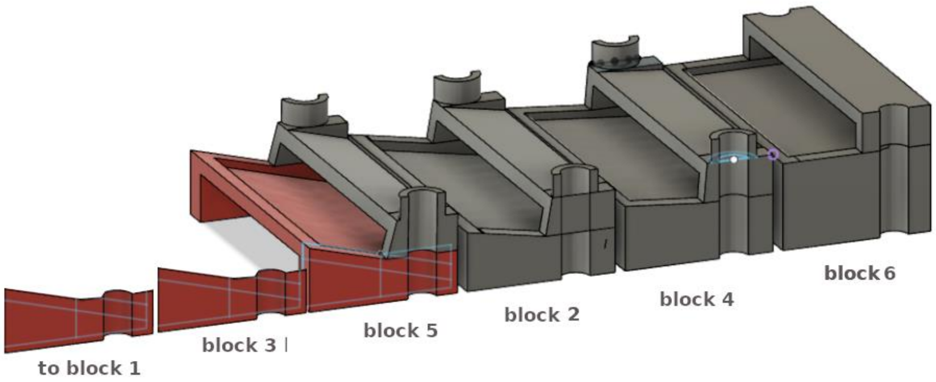


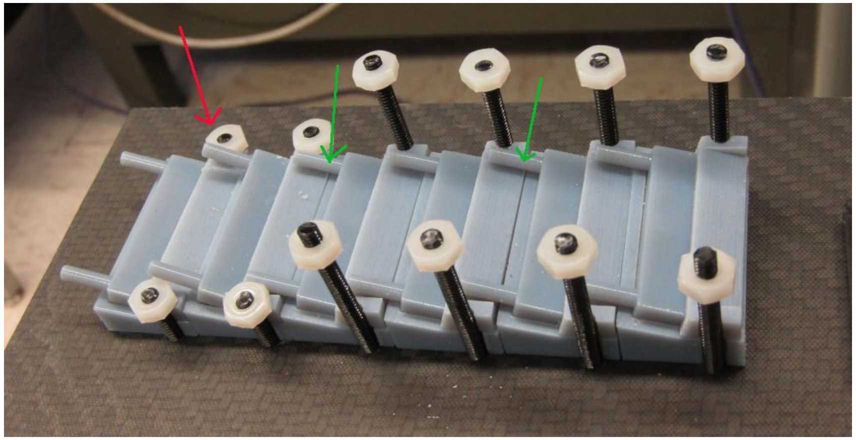


Hubert van Hecke (LANL)

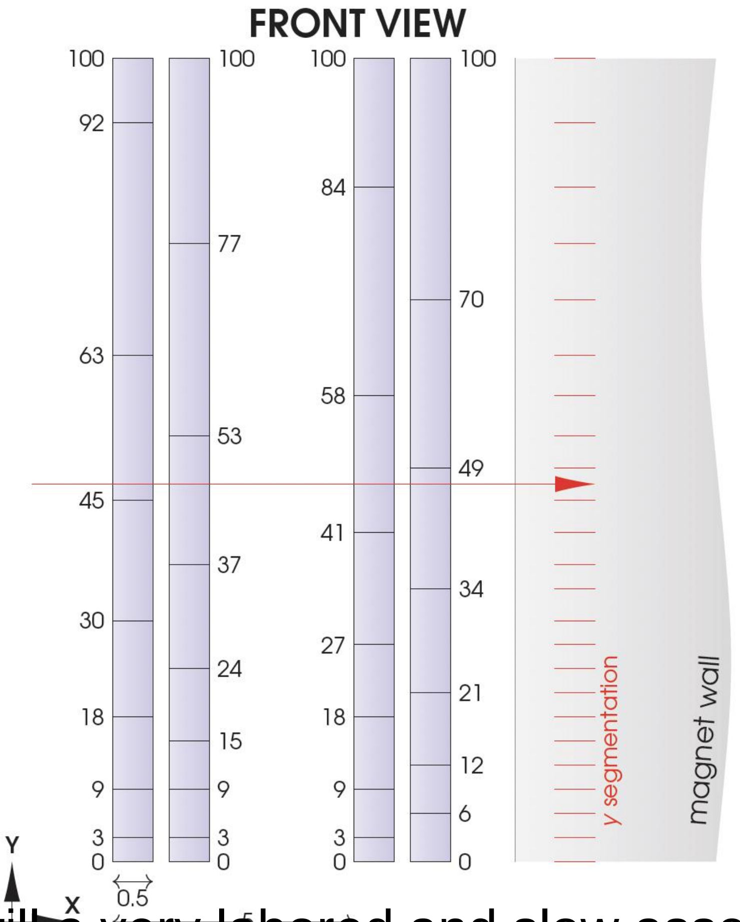
Patch panel for the WS to CL fiber connectors.







Hubert van Hecke (LANL)



Hubert van Hecke (LANL)

- Still a very labored and slow assembly process.
- Entire magnet station needs 90K bars.
- May require several production sites. Can be a teaching opportunity for colleges not associated to big collaborations …
- Automatization is also an option (necessity ?)

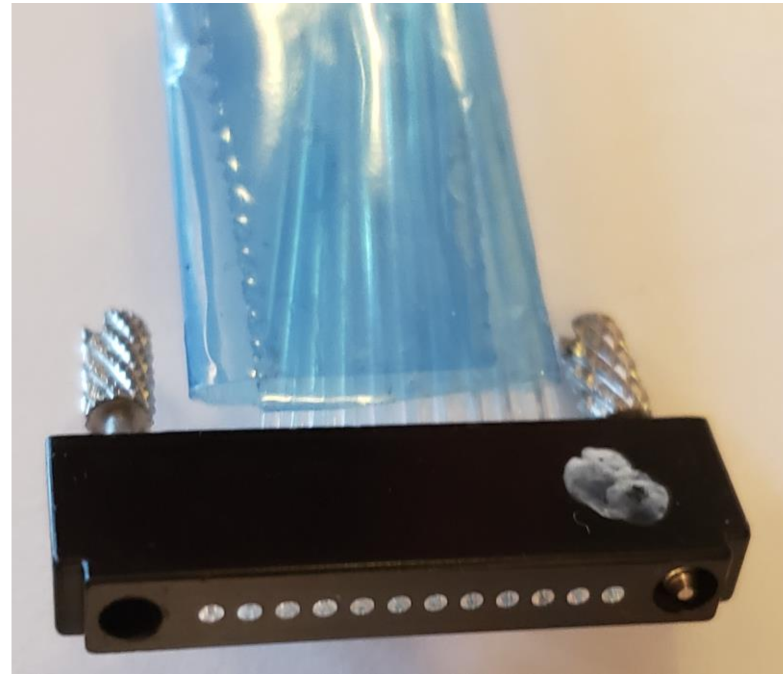
FERMILAB’s fiber connectors.

Clear Fiber Bundles

- Connection from Scintillator to Electronics done via 6.5m long clear fiber bundles
  - Connectors and splitter made of PLA plastic
  - Optical fibers: Kuraray Clear-PSM 1.15mmD

- Outer jacket is PVC (3/4” OD)
  - PVC is not flammable
- Split occurs 4.4m from scintillator (located outside magnet)

eed sEPD - ESRC 4



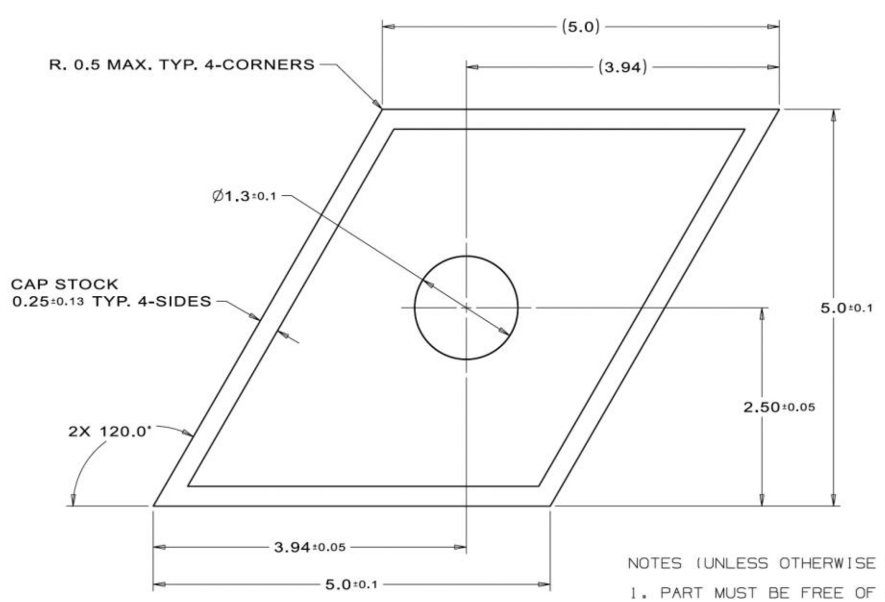
- 1mm wavelength shifter fiber connected to 0.5 mm clear fibers
- Expect to lose ¾ of the light yield in this connection, but it is necessary given how easy is to break 1 mm fibers. Still enough light for SiPMs (to be confirmed)
- James Freeman report on Tuesday.

