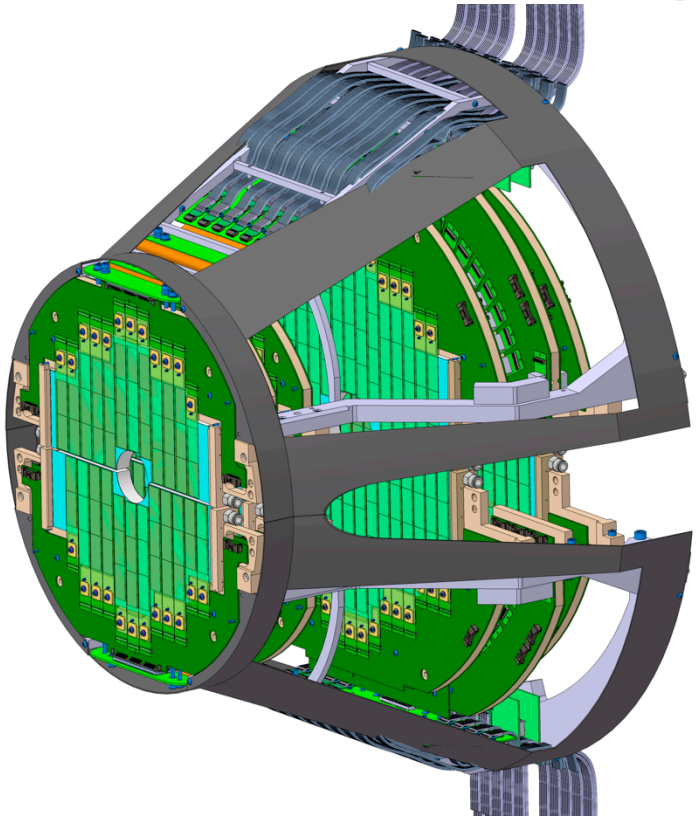


The MFT Project

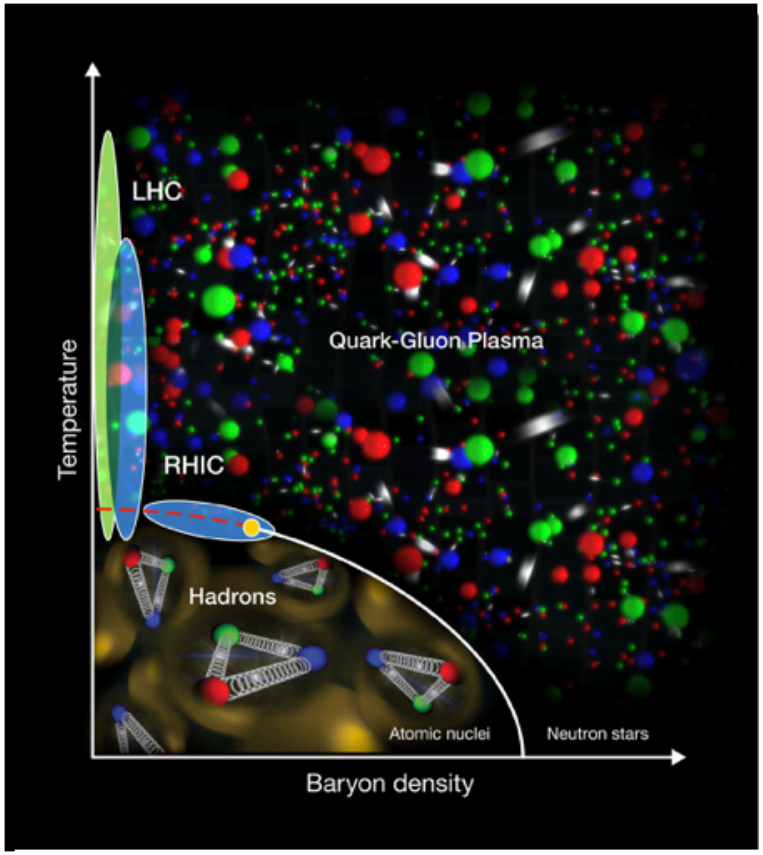
Raphael TIEULENT – IPN Lyon
For the MFT collaboration

