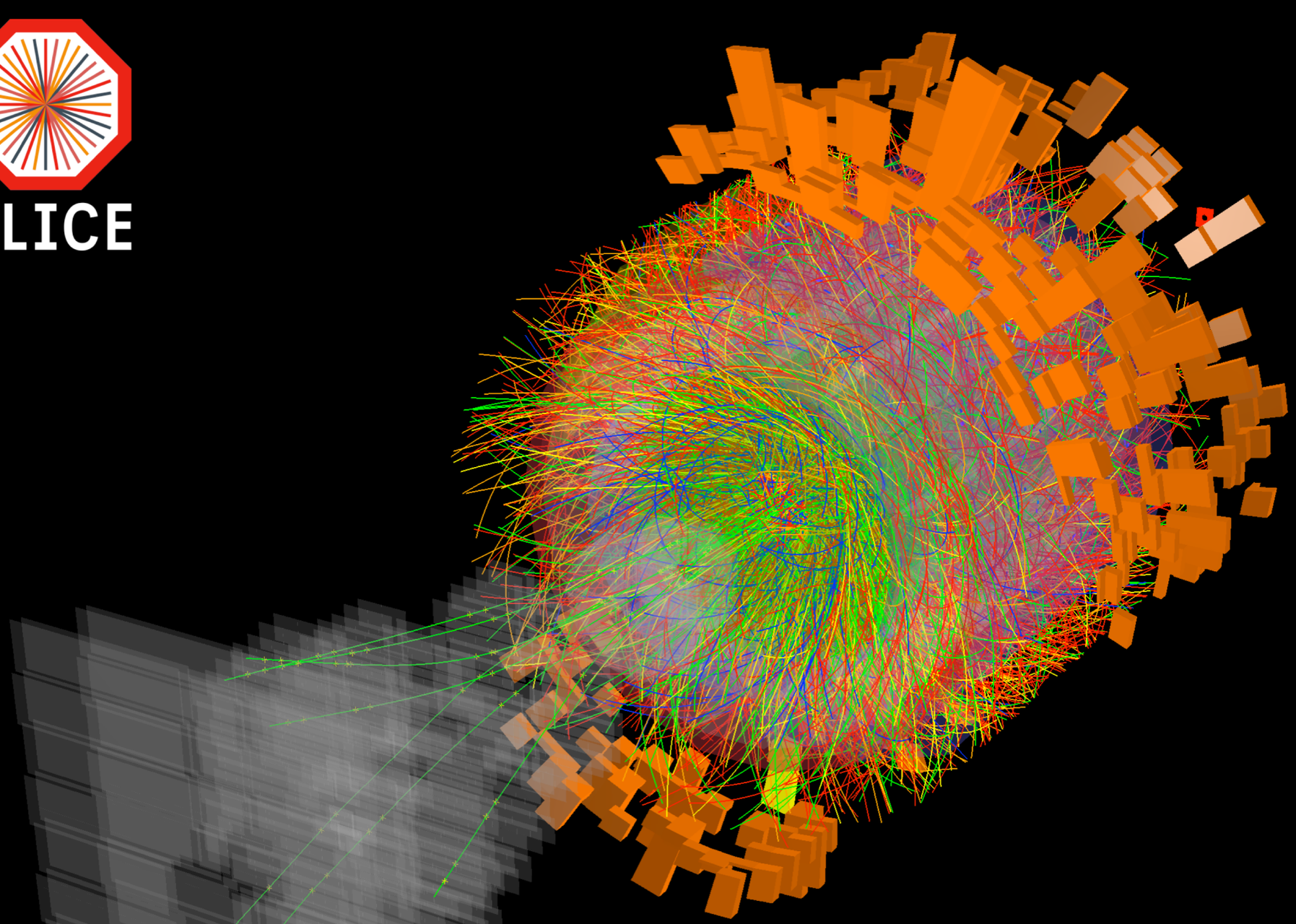
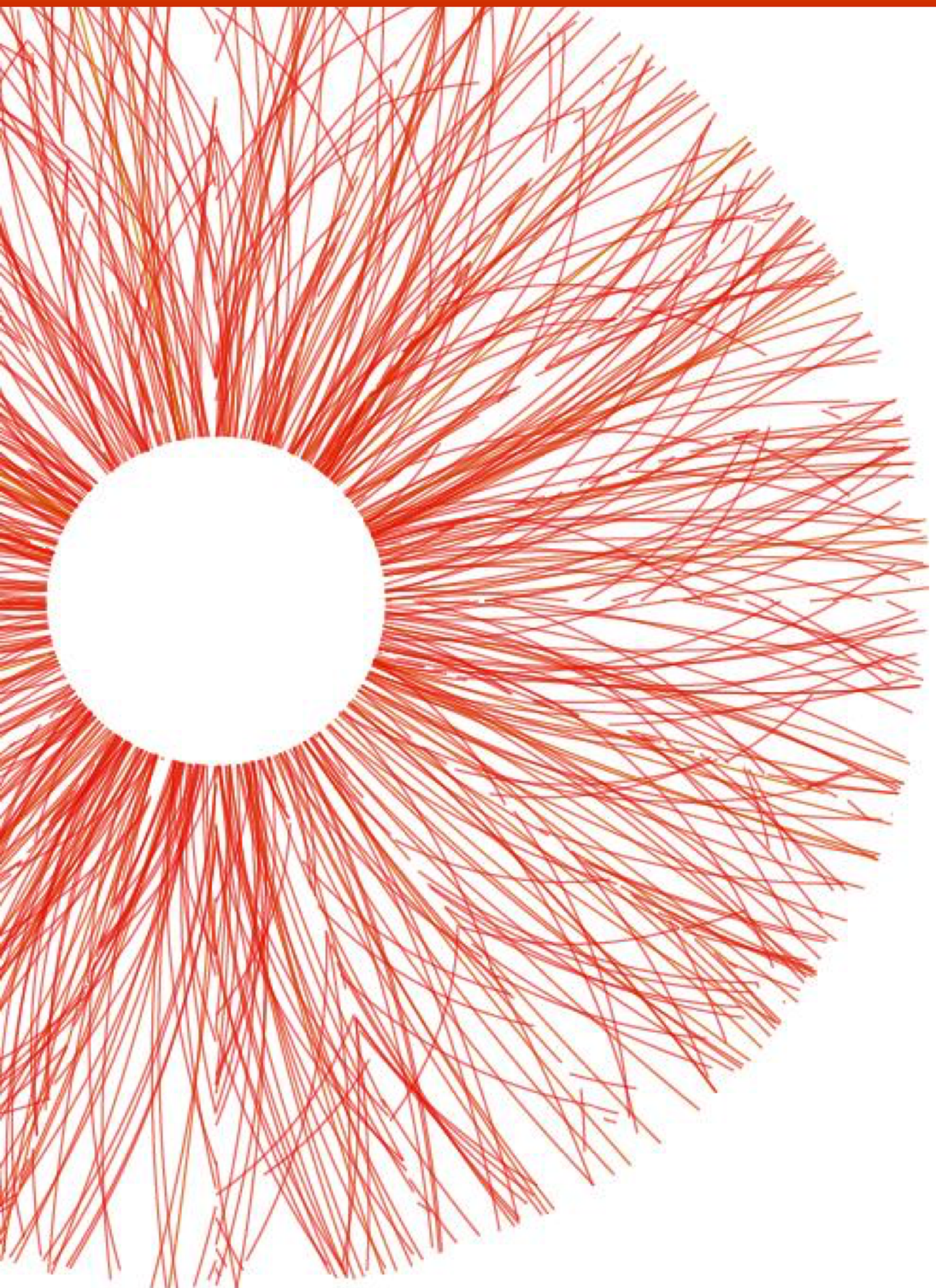


Summary of TYL Hadronic projects HAD_02, HAD_04, HAD_06

TYL-FKPPL joint workshop

May 16-18 2022

Outline



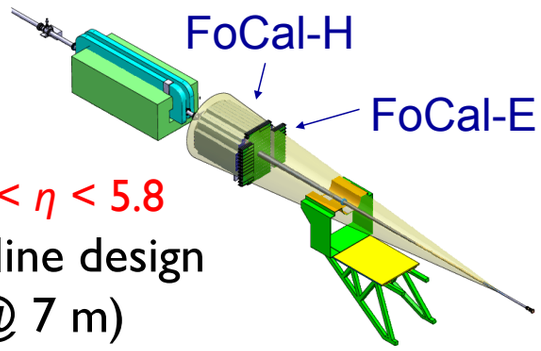
- *HAD_02: ALICE forward upgrade for high precision high statistics single- and di-muon measurements at the LHC*
- *HAD_06: Probing extremely hot partonic matter properties via high precision muon measurements at the ALICE experiment*
- *HAD_04: QGP tomography with jets*

Introduction: ALICE overview

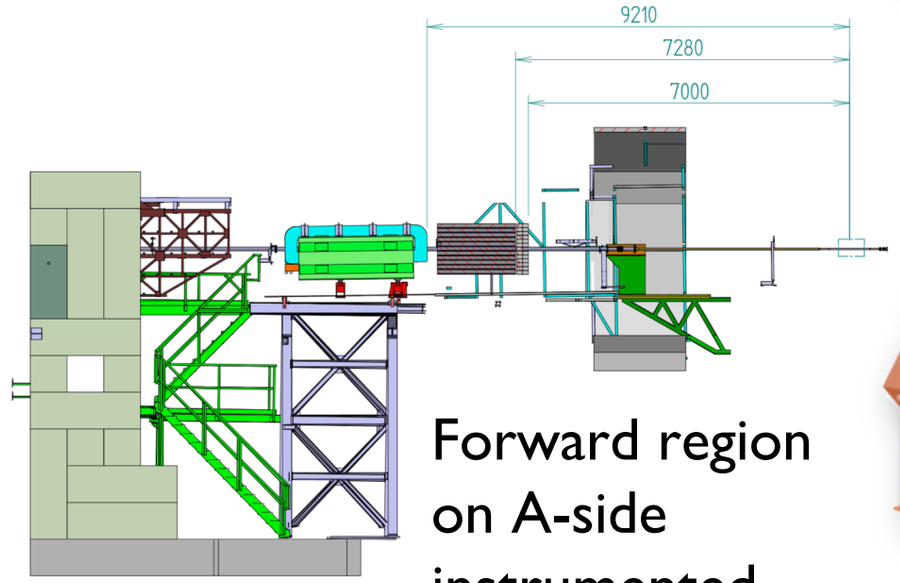
FOCAL:

Upgrade (Run IV)