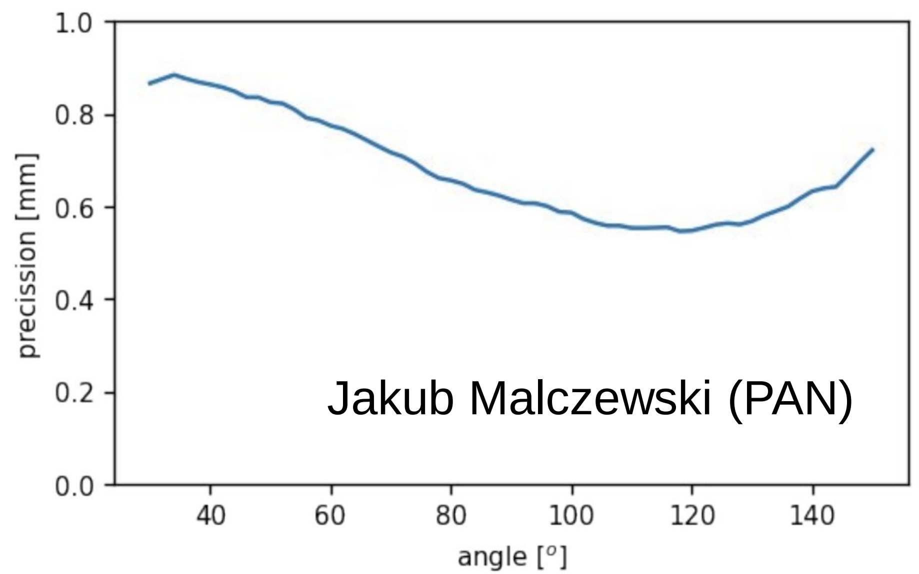
Fiber jacket

It’s not just a question of halogen in the materials. It’s the way that the material burns. The polystyrene fibres produce thick black smoke and drip flaming material. PVC produces hydrochloric acid under irradiation and fire. IS41 lists the plastic (non-metal) materials allowed to be installed in the cavern.
It took quite some time and effort to develop the SciFi to conform to this. In the end we had a company perform a certified fire test on a module. Eric is still busy with the derogation for the SciFi.

Cheers,
Blake

New format for the extruded scintillator bars.





Eileen Hahn (Fermilab)

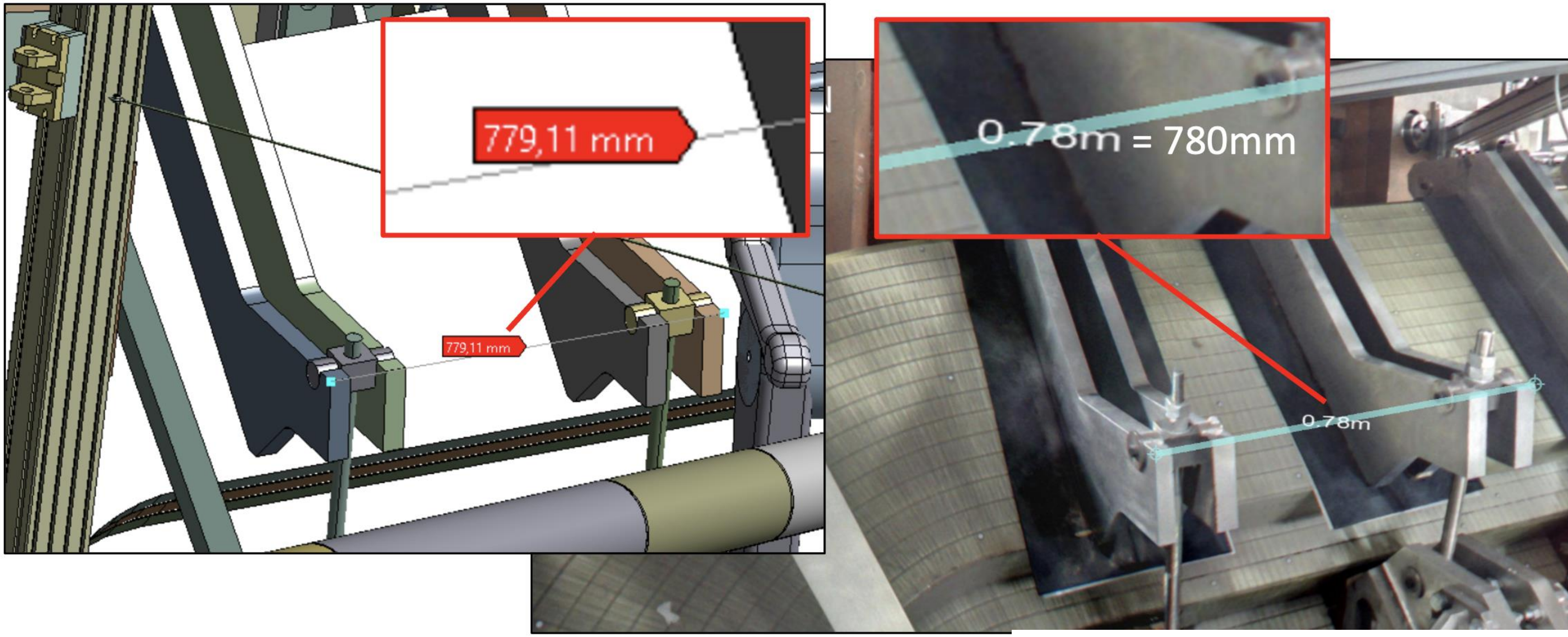
- Changing from triangular to parallelogram shape
  - Reduce the number of fibers by half
  - Easier to fabricate and handle during panel assembly
  - Double light yield per channel
  - Still obtain enough position resolution for the purposes of the MS
  - Some concern on the size of the hole which may have enough space to trap oxygen which becomes fiber corrosive ozone after irradiation

- Entire production (30 Km) quoted in $US165K. Just $5K cheaper than we estimated in the FTDR !!! Enough bars to make 2.5 magnet stations

Mechanical Structure

Checking CAD with measurements inside Magnet

iStar camera and **Spherevision Project Viewer** software to verify measurements.



Piotr Duda
Łukasz Felkowski

Cracow University of Technology

Institute of Heat and Process Engineering (M-5)

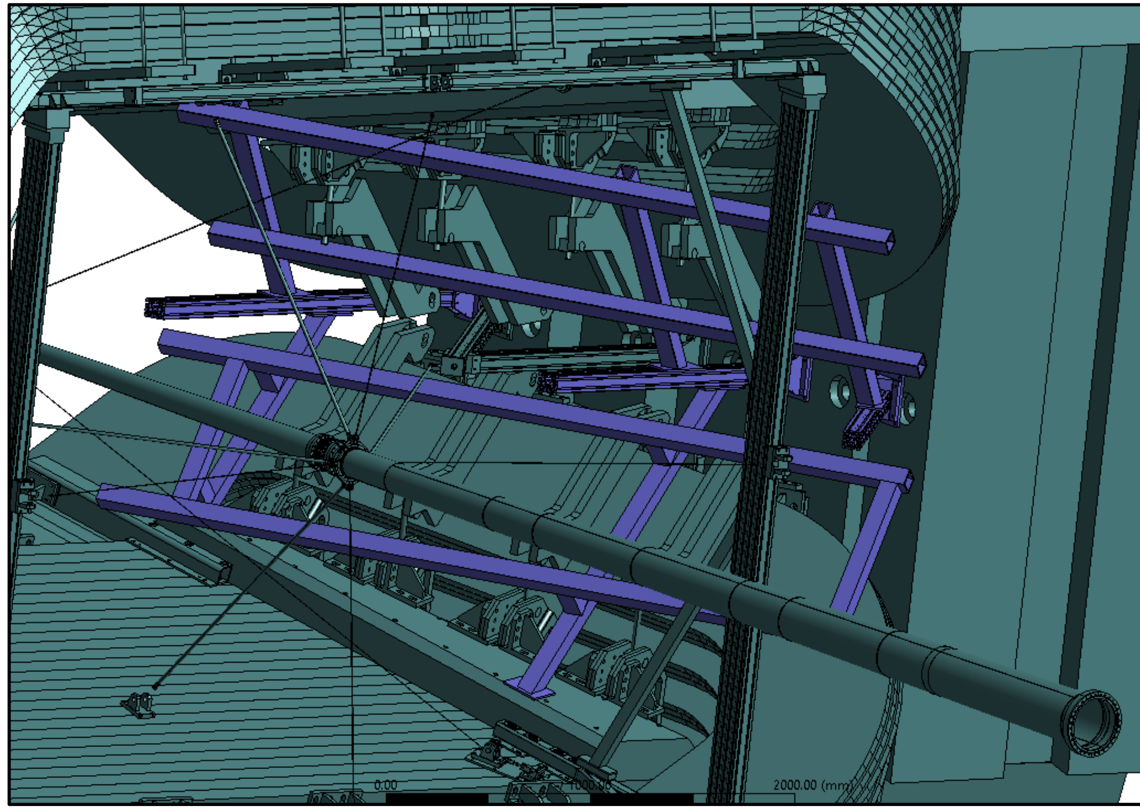
- The dimensions from the inventory confirm that the dimensions are consistent with the 3D model
- The consistency of dimensions allowed for the implementation of a basic design for the frame and its location between the magnets