Outlook

- ✓ Context of the MFT Project
- ✓ MFT principle, layout and performances
- ✓ Sensors
- ✓ Ladders
- ✓ Disks
- ✓ Cone
- ✓ Barrel
- ✓ Readout
- ✓ Services
- ✓ Conclusions

ALICE physics primary goal

Quark Gluon Plasma: Deconfined state of matter produced in heavy-ion collisions heavy ion collisions at the LHC: ε_0~10-40 GeV/fm^3



Study the QGP properties

- Parton interaction with the medium
- Collective phenomena
- Temperature, energy density

Using several probes

- heavy-flavour,quarkonia, light hadrons, jets, photons,…

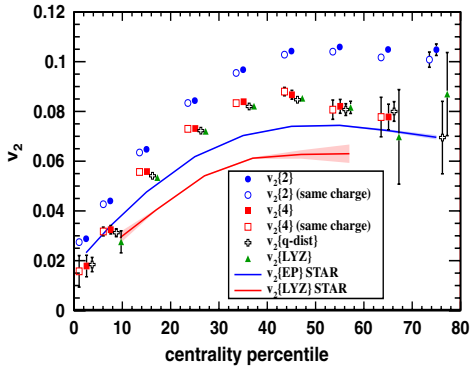
As a function of

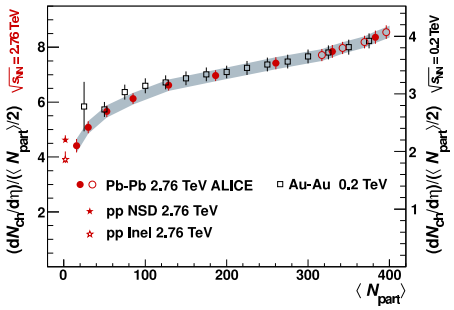
- rapidity, transverse momentum, azimuthal angle, centrality, centre of mass energy, reaction plane, fluctuations, small systems (pp and pA), correlations …

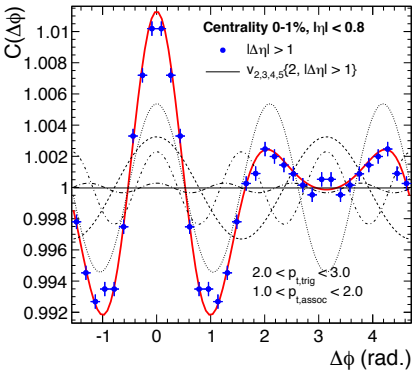
NuPECC Long Range Plan 2017

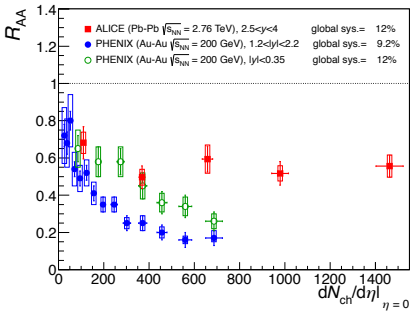
Quick overview of ALICE physics results

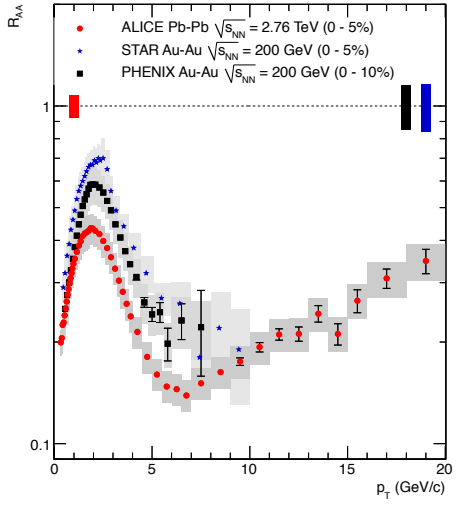
180 papers submitted/published: 2 top+500, 12 top+250, 38 top+100