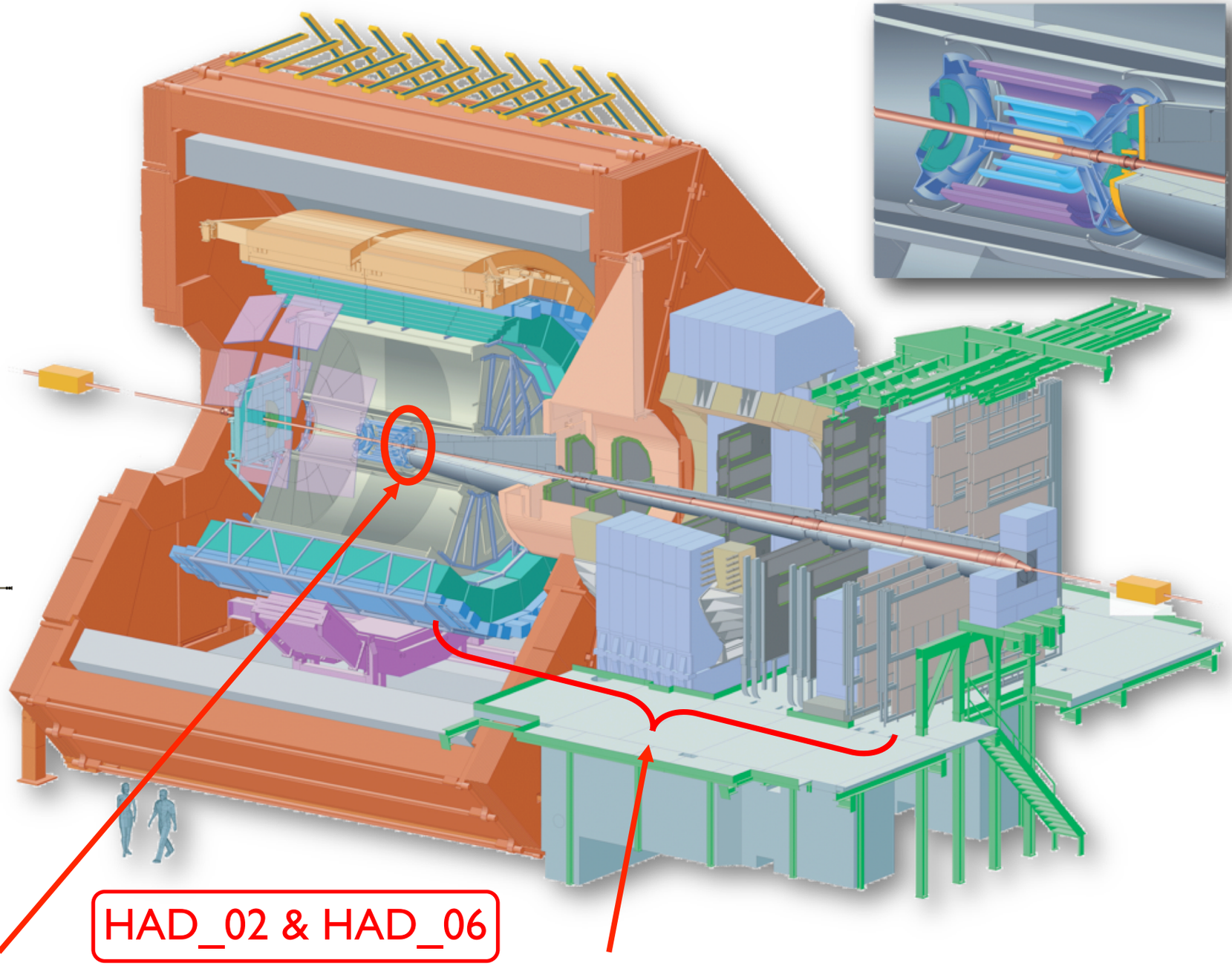
HAD_04



$3.4 < \eta < 5.8$
(baseline design
@ 7 m)



Forward region
on A-side
instrumented
only by FIT
T0/V0



HAD_02 & HAD_06

MFT:

Upgrade (Run III)
ALPIDE sensors (ITS)
Vertexer for MS

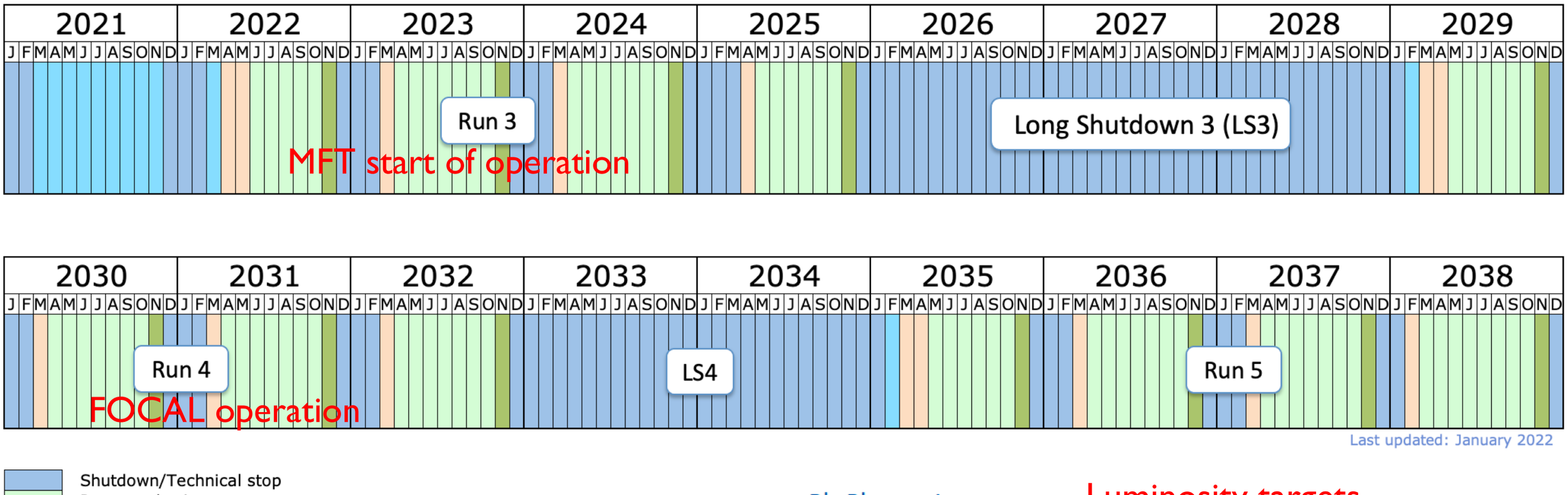
Muon Spectrometer (MS):

Front absorber + Tracking chambers
+ Iron wall + Trigger Chambers
Acceptance: $-4 < \eta < -2.5$

Introduction: LHC schedule

FOCAL R&D →

Long shutdown 3 (LS3) to start in 2026 and last for 3 years



Last updated: January 2022

Shutdown/Technical stop
Protons physics
Ions
Commissioning with beam
Hardware commissioning/magnet training

- Heavy-ion program will continue during Run 3-4 (at least)
  - Typically 1 month/year Pb-Pb or pPb running

Luminosity targets

Pb-Pb running

Experiment	Run 3	Run 3+Run 4
ALICE, ATLAS, CMS	6/nb	13/nb
LHCb	1/nb	2/nb

Proton-Pb running

Experiment	Run 3	Run 3+Run 4
ATLAS, CMS	0.5/pb	1/pb
ALICE	0.25/pb	0.5/pb
LHCb	0.1/pb	0.2/pb

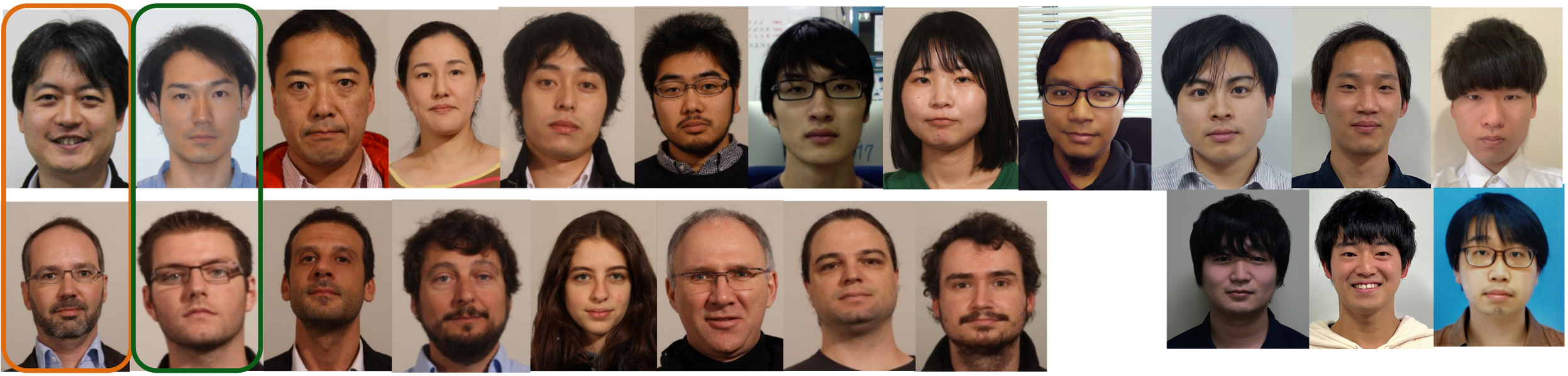
MFT: France-Japan Team

Institutes involved:

Hiroshima University, Nara Women University, Nagasaki IAS
Subatech, IP2I, Irfu-Saclay, LPC-Clermont

TYL/FJPPL Project Leaders:

HAD_02: K. Shigaki & G. Batigne
HAD_06: Y. Yamaguchi & M. Guilbaud



MFT: Muon Physics in ALICE

Heavy Quarks (*c* & *b*):

Created at the early stage of the collision: 0.1 fm/c compared to 10 fm/c of QGP lifetime

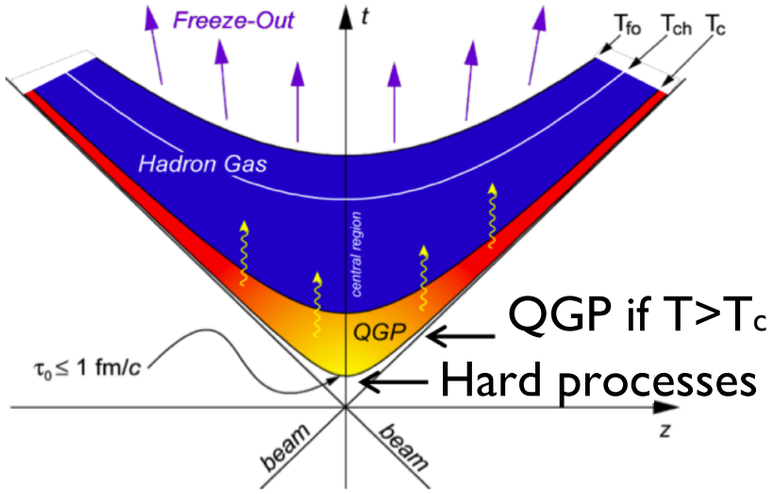
⇨ Experience of the full history of collision

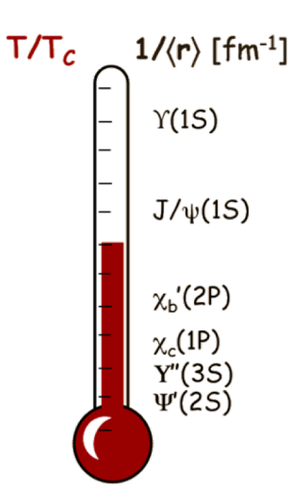
Quarkonia (J/ψ and ϒ families) sensitive to energy density/temperature

⇨ Quarkonia « melted » in the QGP ⇨ decrease of production rate (…?…)

⇨ At LHC energies, regeneration of charmonia?