Support Structure

Piotr Duda
Łukasz Felkowski

Cracow University of Technology

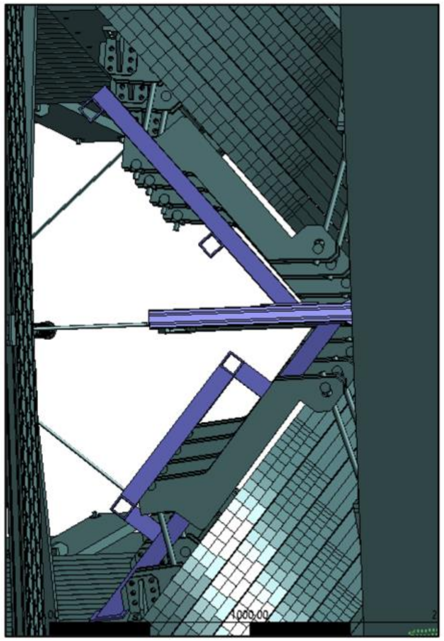
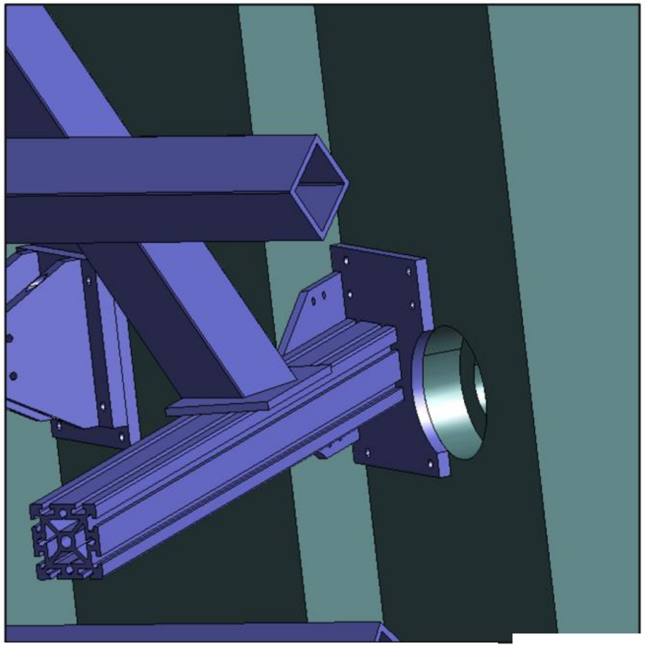
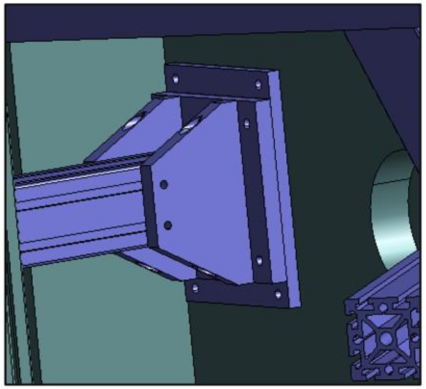
Institute of Heat and Process Engineering (M-5)



Assumed total weight of the structure (left and right sides): ~800 kg
Material – aluminium:

- square profile 90mmx90mm, thickness 8mm
- Plates thickness: from 8mm to 30mm
- Bolts – stainless steel

Support Structure

Piotr Duda
Łukasz Felkowski

Cracow University of Technology

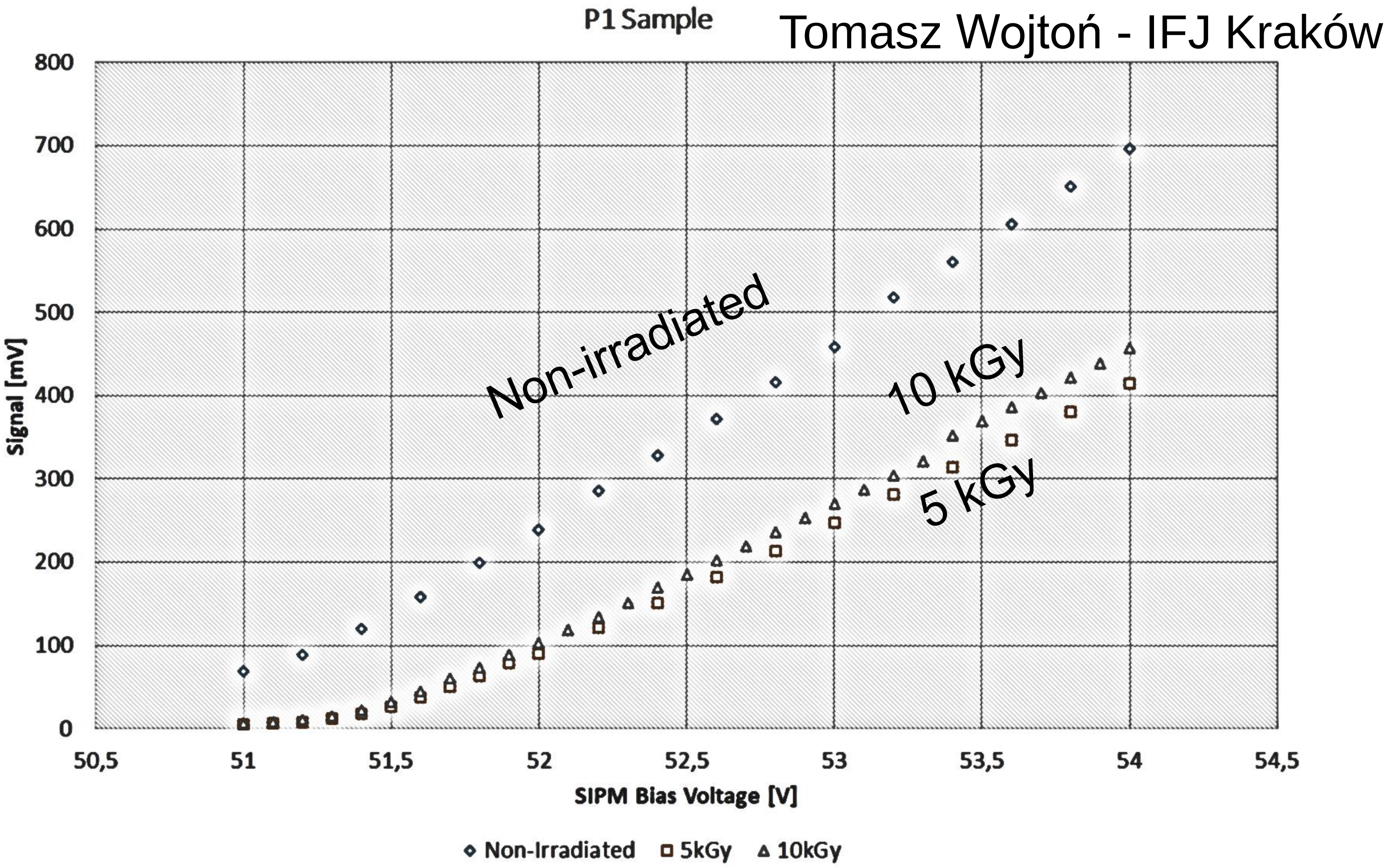
Institute of Heat and Process Engineering (M-5)

- Main question is the distance between the panels and the magnet walls.
- Needs to be out of the SciFi acceptance (tracks producing at least 8 hits in SciFi)
- FEM analysis of the frame
- design of a device for sliding out packages of panels
- Detailed design
- Needs a design for the fiber trails and racks on the sides of the Magnet
- Cooling system for the SiPM+electronics racks