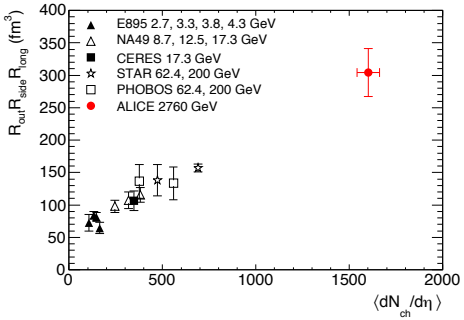


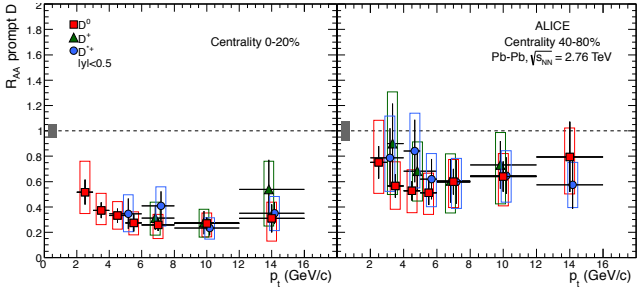


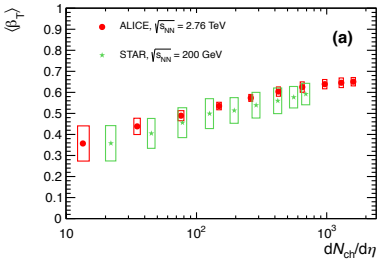


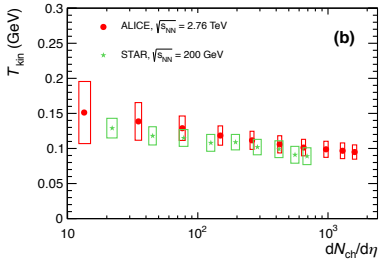


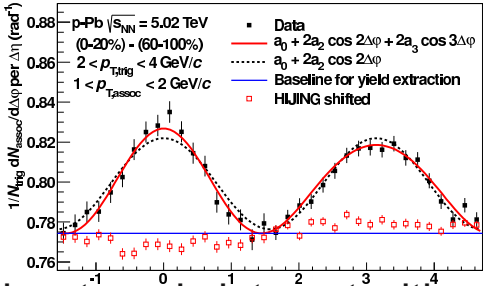










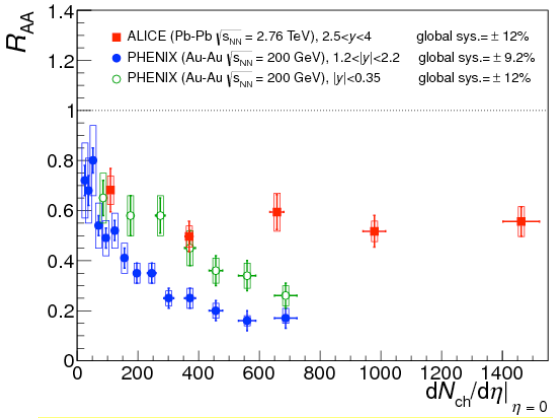


QGP behaves as a near-perfect liquid, opaque medium, charm quarks strongly interact with the medium, and collectivity-like behaviour is observed in small systems

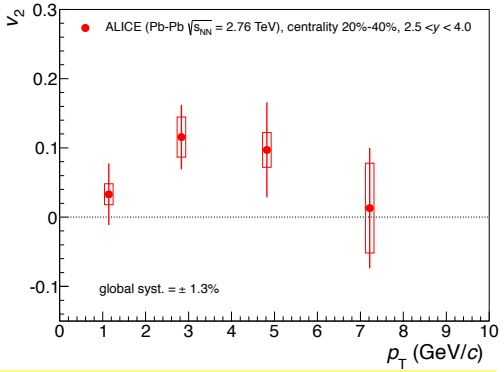
PRL105(2010)252302, PLB696(2011)30, PRL106(2011)032301, PLB719(2013)29, PRL107(2011)032301, JHEP1209(2012)112, PRC88(2013)044910, PRL109(2012)072301, PLB 696(2011)328 ...