(see JaeBeom's talk on Tue)





Energy loss of Heavy Quarks depends on medium density

⇨ Measurement of Open Heavy Flavors (*D* & *B*)

Low masses:

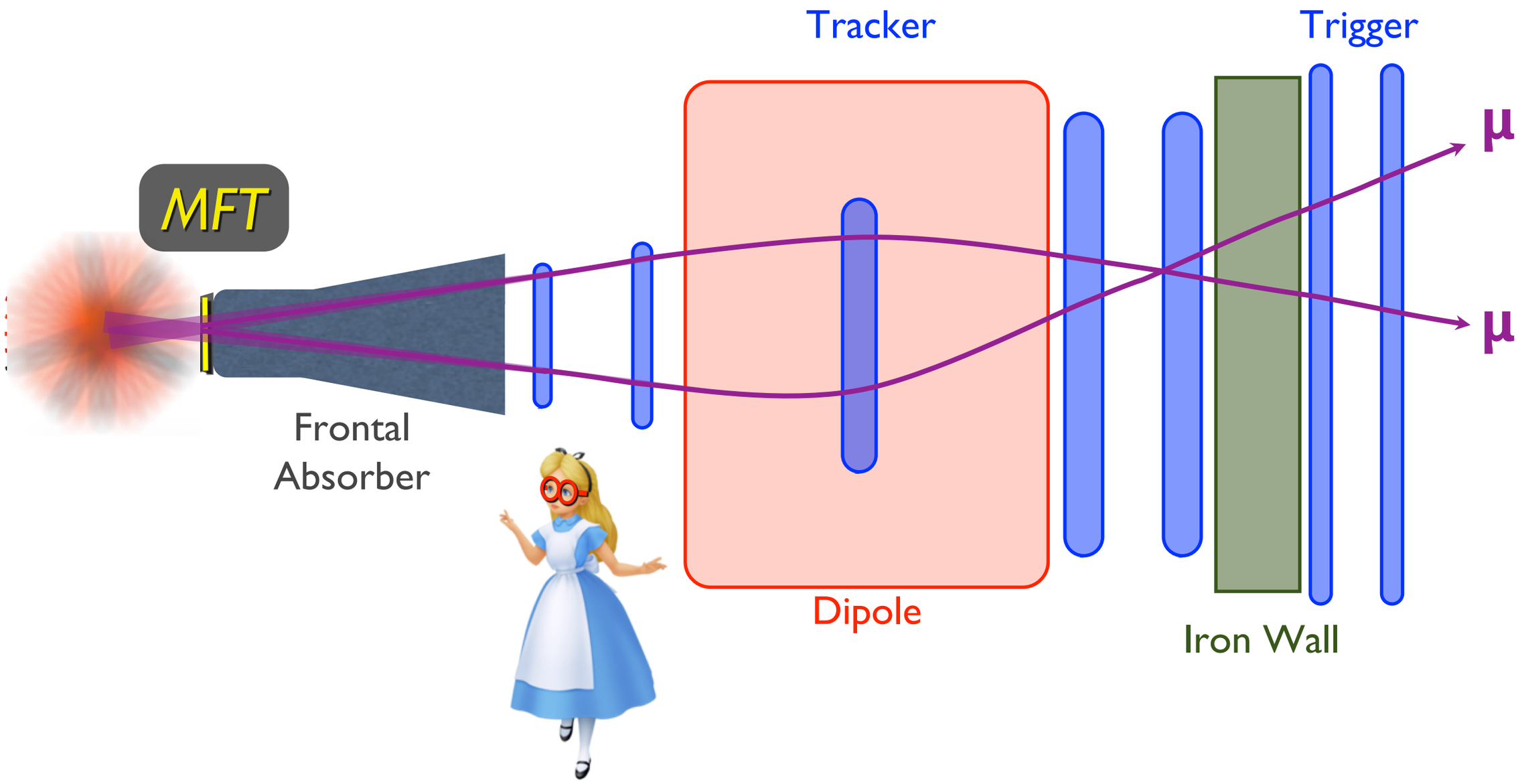
Vector mesons ($m_{\mu\mu} < 1 GeV/c^2$):

Study of chiral symmetry restoration through spectral function modification

Thermal dimuon ($1 GeV/c^2 < m_{\mu\mu} < 3 GeV/c^2$):

Medium temperature

MFT: In a Nutshell



Silicon telescope in front of the absorber
Track matching MUON ⇨ MFT

Improvement of pointing accuracy at Interaction Point (≃100 μm)

Separation of displaced vertices from beauty/charm

Presently, inclusive measurement of J/Ψ (*B* feed-down)

$$c\tau_B \simeq 500\mu m$$
$$\eta < -2.5 \Rightarrow \gamma > 10$$

Detector with low material budget and high granularity

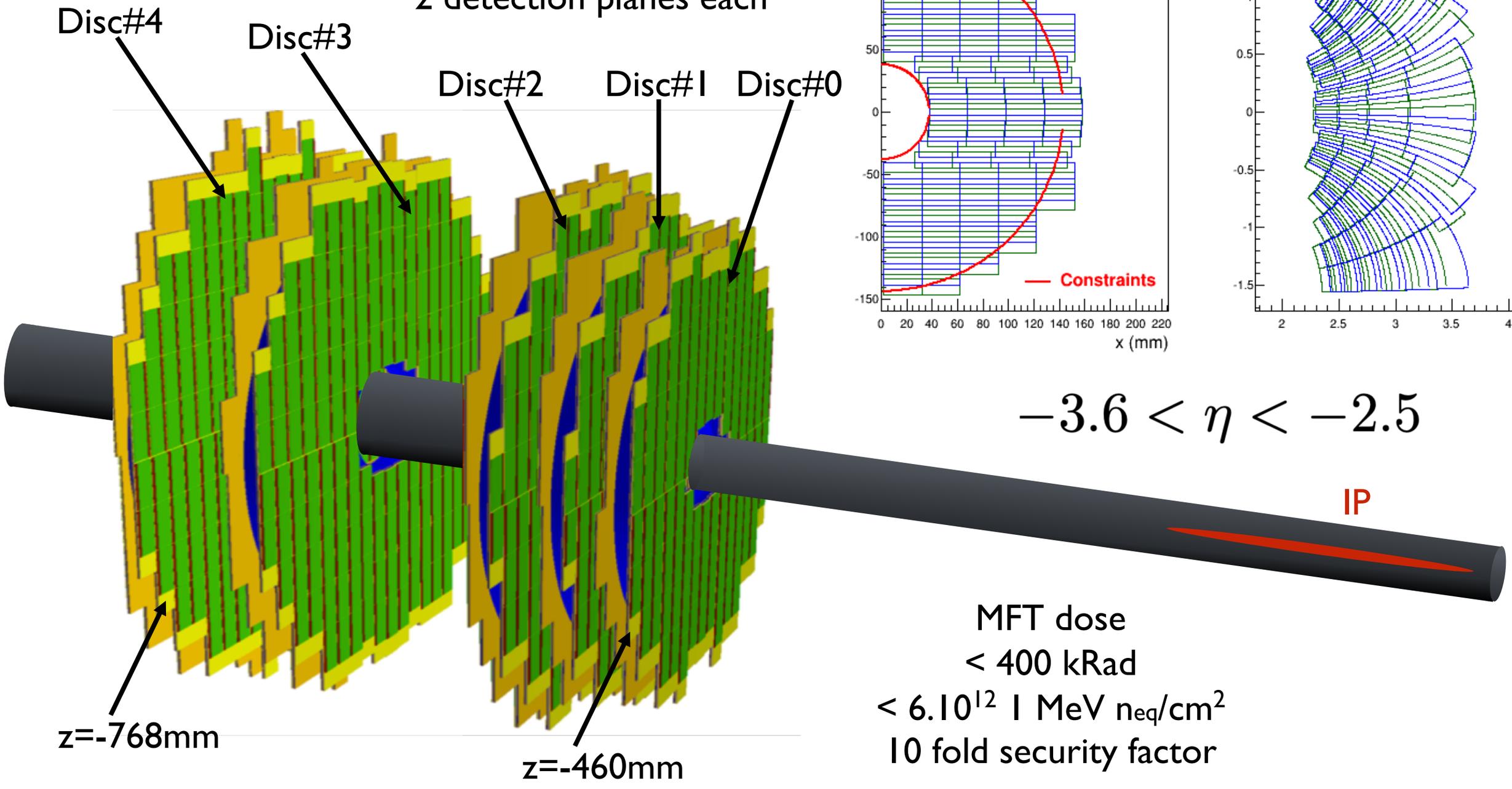
MFT: Layout

936 silicon pixel sensors (0.4 m^2) in 280 ladders of 2 to 5 sensors each.