Beam Test

Irradiation on the clear fibers

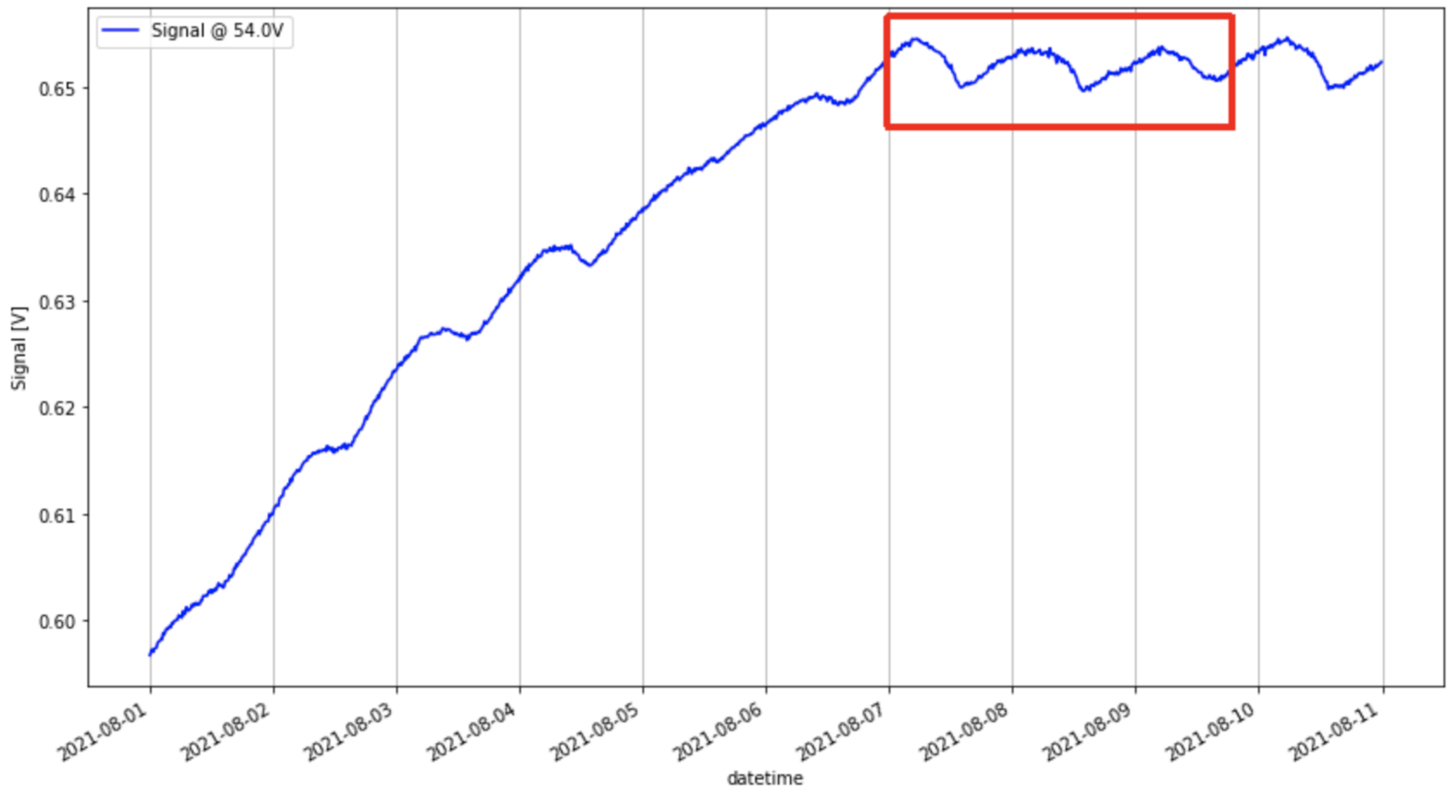
Kuraray clear fiber (sample 4)



- 40% drop in light yield after 10 kGy on covered fibers (P1 sample)
- Expect < 2kGy radiation after 50 fb^{-1} on the clear fibers running on top an bottom of the magnet.

Fiber healing

Tomasz Wojtoń - IFJ Kraków



temperature fluctuation

Self-healing after 3-4 weeks (for 10kGy)

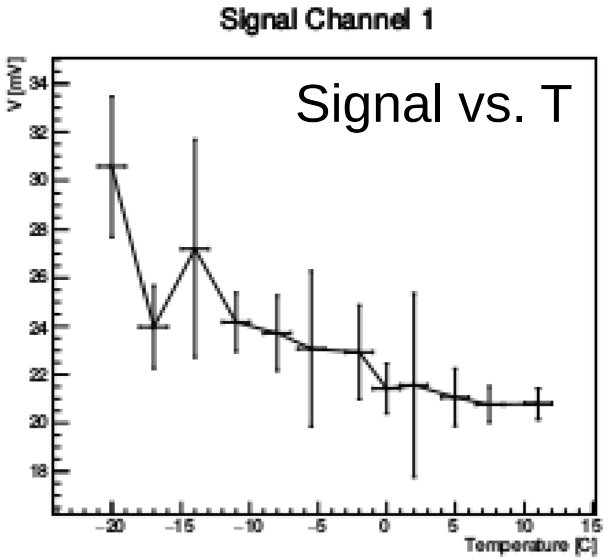
- SciFi left fibers in the cavern for their beam tests. Test with 0.5mm clear fibers

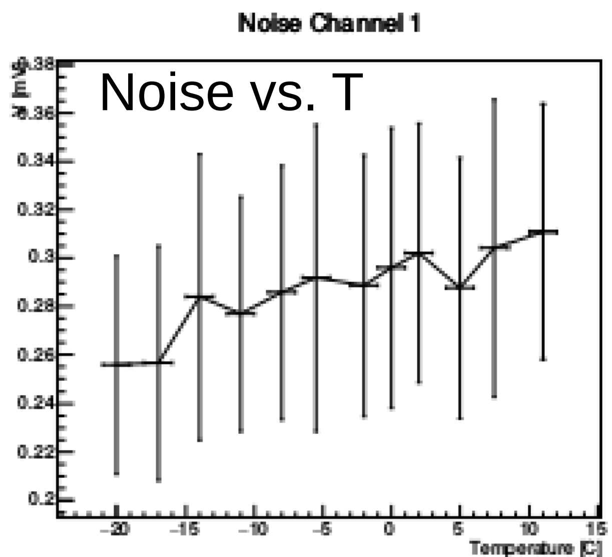
Cooling Test

SiPM performance with Temperature

Proposed to run cold water (5 C) with negative pressure.

Power load for the electronics ???

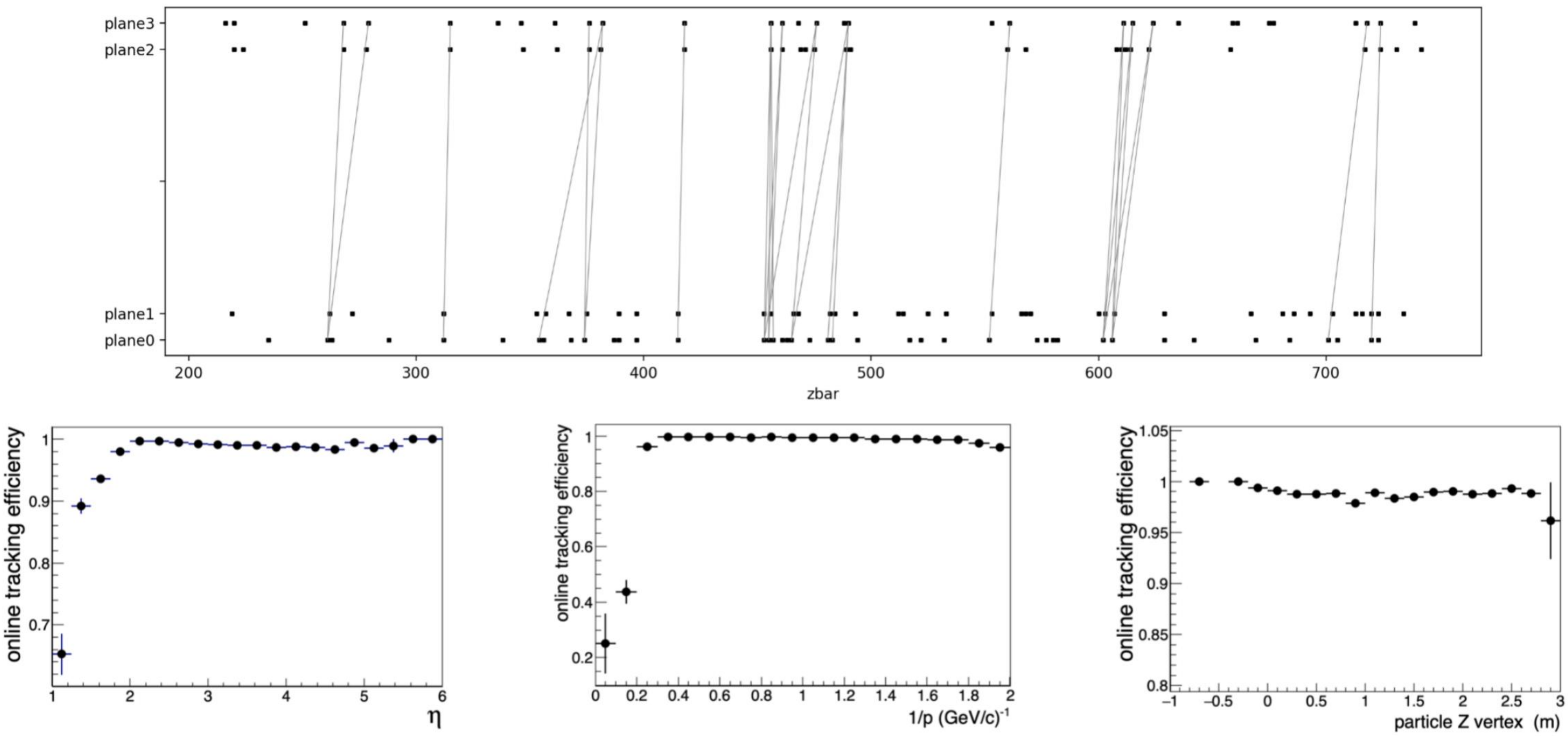




Jihyun Bhom (PAN)