QGP Physics results at forward rapidities at the LHC

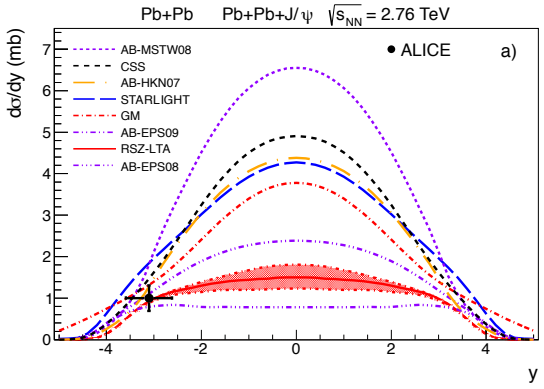
More than 30 published papers at forward since 2010



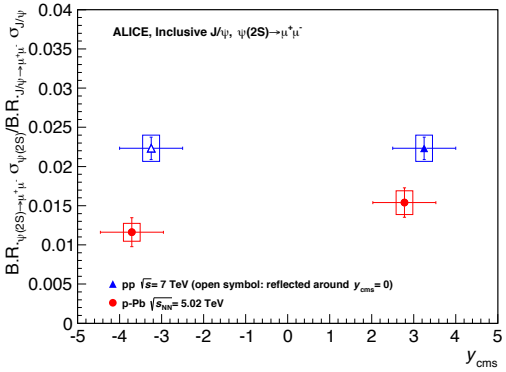
PRL109 (2012) 072301 250+



PRL111 (2013) 162301 50+

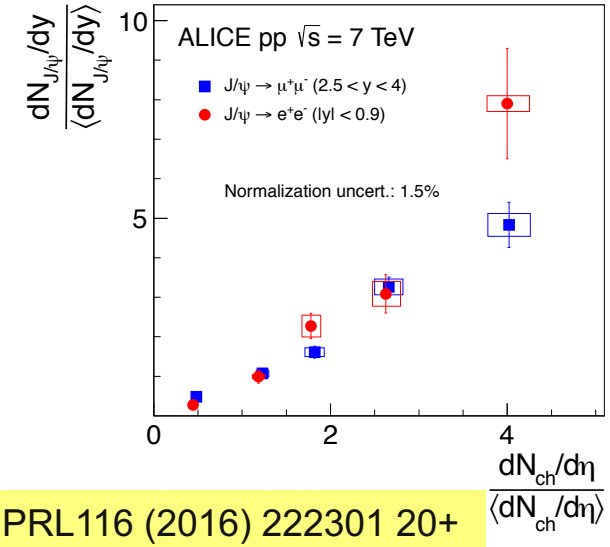


PLB718 (2013) 1273 100+

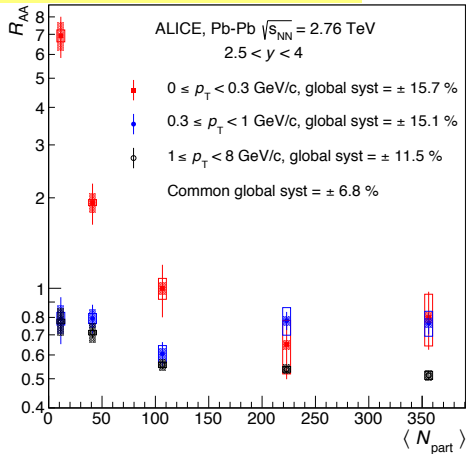


JHEP1402 (2014) 073 100+
JHEP 1412 (2014) 073 50+

PLB712 (2012) 165 50+



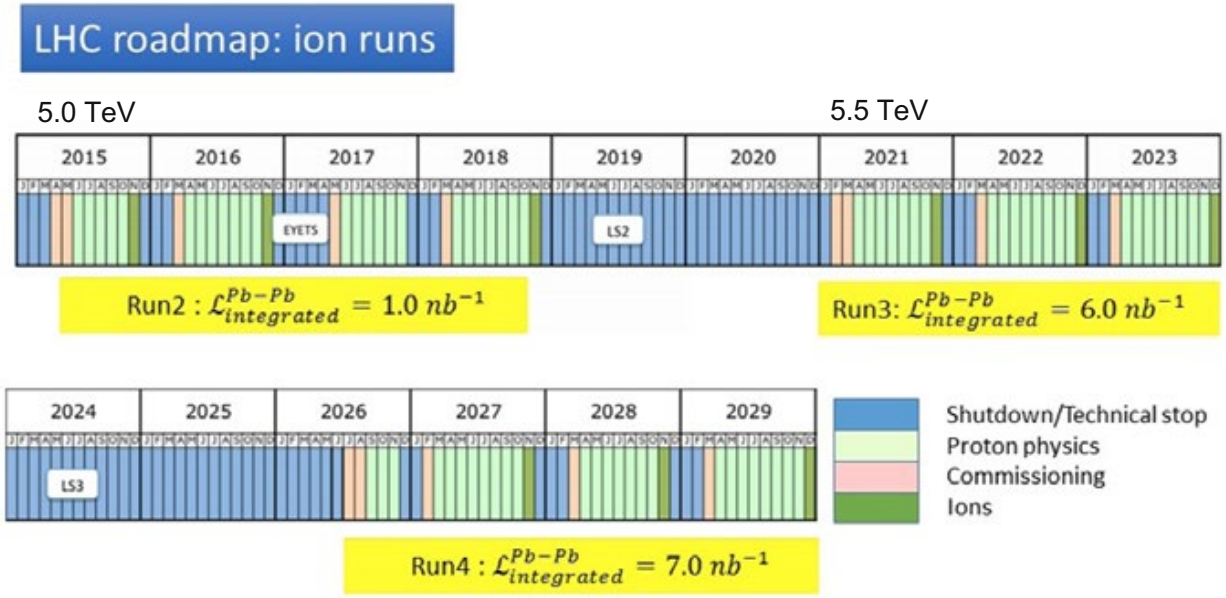
PRL116 (2016) 222301 20+



Remaining questions about QGP at the LHC

Higher precision and new probes

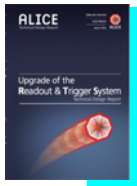
- ✓ Characterisation of the QGP at the LHC: viscosity, diffusion coefficients, initial temperatures, screening scales, …
- ✓ How does collectivity develop? the small systems



- ✓ 10-fold higher luminosity in Pb-Pb collisions at the highest energy in the centre of mass
- ✓ All 4 experiments will take part in the LHC HI runs
- ✓ Possible interest on lighter ion run (Ar or Xe)

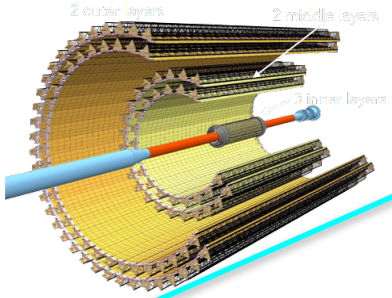
ALICE Detector Upgrade

Increase of luminosity (50kHz IR) and improve vertexing and tracking at low p_T



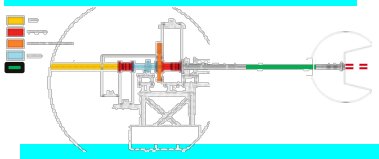
TPC, Muon Spectrometer, TRD, TOF, PHOS, EMCAL/DCAL, ZDC