5 % of the ITS and twice the inner barrel of ITS

10 Half-discs

2 detection planes each



$$-3.6 < \eta < -2.5$$

MFT dose

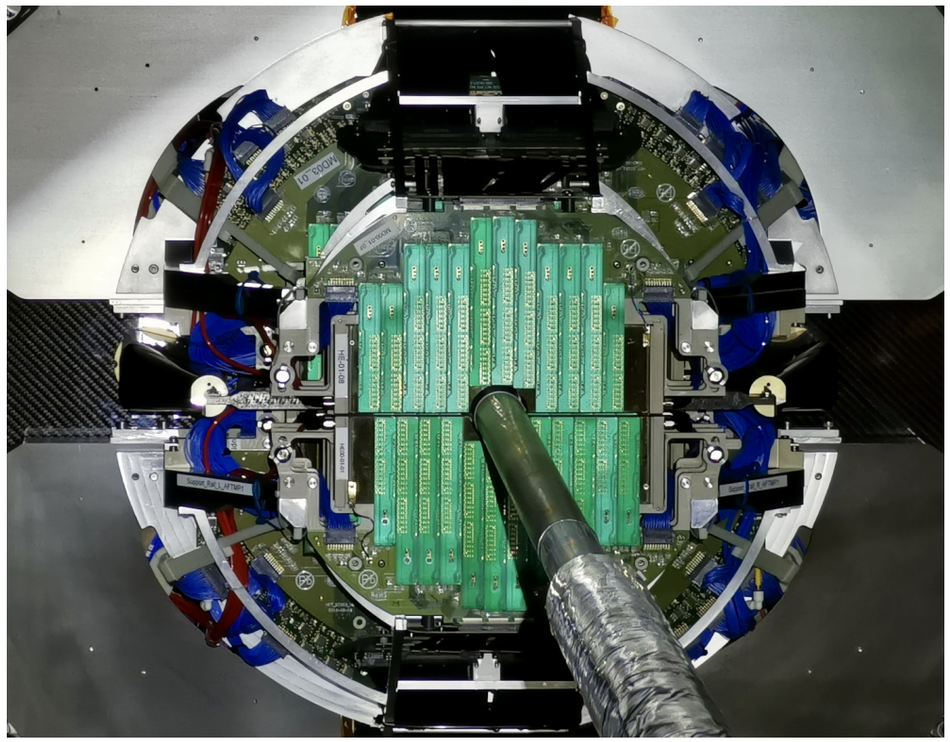
< 400 kRad

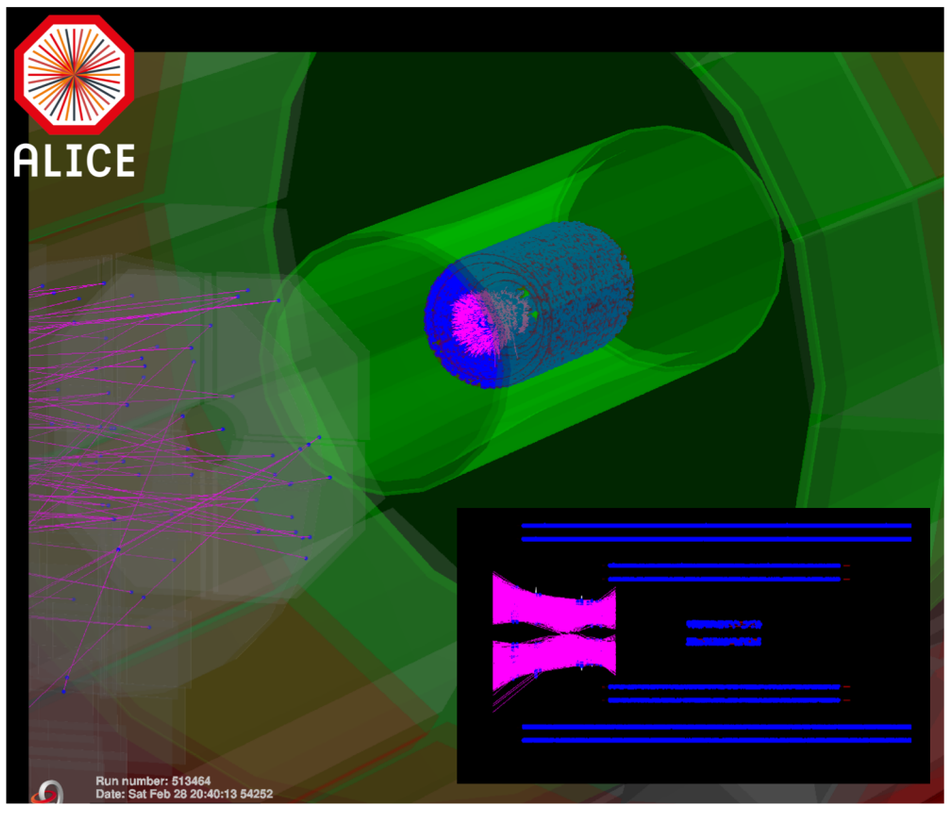
< 6.10^{12} 1 MeV n_{eq}/cm^2

10 fold security factor

MFT: Major Milestones

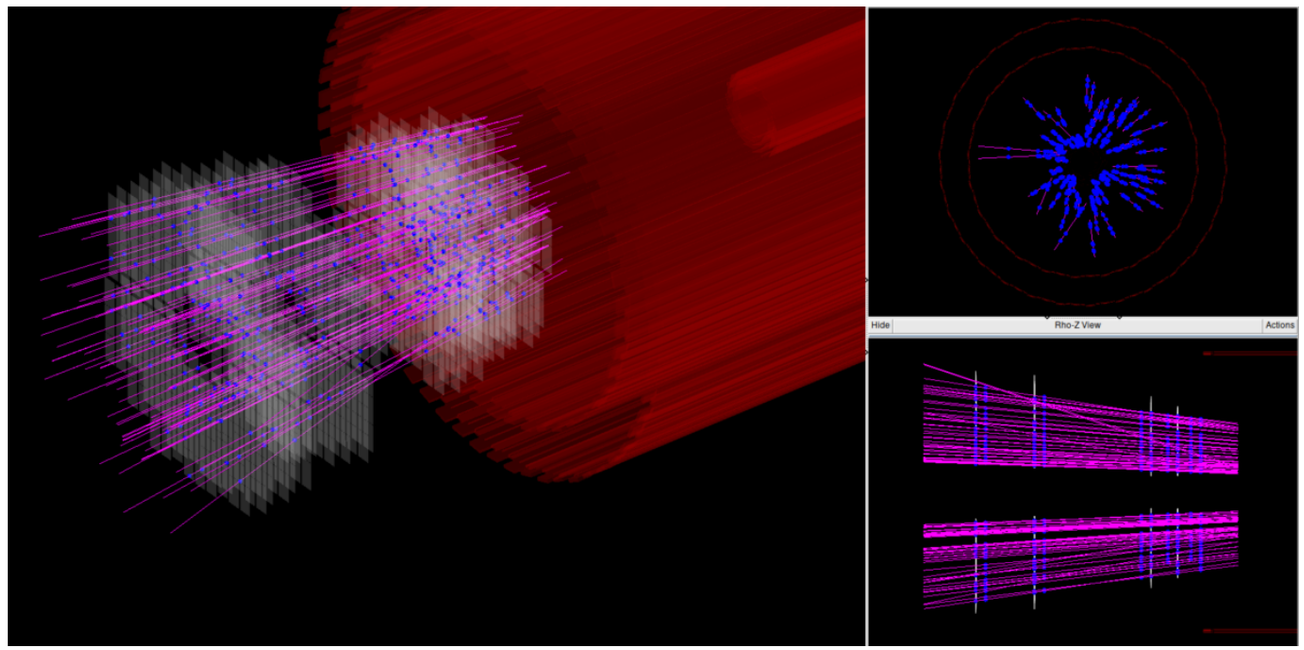
Installation into ALICE in December 2020 (first detector to be installed)





LHC Pilot beam on November 2021

2 colliding bunches at 0.9 TeV



TED Shots in February 2022

Collisions at @ 80 m from ALICE (injection point)

First track reconstruction with MUON spectrometer

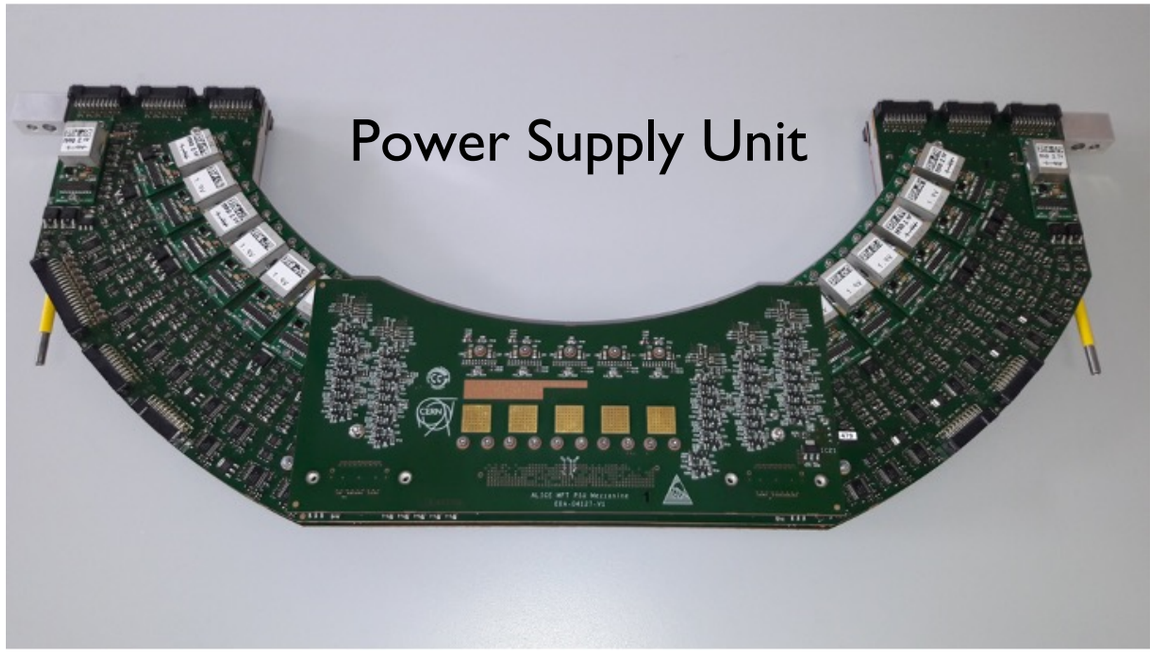
HAD_02: Main Achievements

Detector Control System:

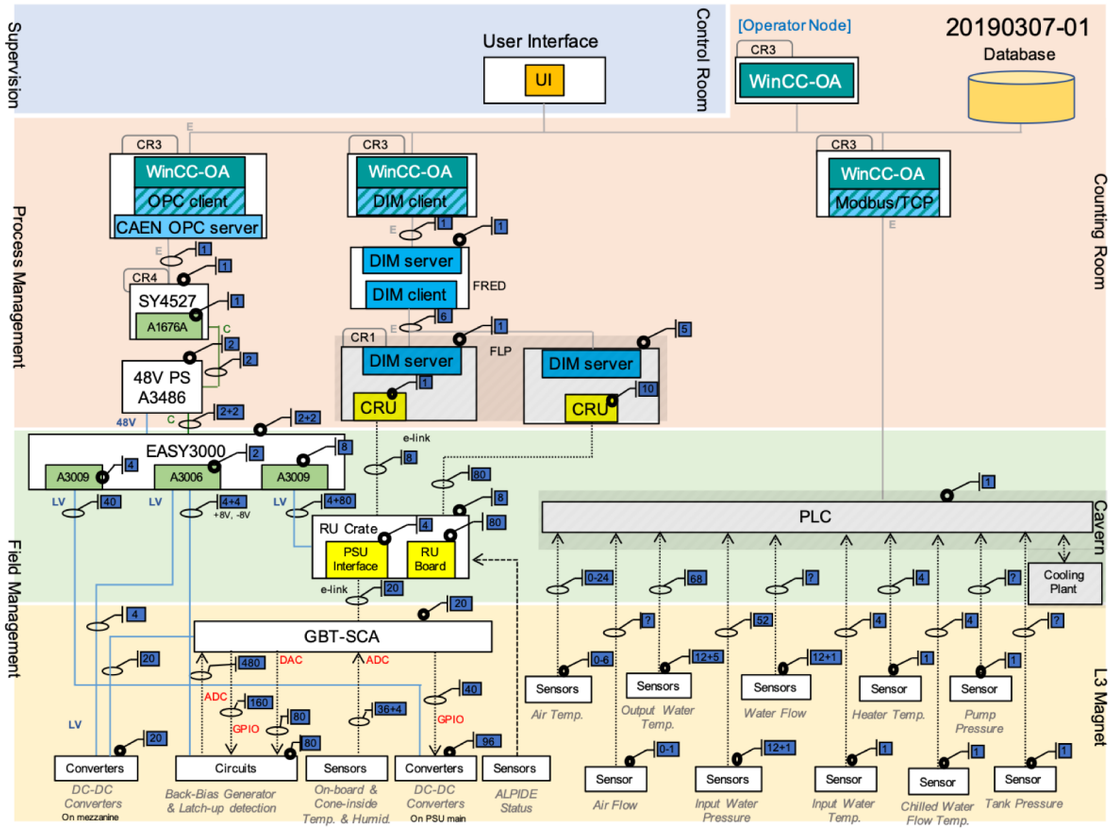
Control Power Supply, Cooling and Configurations

Management of state transitions

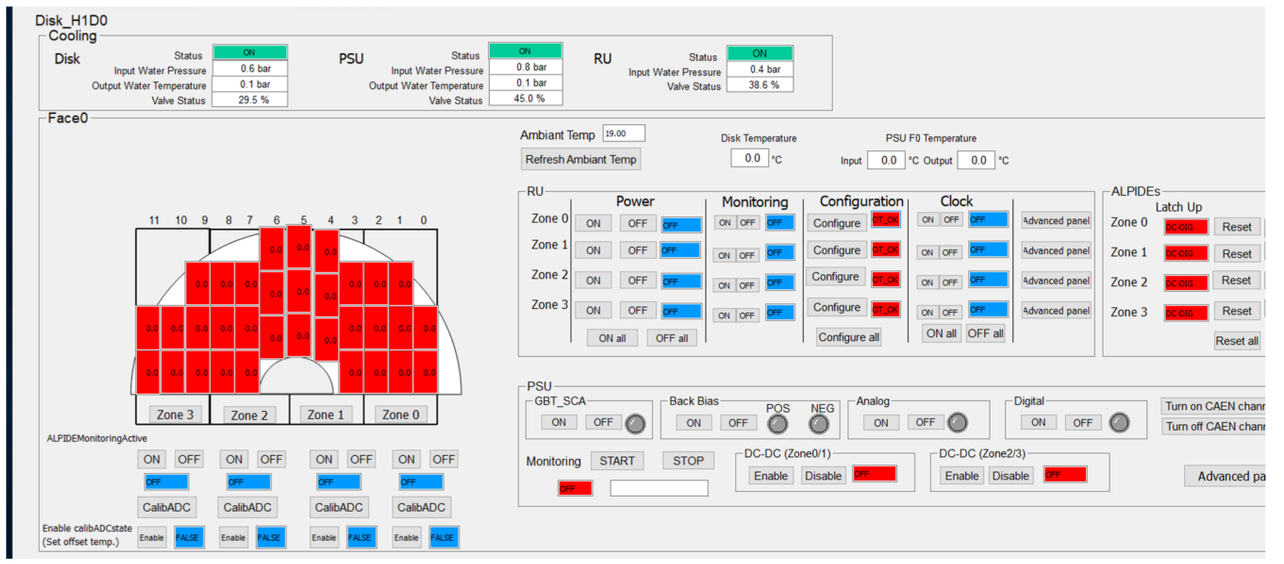
Automatic safety procedures and interlocks



MFT DCS Architecture



Example of Control Panel



Project HAD_02:

Hardware oriented.