Clustering and Tracking

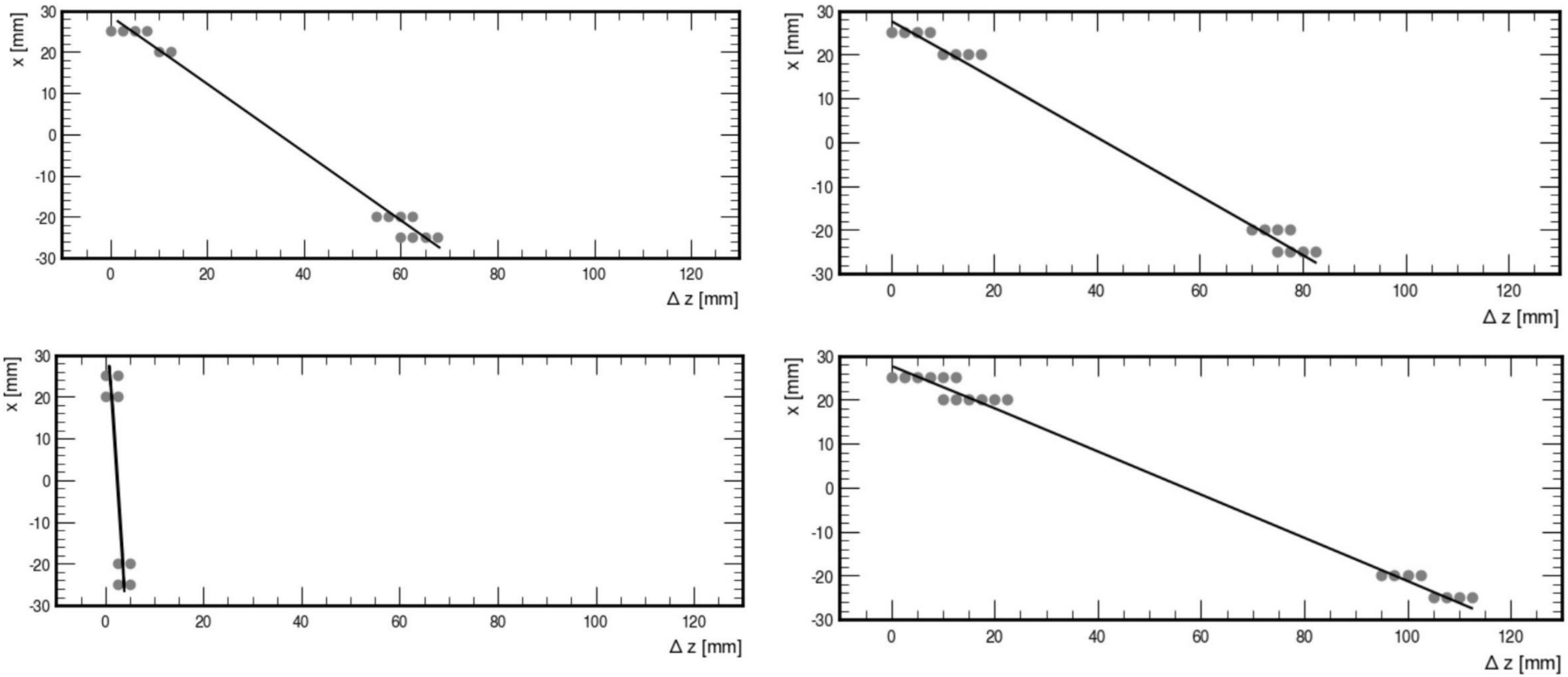
FPGA Tracking



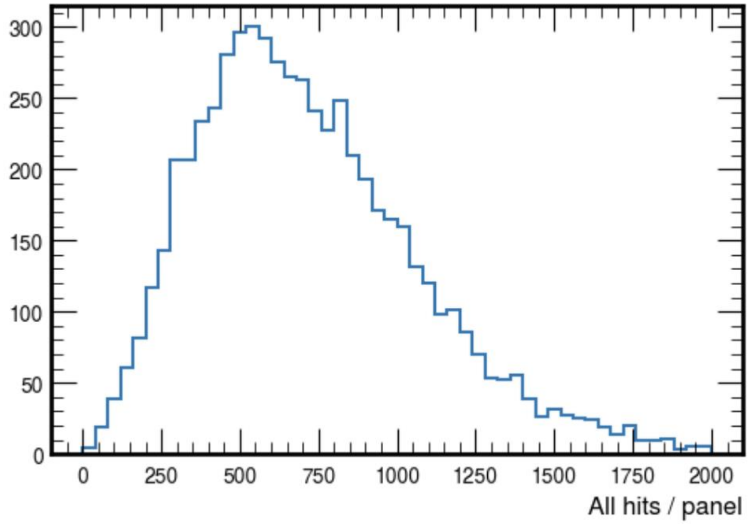
Tracking based on LUT implemented in FPGAs.
No clustering was considered for the FTDR

First clustering algorithm

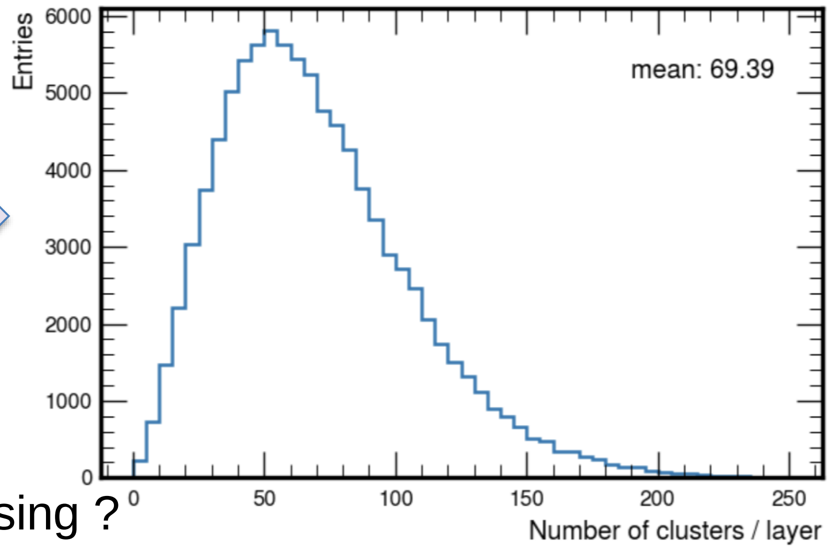
Jakub Malczewski. (PAN)

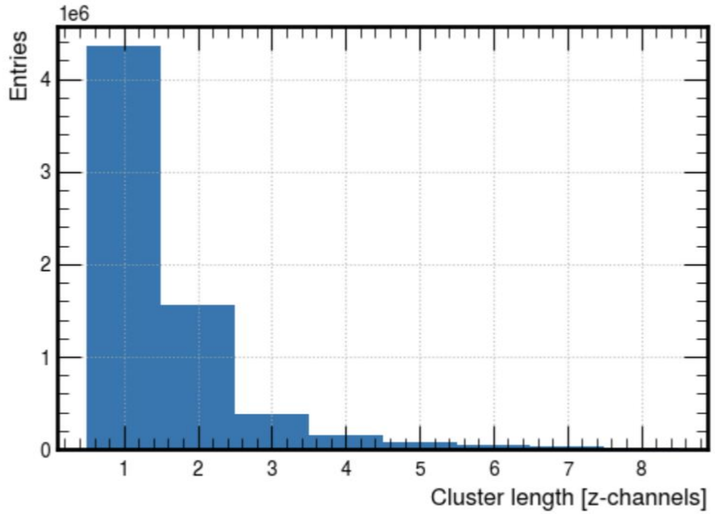


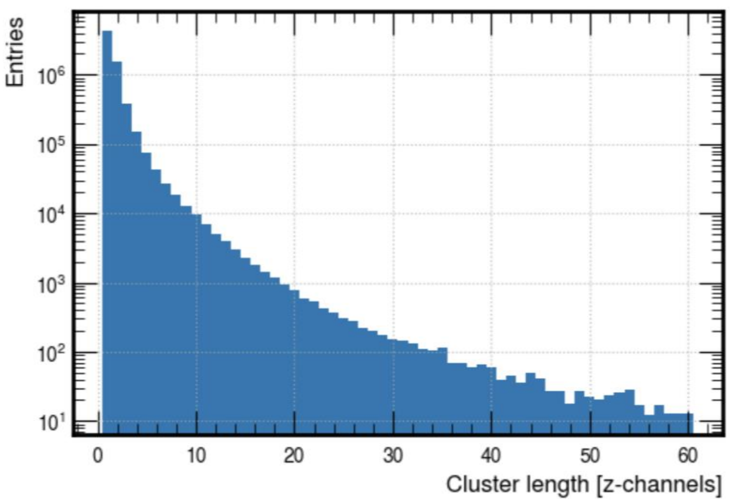
First clustering algorithm



Per crossing ?