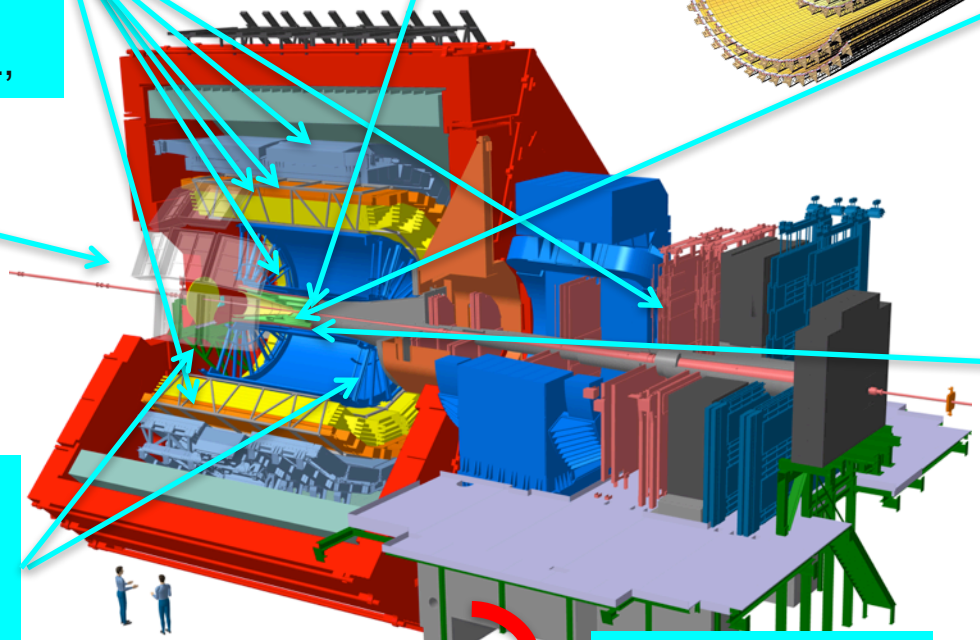
New MB trigger detector FIT



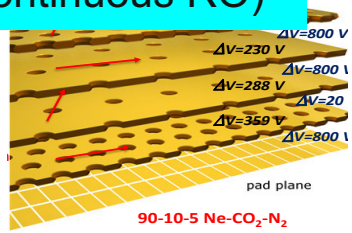
New Inner Tracking System, high resolution, low material budget

New beryllium beam-pipe smaller radius

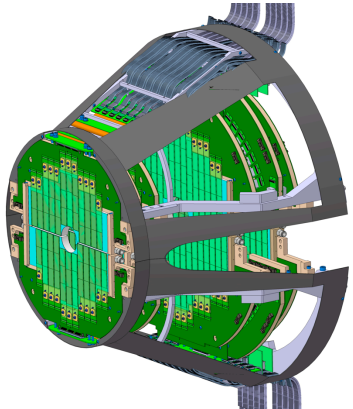




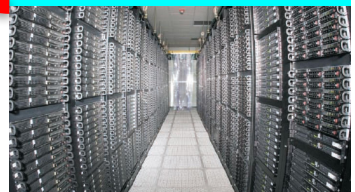
New TPC GEM Chambers (low ion backflow, continuous RO)