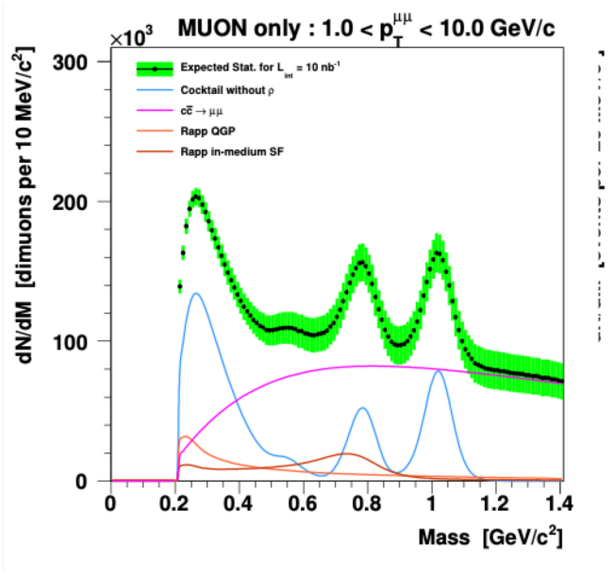
Will finish with MFT fully operational (first collisions this summer).

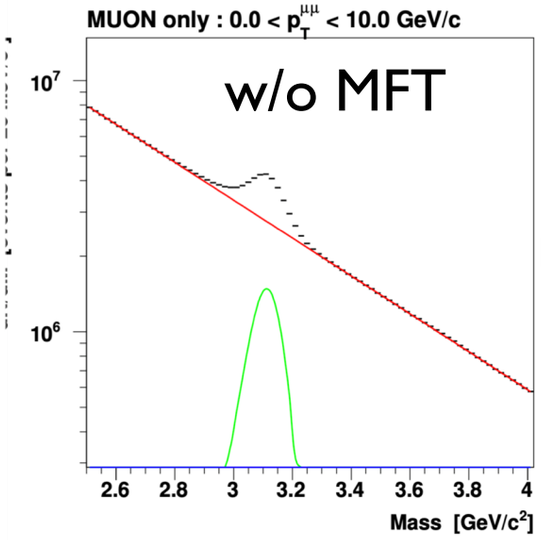
But collaboration will continue

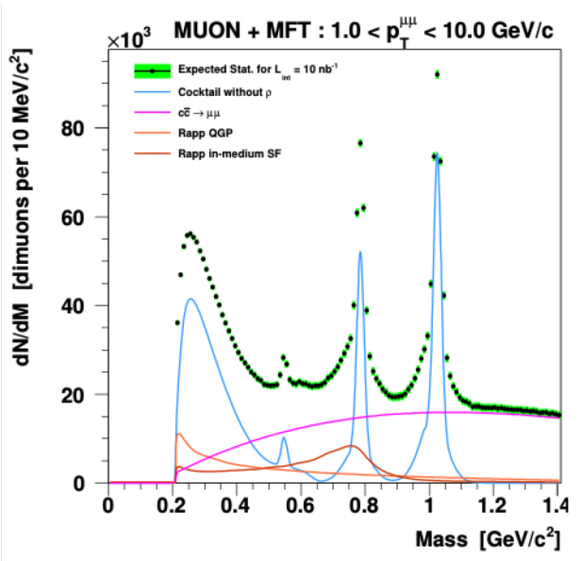
HAD_06: Track Matching

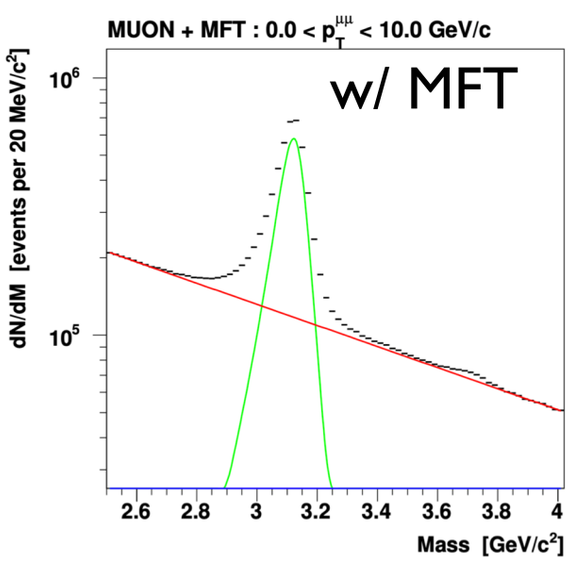
MUON+MFT track matching:

Improvement of S/B ratio and mass resolution

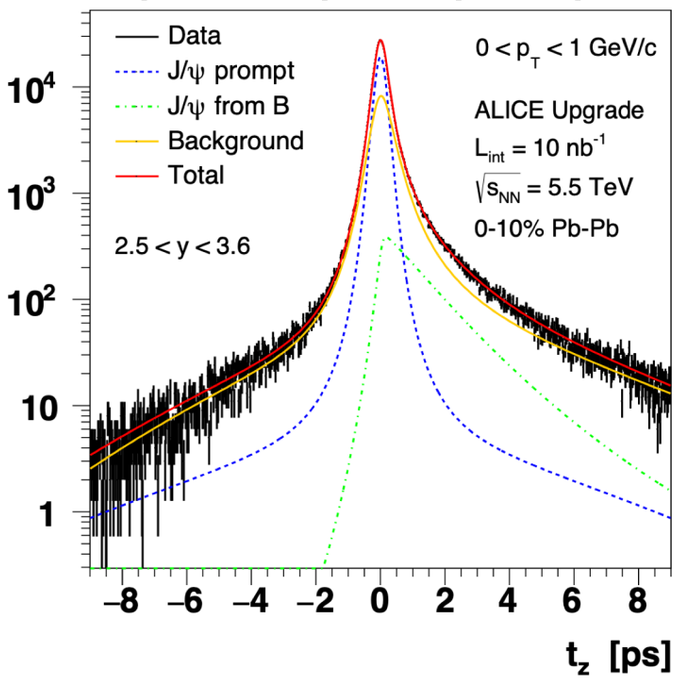


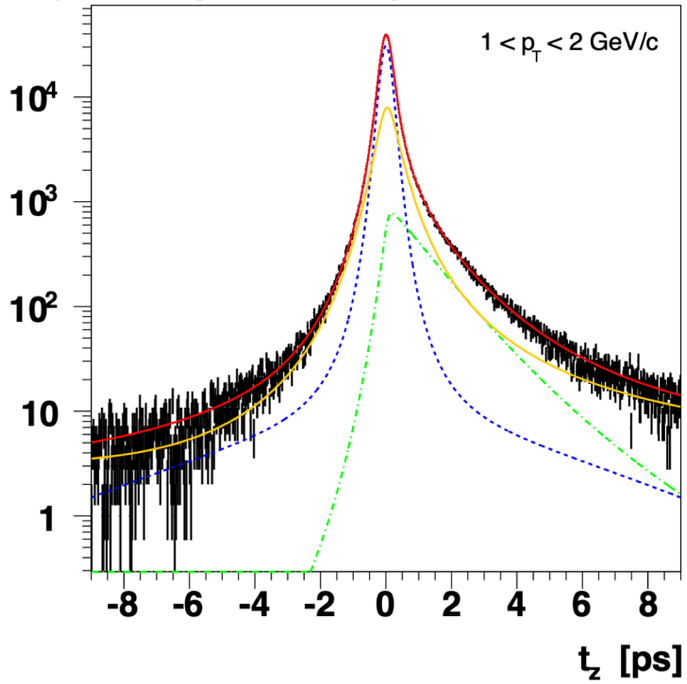


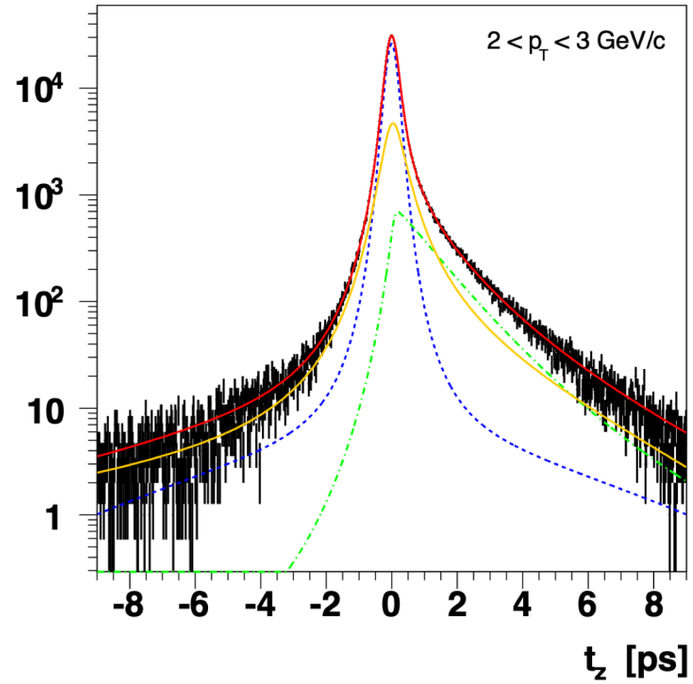




Prompt/non-prompt separation (beauty/charm)





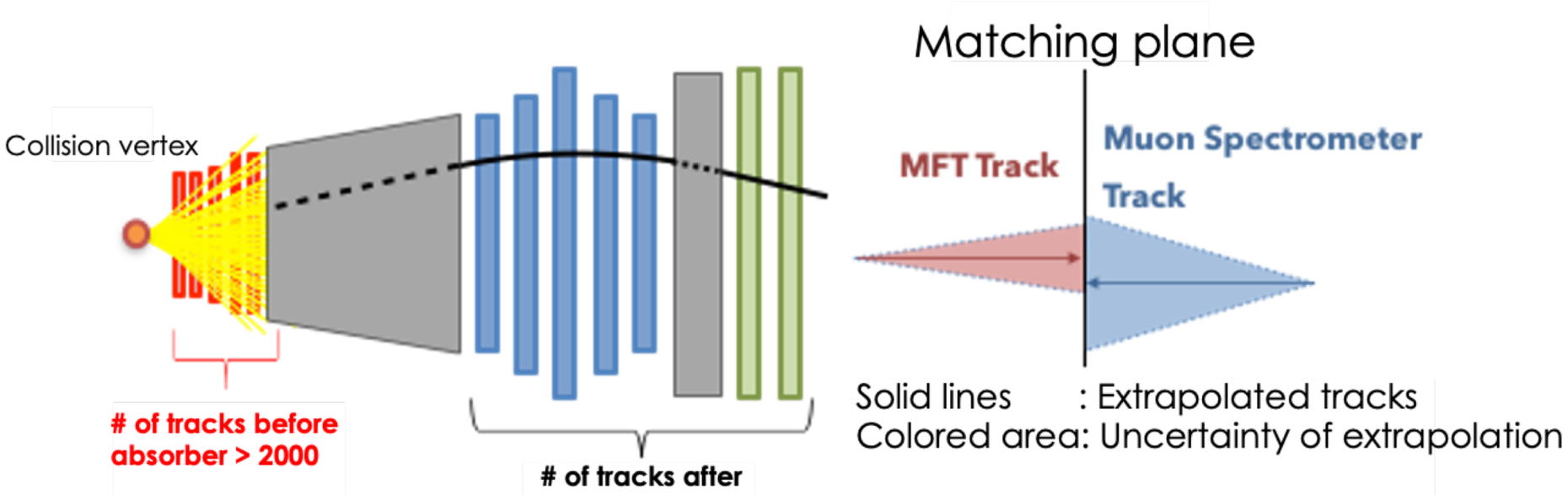


t_z: decay time along beam axis

HAD_06: Machine Learning

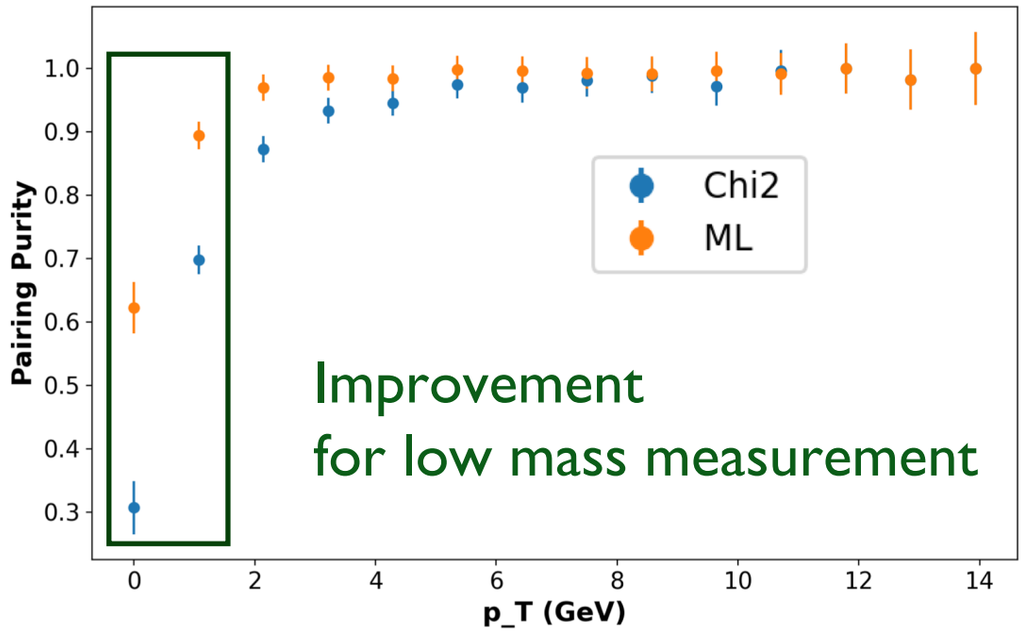
MUON+MFT muon track matching:

Limited matching purity (true/reconstructed) with traditional χ^2 method



Machine learning techniques:

Developments based on TensorFlow



Under integration in ALICE software
Under improvement for optimisation of ressources.