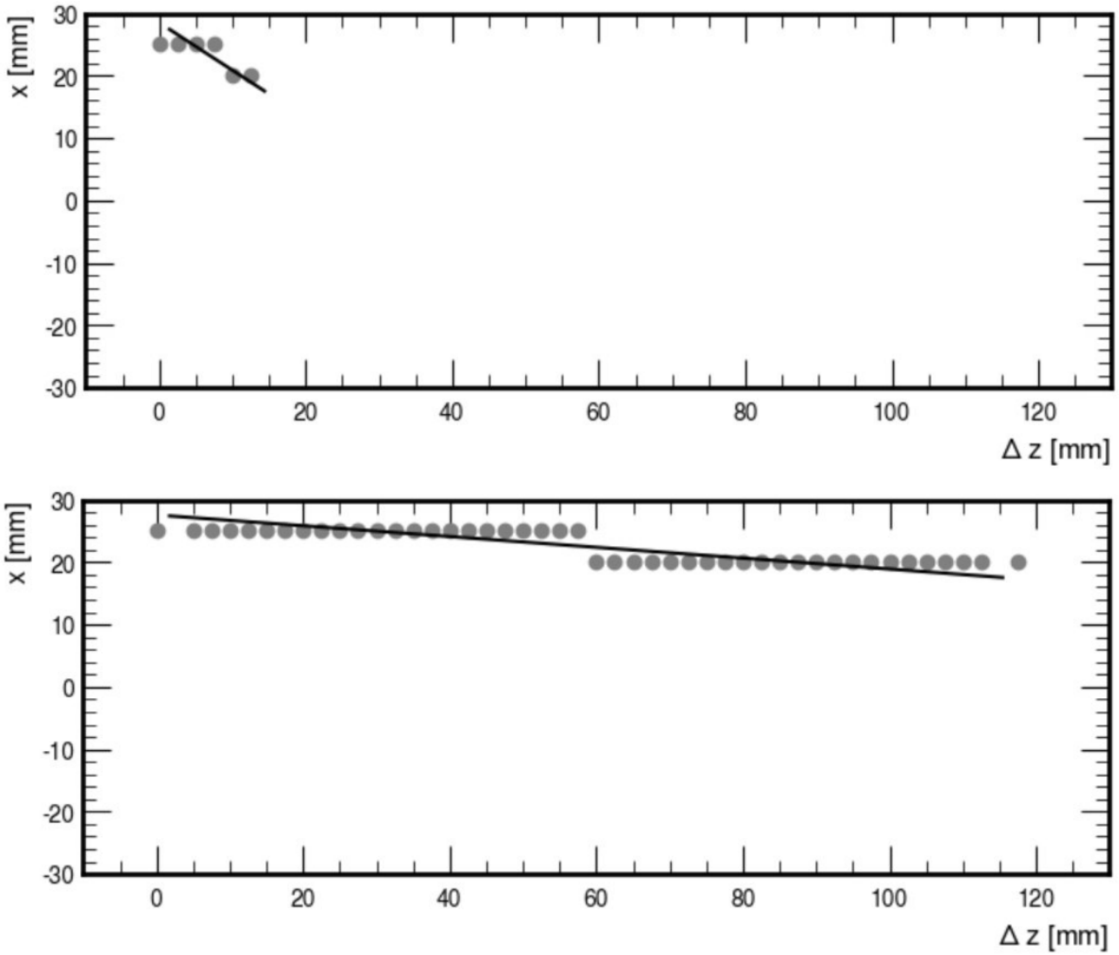




Jakub Malczewski. (PAN)

Challenges in clustering

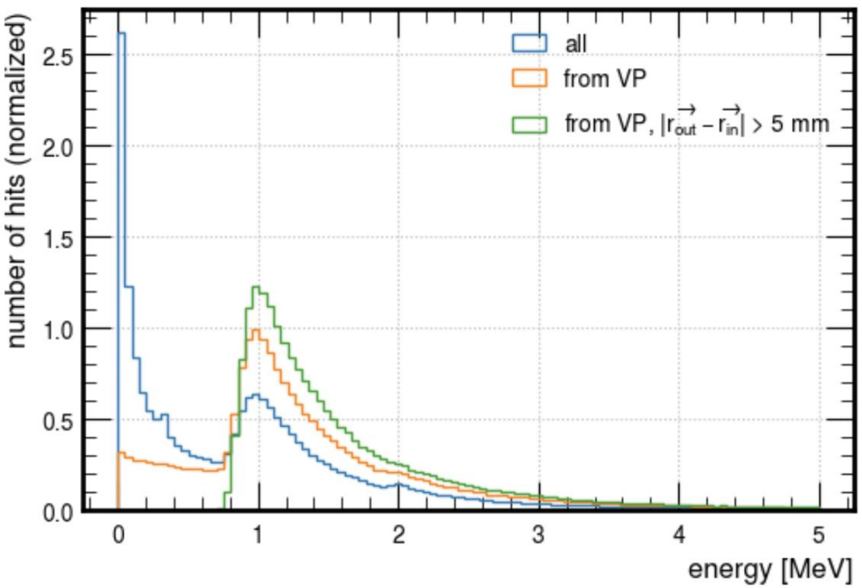
Jakub Malczewski. (PAN)



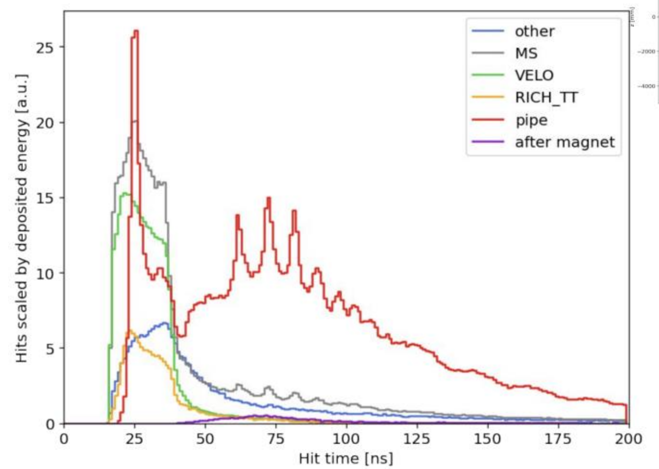
Clusters from particles we are not interested in.
Cluster algorithm may have constraints on cluster size.

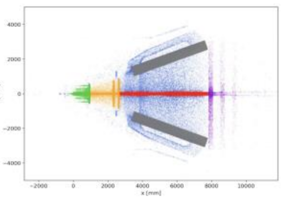
Room for improvement in clustering

Jakub Malczewski. (PAN)



Histogram of hit times for all particles





Energy threshold study.

Possible to implement in U1b with limitations from the PACIFIC 2bit ADC

TDC cut study.

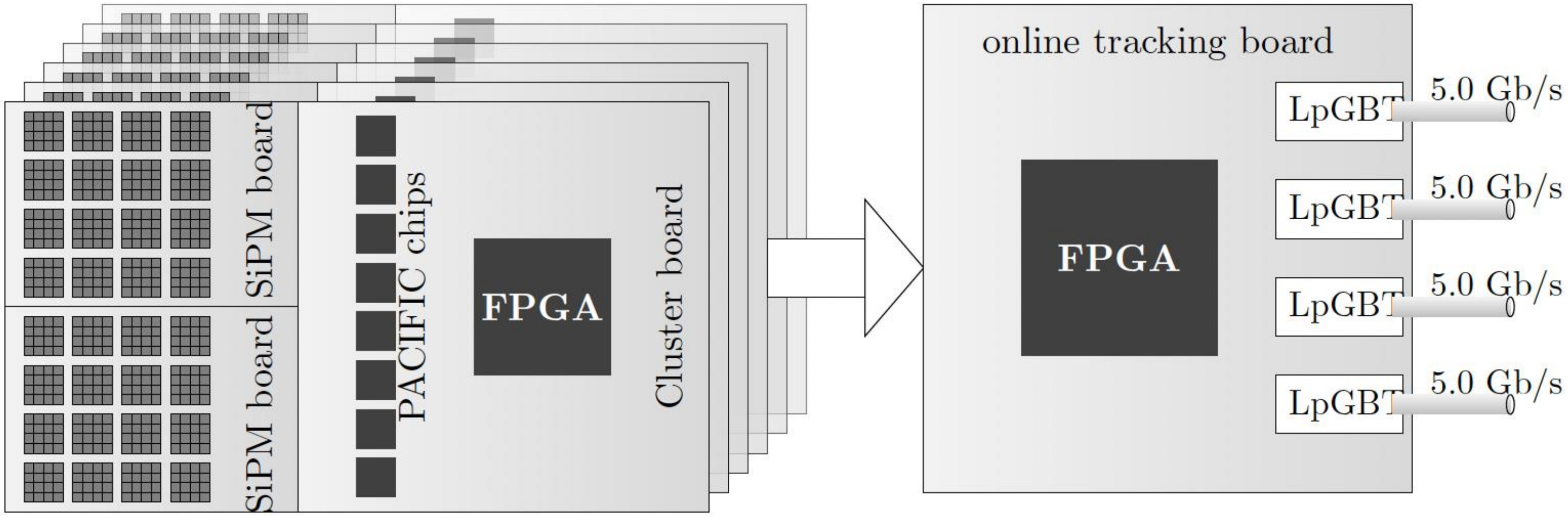
Require a new ASIC for U2.