Muon Forward Tracker, high resolution, low material budget



Computing O^2



3.4 TBytes/s
100 GBytes/s
Online reco

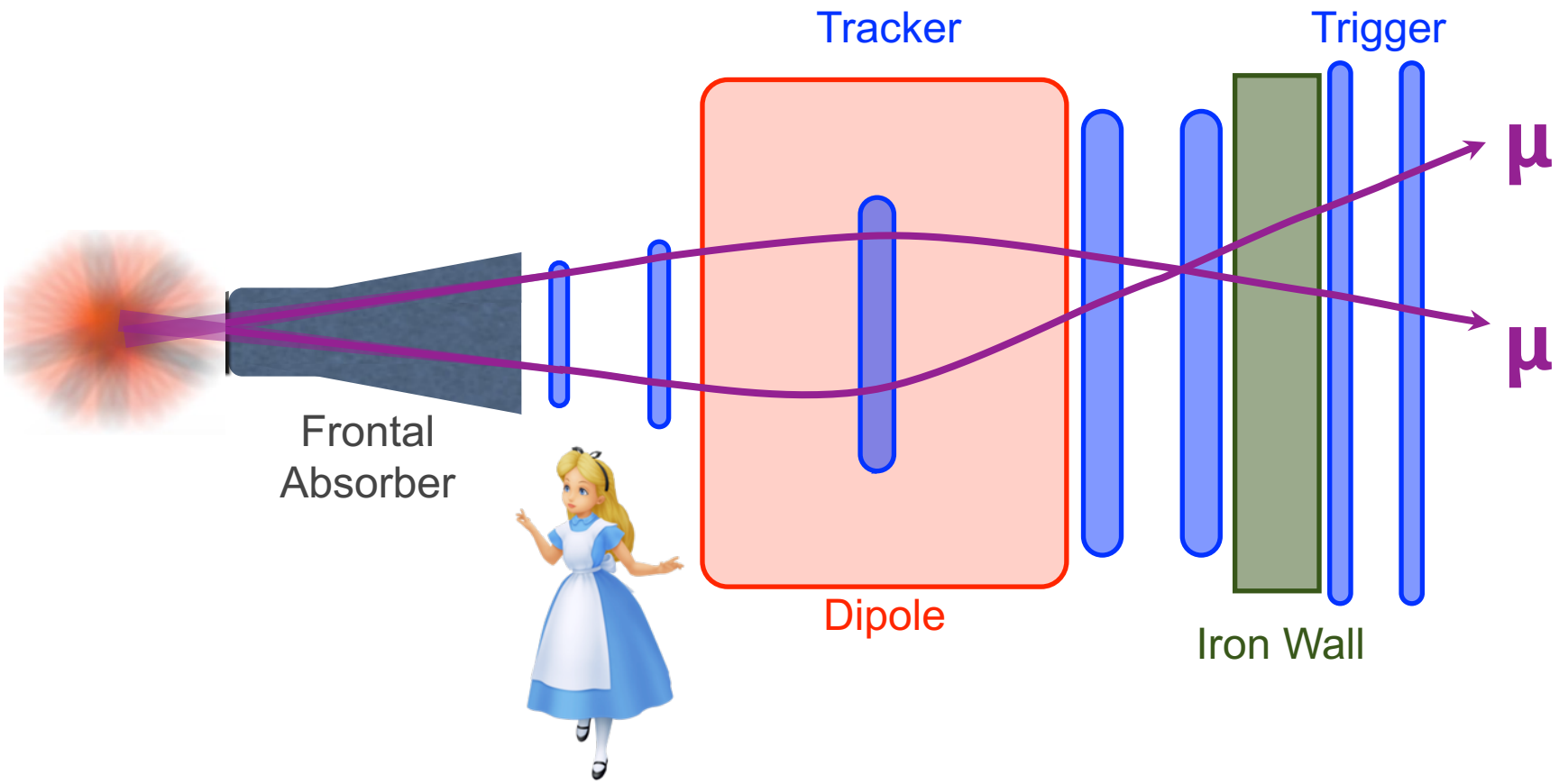
ALICE Detector Upgrade for Run3 and Run4

Letters of Intent and Technical Design Reports

- ALICE TDRs for the Run3 upgrade
  - CERN-LHCC-2013-019 (System upgrade TDR)
  - CERN LHCC-2013-013 (TPC Upgrade TDR)
  - CERN-LHCC-2013-023 (ITS Upgrade TDR)
  - CERN-LHCC-2015-001 (MFT TDR)
  - CERN-LHCC-2015-006 (O2 TDR)
- Alice Upgrade LoI and its addendum
  - CERN-LHCC-2012-012 (LoI)
  - CERN-LHCC-2013-014 (addendum)