HAD_02 & HAD_06: Training and support to students

PhD Students:

Kosei Yamakawa (04/17-03/22): Control system structure design, Test bench setup, Chip test setup.

Rita Sadek (11/19-10/22): Software developments for Power Control, Machine Learning technics for track matching and preparation of first data analysis.

Motomi Oya (04/21-03/24): Control system implementation, Finite state machine, Graphical User Interface, preparation of first data analysis.

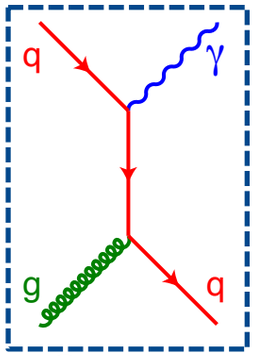
Long stay periods at CERN:

Kosei Yamakawa (01/06-03/16, 06/17-12/17, 06/18-12/18)
Motomi Oya (10/19-12/19, 02/20-03/20, 08/21-12/21, 06/22-09/22)
Ryoka Tokumoto (05/22-07/22), Kento Kimura (06/22-08/22)
Ren Ejima (06/22-08/22), Tomo Ito (07/22-09/22),
Koki Soeda (08/22-09/22), Hiraku Soeta (08/22-09/22)

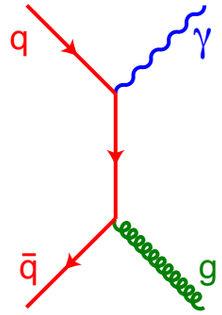
HAD_04: Low-*x* Physics in ALICE

- Probe the low-*x* gluon density with isolated photons at forward rapidity
  - Prompt photon production (LO) is sensitive to the gluon density inside the colliding hadrons

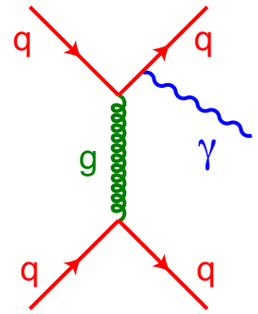
Prompt photons



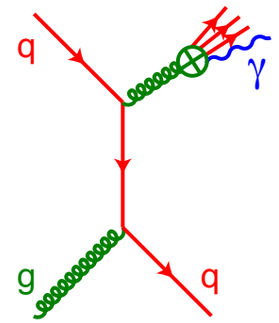
Compton



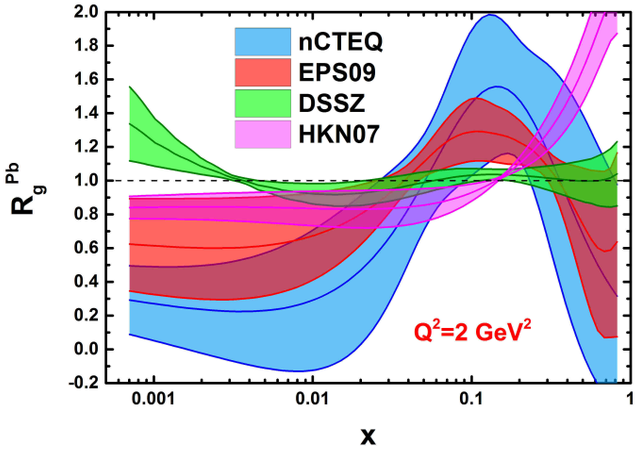
annihilation

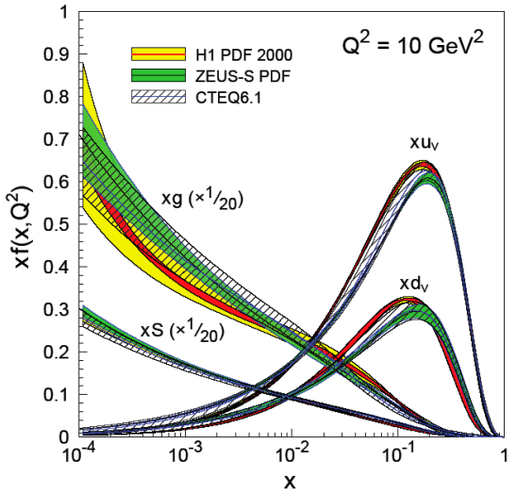


bremsstrahlung

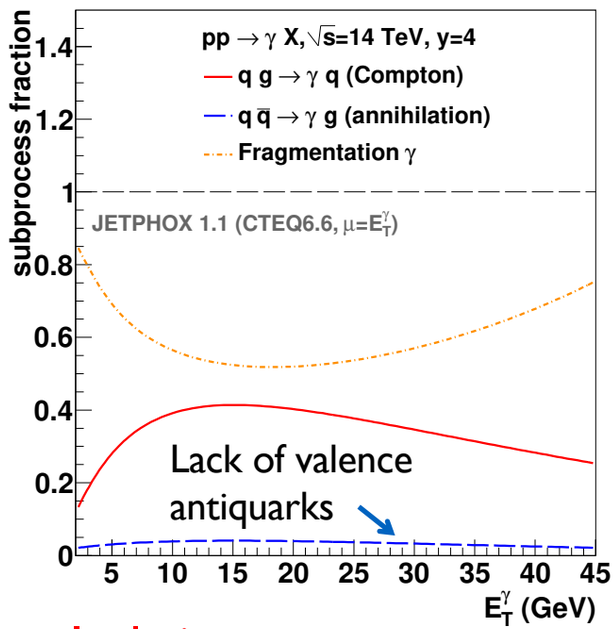


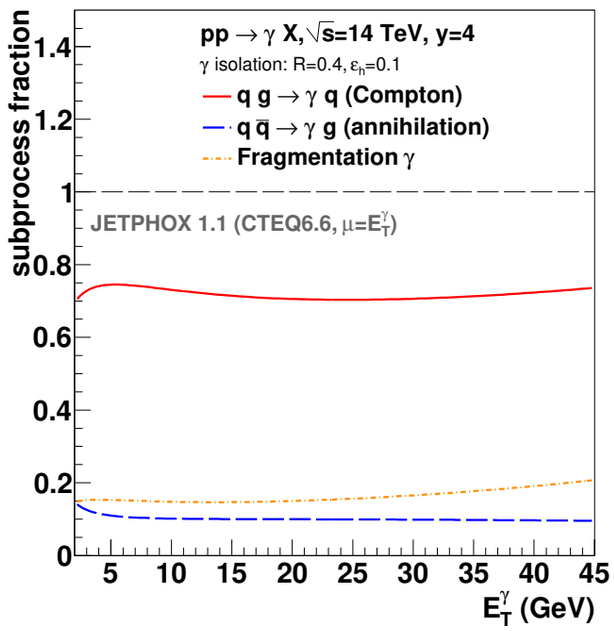
fragmentation





- Large uncertainties on the gluon content of the nucleus at small *x*
- Explore non-linear evolution and saturation at small *x*



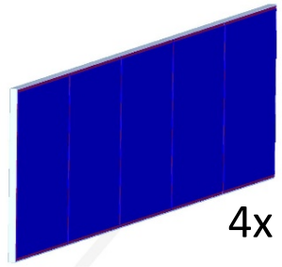


Isolation cut

- Significantly suppresses fragmentation and bremsstrahlung
- Reduce the background of decay photons in the measured signal

H. Pillot (Master) internship, summer 2021, Tsukuba-Grenoble

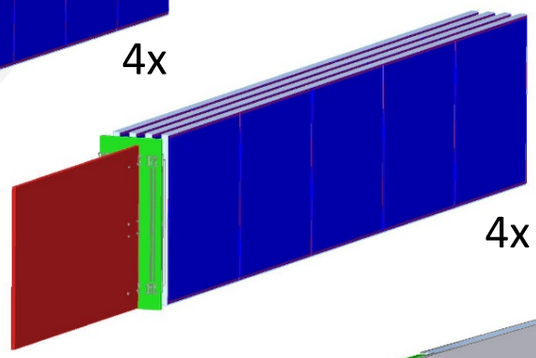
HAD_04: FOCAL-E Layout



PAD layer

4x

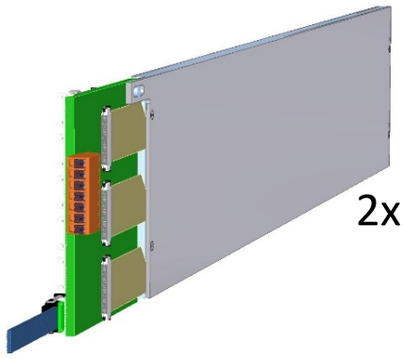
3kg



PAD segment

4x

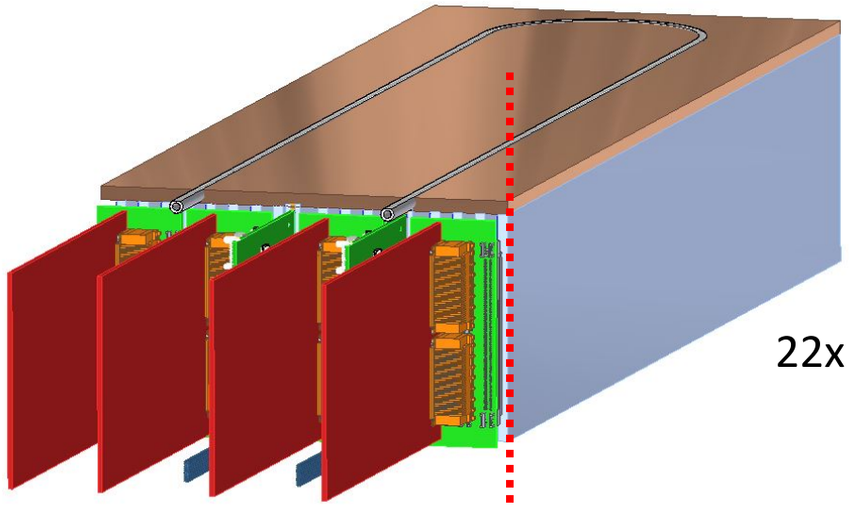
12kg



Pixel layer

2x

3kg



FoCal module

22x

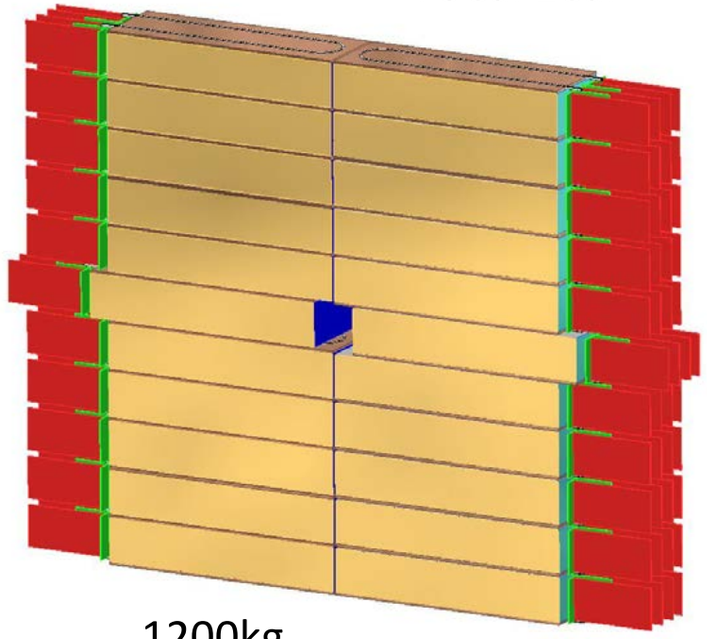
56kg

FR
LPSC Grenoble
with support
from IN2P3 C4Pi
& OMEGA)