Readout Electronics

PACIFIC chips

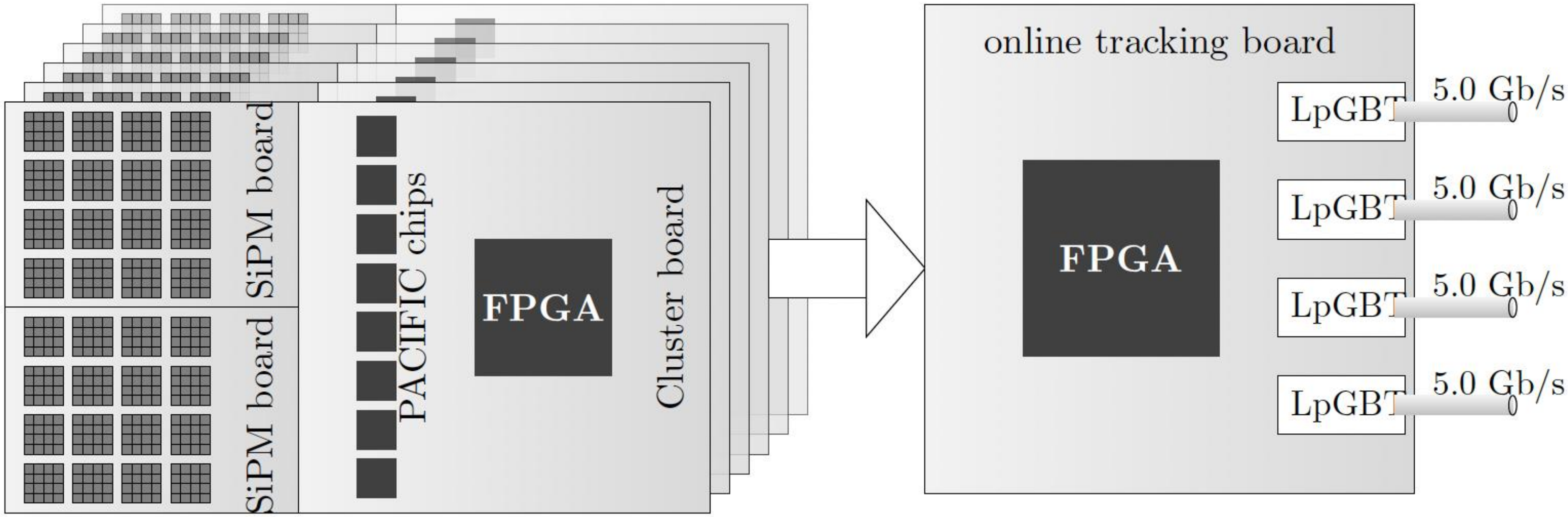
- Ongoing interaction with Heidelberg to purchase 2k PACIFIC chips
- Decide to use a category B quality PACIFIC chips already available
  - No dead channels
  - Larger gain fluctuation between channels
    - Not a problem for MS which will have big channel-by-channel fluctuations because of the fiber connections

Readout System



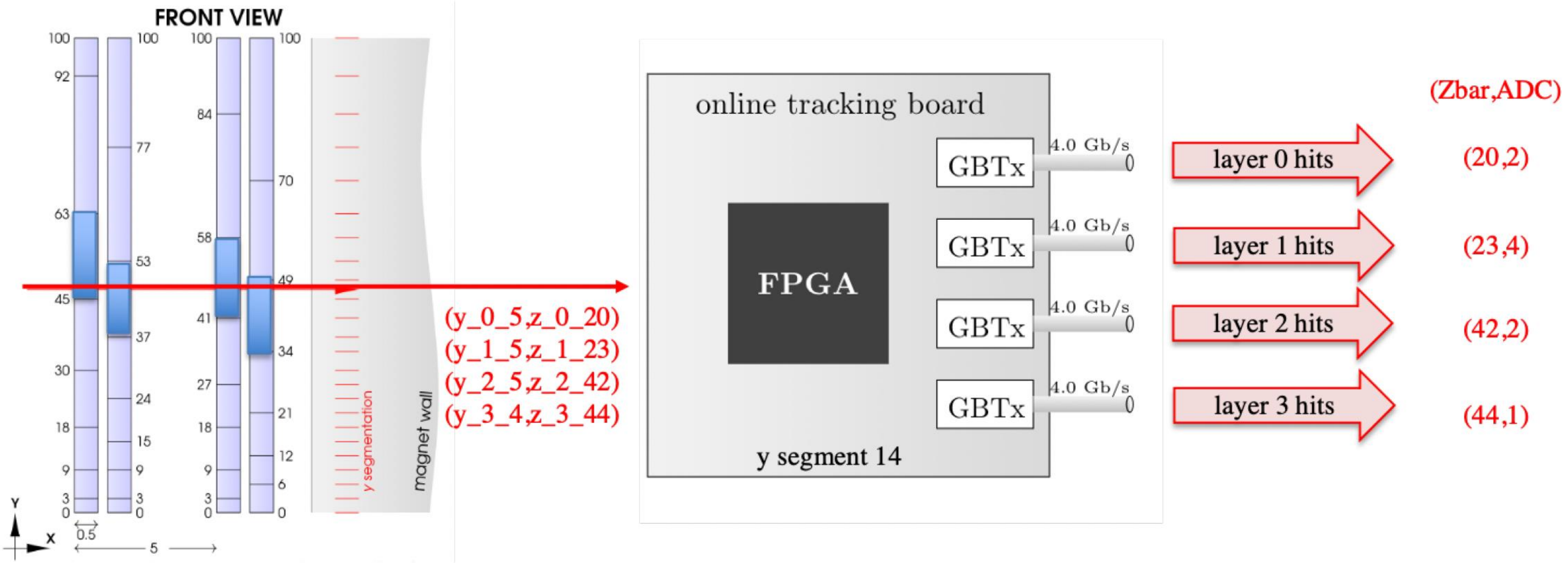
- SiPM arrays (512 channels) plugged to a cluster board with 8 64-channels PACIFIC chips.
- PACIFIC chip signal encoded in 2 bits and 2 channels serialized at 160 MHz
- Clustering FPGA responsible for zero suppression and clustering
- According to Jackub’s simulation using top hit/clusters in U2 crossings :
  - Expect ~ 50 hits per PACIFIC chip / crossing -> 2.1 GHz
  - ~ 170 clusters/ cluster board (CB) / crossing -> 7 GHz
  - Can cut by ½ if applying minimum energy thresholds
- Hit or Cluster data pattern : 9b (bar ID) + 2b (ADC) = 11 bits per hit or cluster

Readout System



- Online Tracking Board (OTB) loaded with a Look-Up-Table (LUT) for online tracking
- FPGA choice will depend on
  - How many cluster boards streaming 70 GHz signal from clusters can a single modern FPGA afford
  - Number of logical unities needed for the LUT (100K for 6 cluster boards)

Readout System

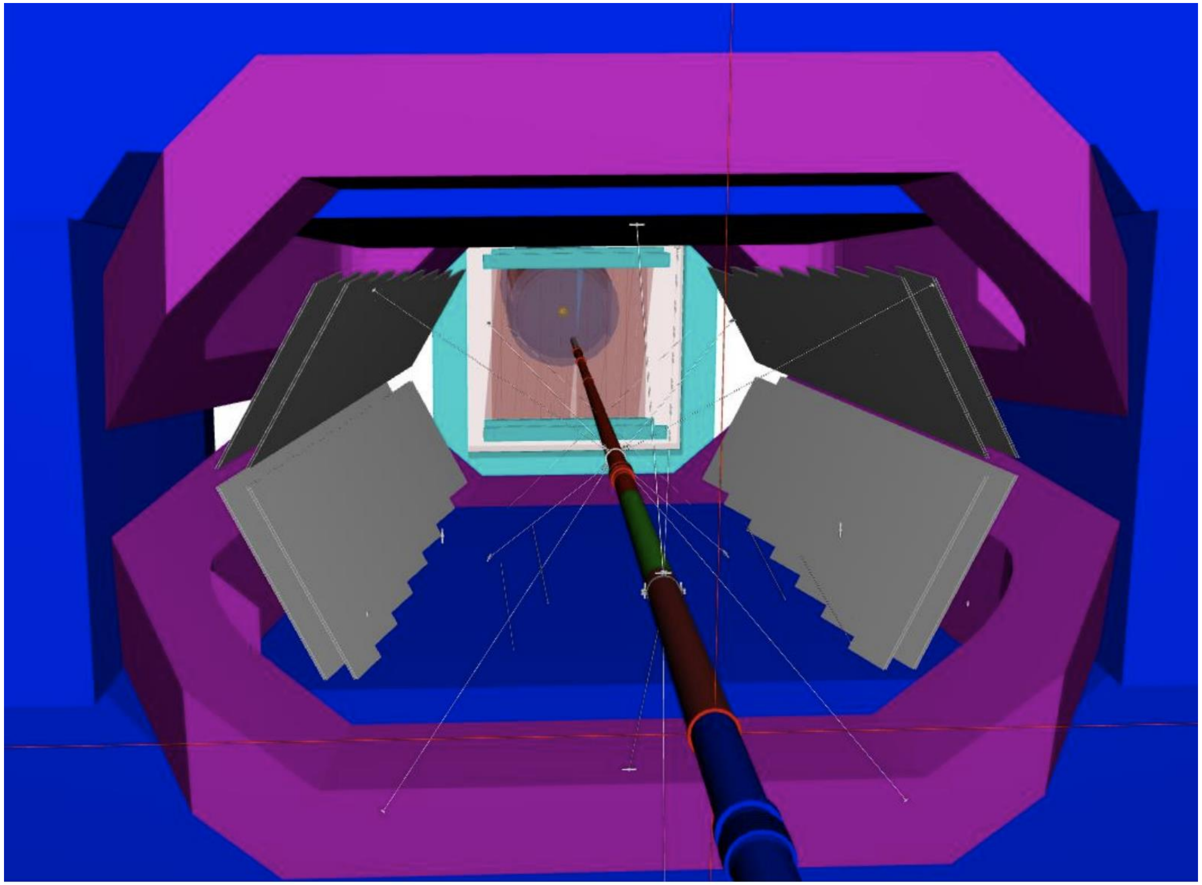


- There are 23 OTBs per panel in the FTDR version. One OTB per y segment
- OTBs stream hit information from online tracks
  - Demonstrated in simulation to be the best option
- A larger FPGA (1M logical unities) could help reduce the number of OTBs
- GBTx -> LpGBT (limit of 10 Gb/s)

Simulation

DD4hep geometry

Jakub Malczewski. (PAN)



Project is currently in a private repository.

Waiting for a stable version to implement MS in the standard LHCb simulation.

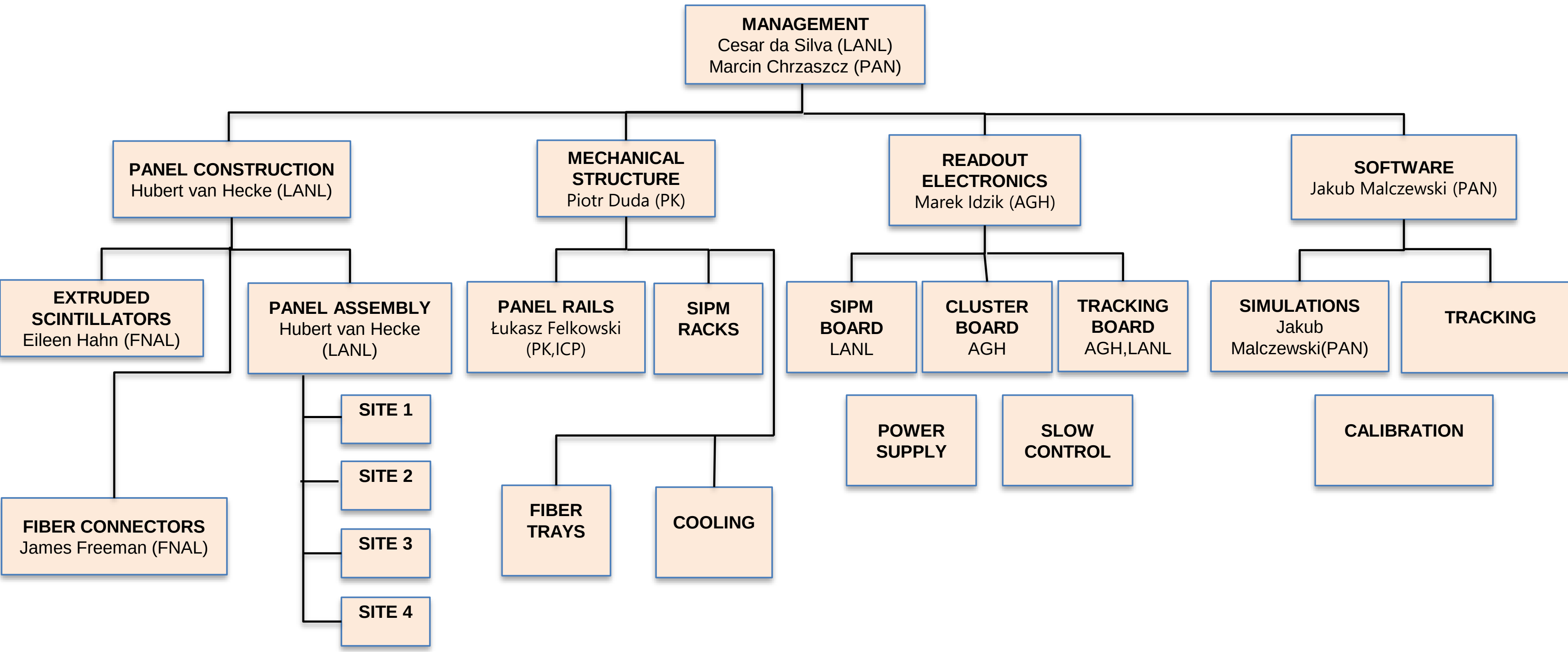
Simulation status

- Detector description in dd4hep
  - xml description
  - C++ builder
- Gauss-on-Gaussino changes
  - based on nightly builds of lhcb-gaussino/1225 branch
  - MS configuration
  - small hacks
- MCHit packer
  - More advanced hit registration requires new class in the LHCb project
- Digitalisation
  - Unique shape of cells
  - Segmentation in the dd4hep framework

Needs to make it user friendly for UNAN (Cost Rica) and other students and postdocs.

Project Management

Project Organization



Up for discussion.

Timeline

- TDR : September 2023
  - Final design
  - prototype tested with some readout electronics
  - Institutions and funding agencies defined : who is going to do what
  - Project Manager file with timeline and resources
- 2023 – 2026
  - Panel assembly in different sites
  - Mechanical engineering design and mockups
    - mockup panel rails to check installation procedure and panel replacement
  - Design and testing of the cluster and tracking boards with LpGBT and TELL40s
  - Final SiPM+electronics racks design
- Installation during LS3 (2026-2028)
  - Rails and fiber trails installation (2nd semester of 2026)
  - Panel installation (2026-2027)
  - Racks, power, colling, safety controls installation (2027)
  - Debugging (2028)
- Both managers (Cesar and Marcin) planning to move to CERN in 2026
- Software development
  - Integration of Magnet Station simulation package in Gaussino+Moore
  - Offline tracking development along RTA
  - Develop HLT2 lines using MS tracks

First Magnet Station Workshop

26–28 Sept 2022
Institute of Nuclear Physics, PAS - Krakow

- Sharing experience with U1 projects
  - Uli Uwer – SciFi
  - Rolf, Eric
- R&D reports on
  - Panel assembly
  - Bar assembly
  - Mechanical Structure
  - Electronics
  - Simulation
- Theorist participation with physics proposals
  - Jamal Jalilian-Marian – Color Glass Condensate
  - Mariola Kłusek-Gawenda – Gamma-Gamma scattering

Expect to come up with two documents : technical and physics reports.
Write a proposal for DOE/US to support project management, panel assembly in different US institutions and software development.

Summary

- Good News
  - Beam tests indicating that radiation inside the magnet may not dramatically damage the light guide fibers
  - It seems we found a final solution for the fiber connectors
  - Software development in pace with the ongoing efforts for U1 and U2
  - Enough good quality PACIFIC chips available for MS
  - Good feedback from funding agencies in Poland and US
  - First Magnet Station workshop

- Risks and challenges ahead
  - Slow response from Fermilab on extruded scintillators indicating a shift in priorities towards DUNE
    - Mitigation: try to get a full production asap, perhaps even before final project approvals ?
  - Slow panel assembly requiring some planning and people