JP
Tsukuba,
RIKEN,
NWU,
Hiroshima,
NIAS, Saga

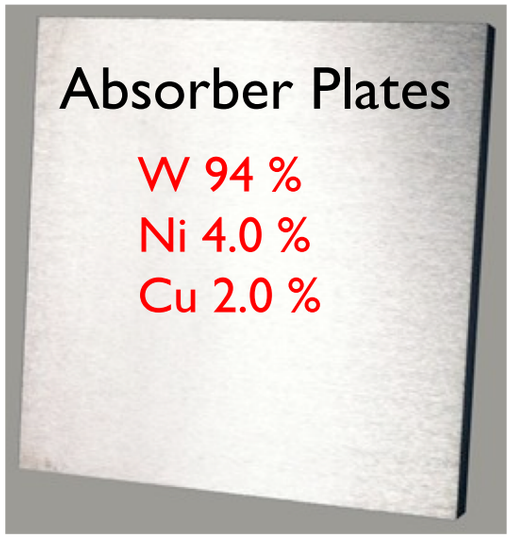
+ KEK (see next slides)

FoCal ECal



1200kg

HAD_04: FOCAL-E R&D



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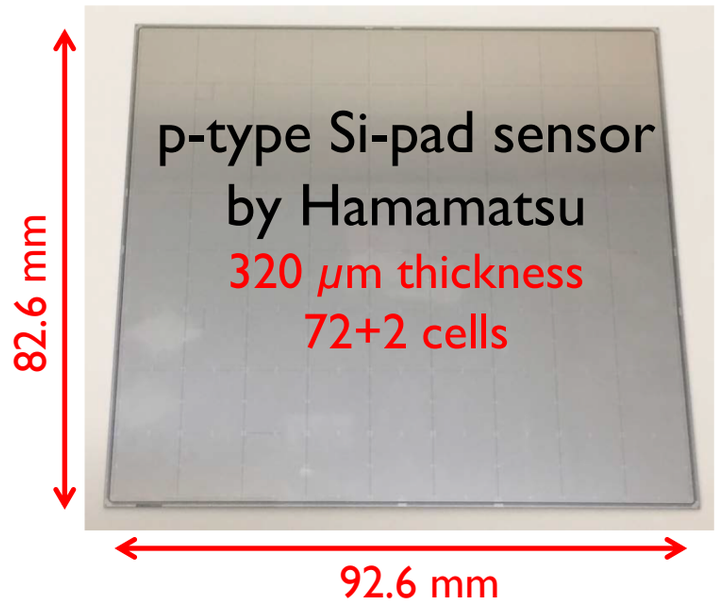
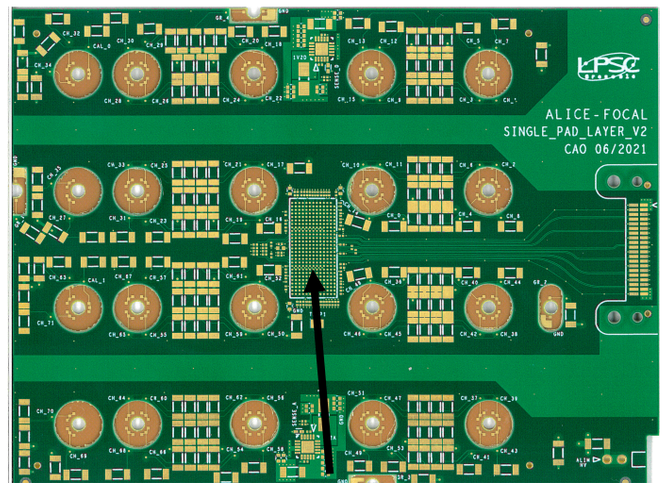
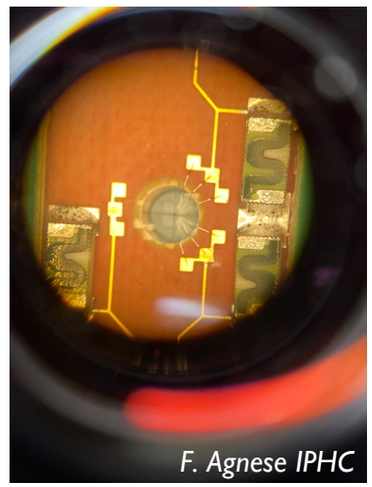


+

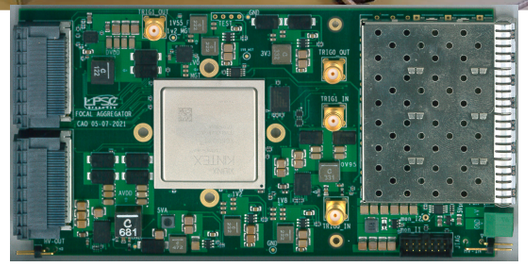


PCB with HGCROC by Ωmega



Wire bonding at C4Pi IPHC

FEE and backend by LPSC

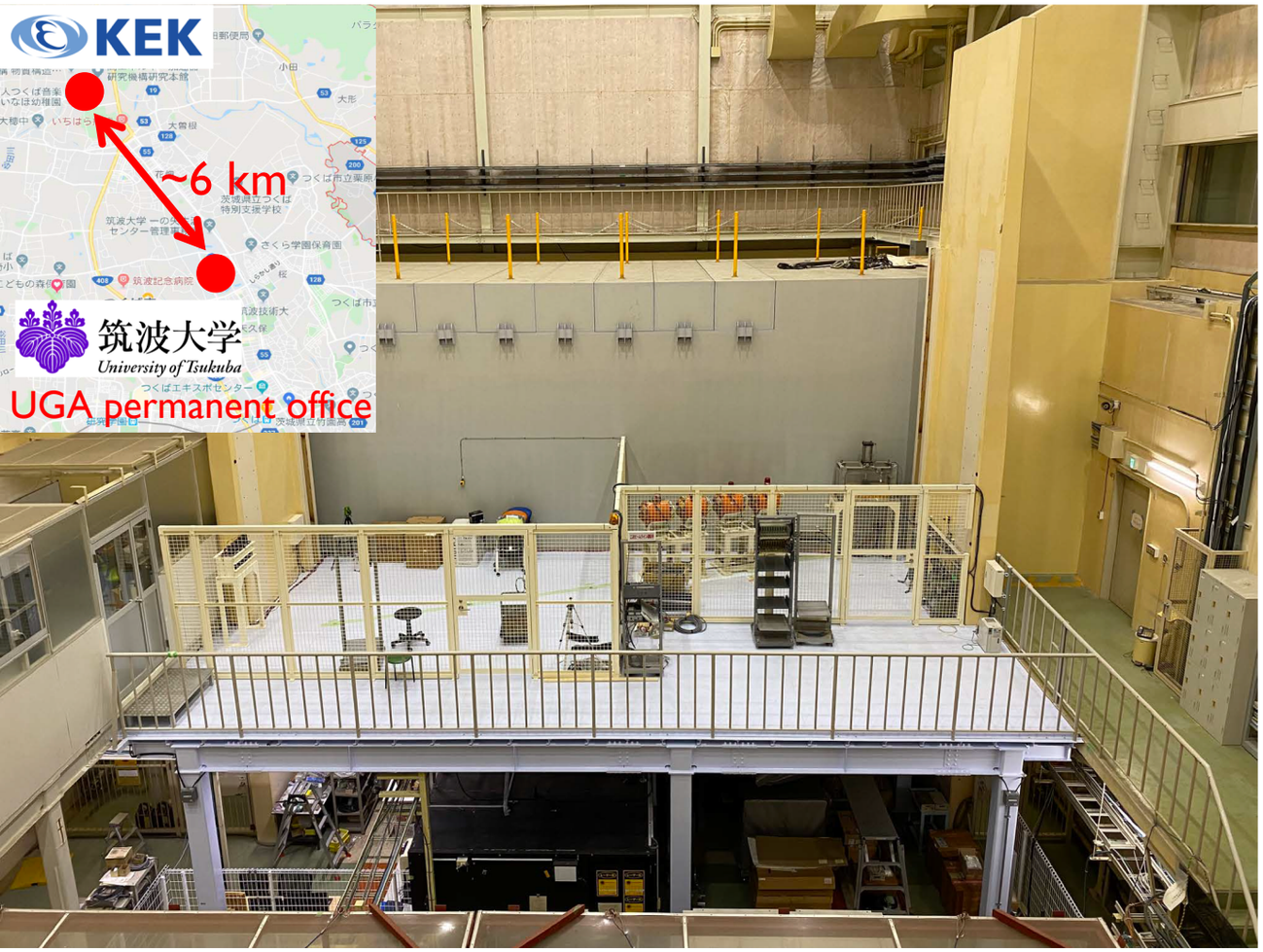


CRU PCIe40 by CPPM (+ fw by LPSC)

+ Triggering (T. Kumaoka PhD UT-UGA)

HAD_04: FOCAL @ KEK

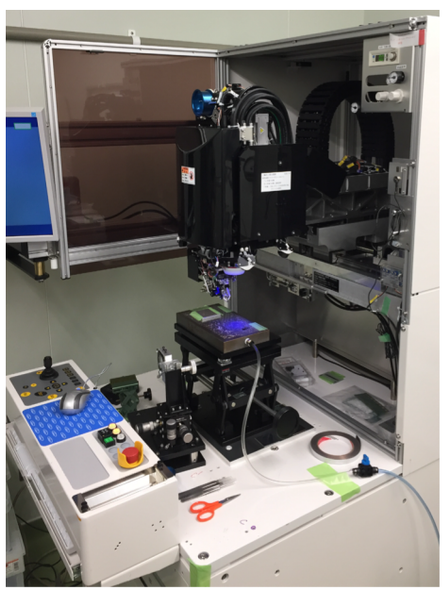
KEK PF-AR new test beam line



- Successfully extracted beams of GeV electrons (< 6 GeV) at few kHz in March 2022
- Commissioning from May 16, 2022, user in fall 2022?
- 100 days/year (1 mon. x 3): before summer, Nov, Feb
- KEK PF-AR workshop, and visiting event (Jan.13, 2022): https://kds.kek.jp/event/40468/
  - FoCal project has been presented
- Could be used for single PAD test in 2022 summer, and FoCal calibration for the long term for real FoCal modules

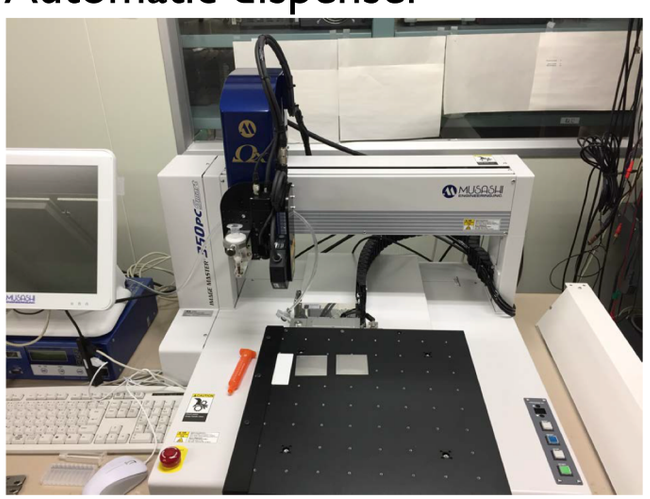
KEK silicon platform

+ OpenIT

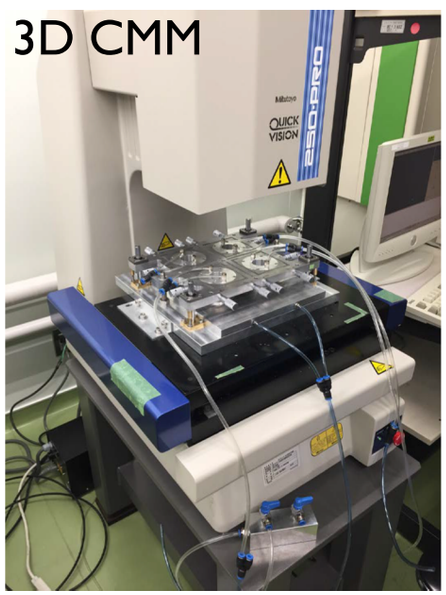


Automatic wire bonding machine

Automatic dispenser

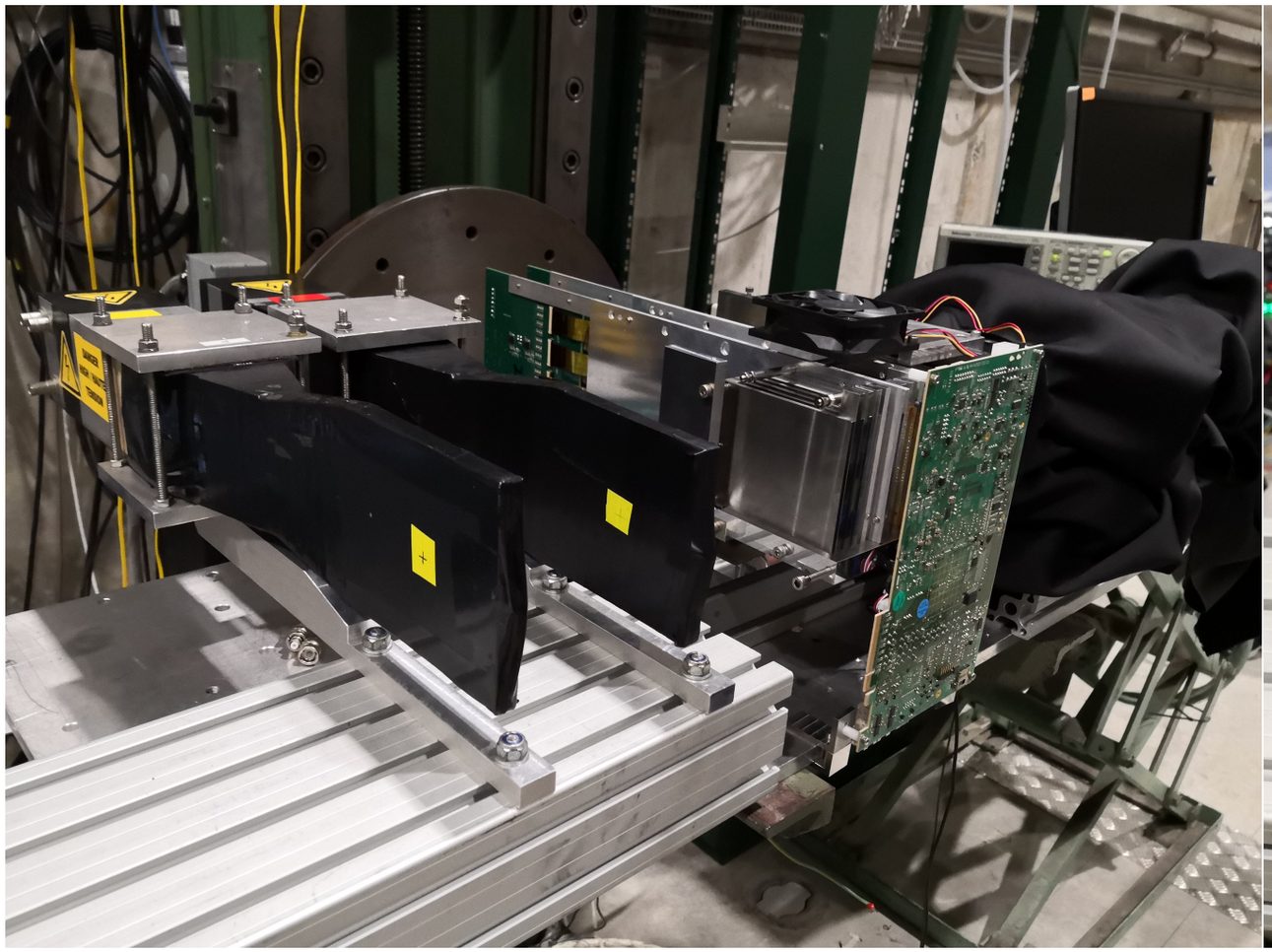


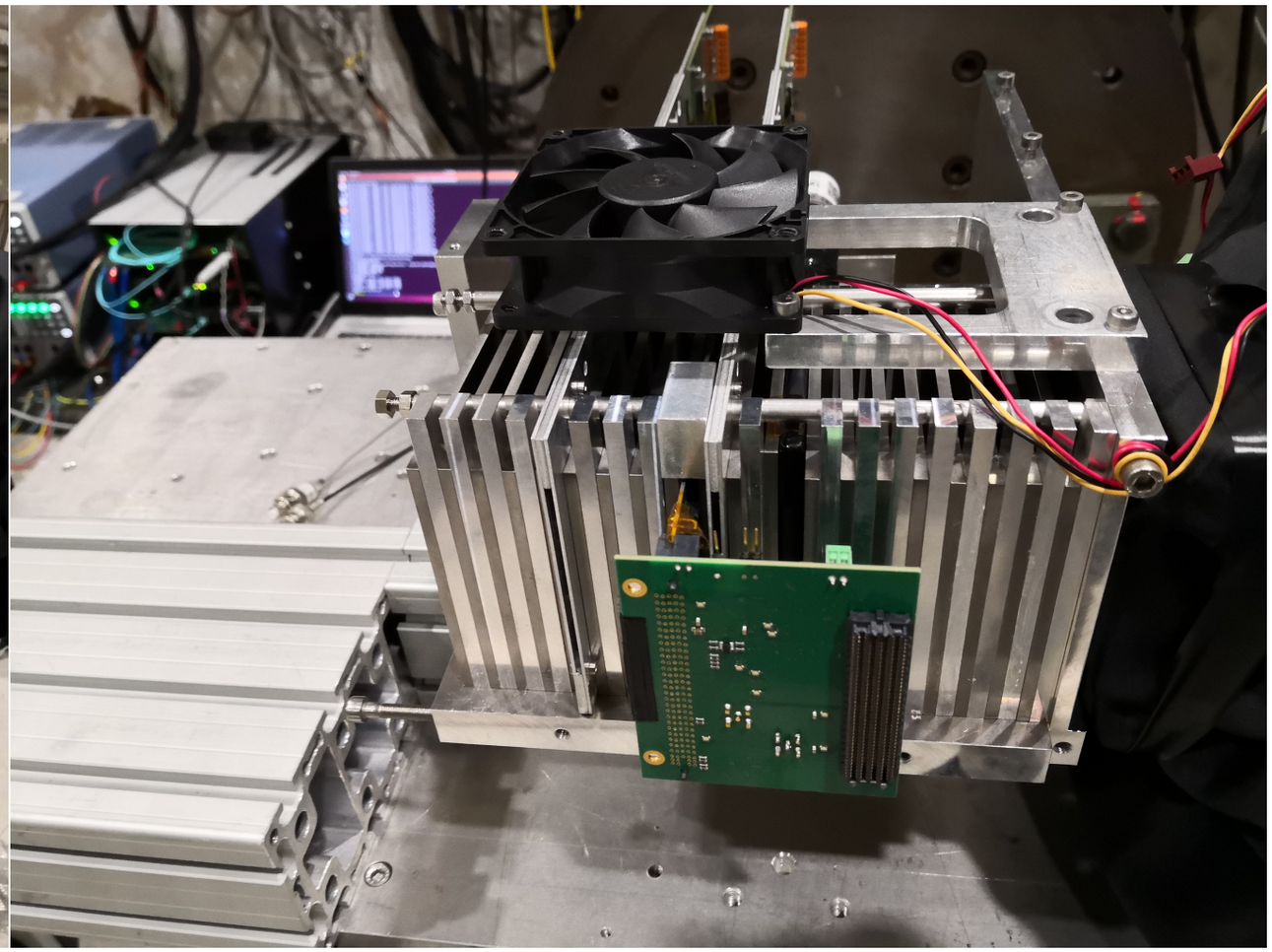
3D CMM



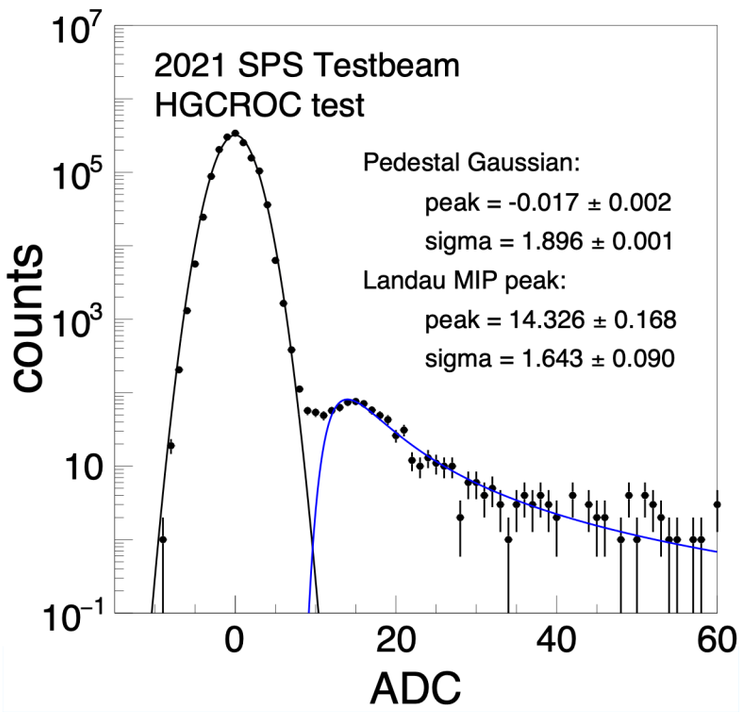
FOCAL Beam Tests at CERN SPS (H6) Sep. 2021

FOCAL Beam Tests at CERN SPS (H6) Sep 2021





- Single particle response:
  - Determination of the pedestals and sigmas:
    - Pedestal ~15 ADC of 10-bit (1024)
    - Sigma ~2 ADC
  - MIP signal response:
    - MIP response ~13.5 and ~12.0 ADC
    - MIP peak width ~2.15, ~1.5 ADC



Fully instrumented tower prototype beam tests at CERN PS/SPS in Jun/Sep 2022!

Summary

- Very active HAD projects despite Covid-19
- Promising prospects for LHC Run 3 and 4!

Thank you for your attention!