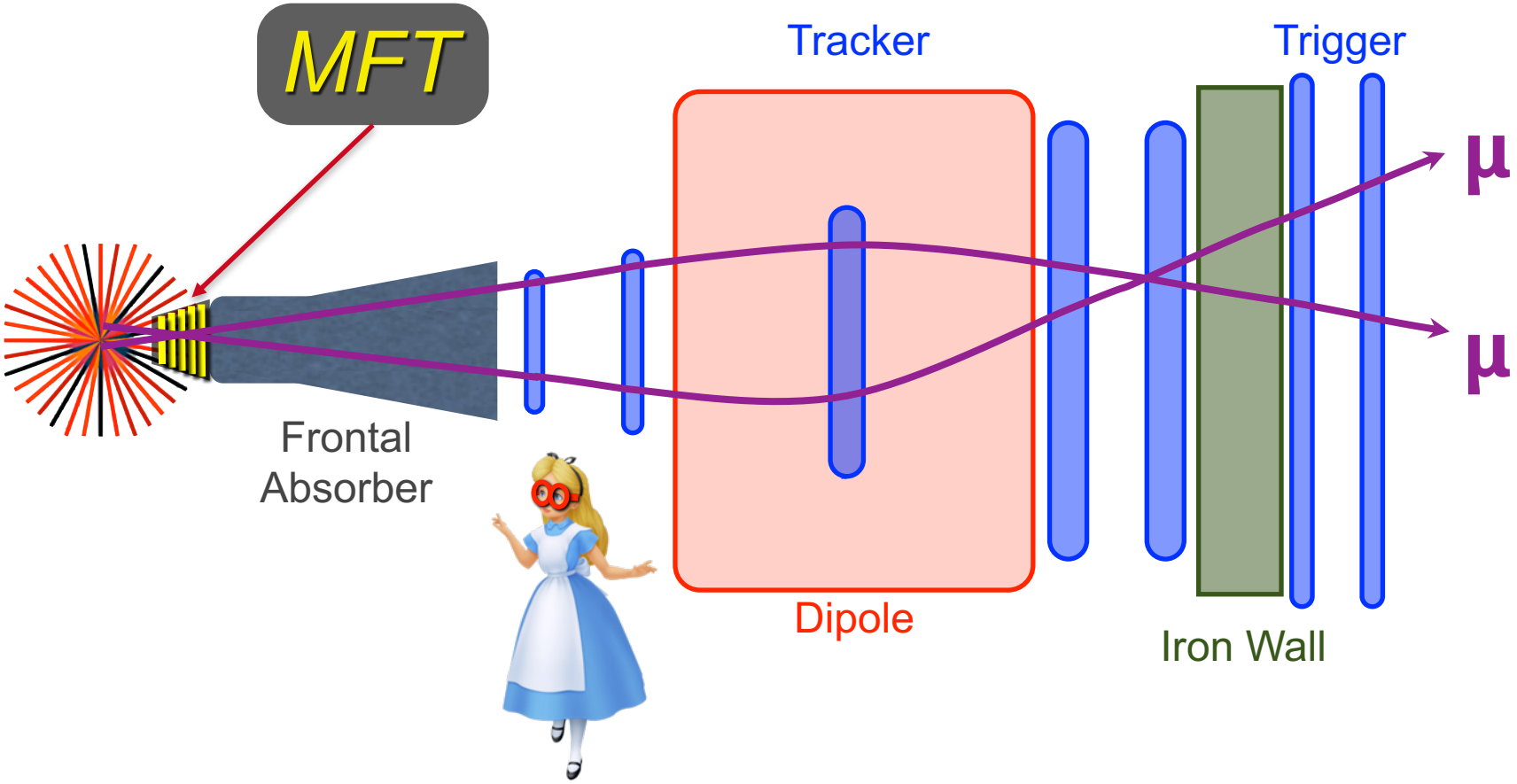
MFT Principle

High resolution muon vertexing for the ALICE muon spectrometer



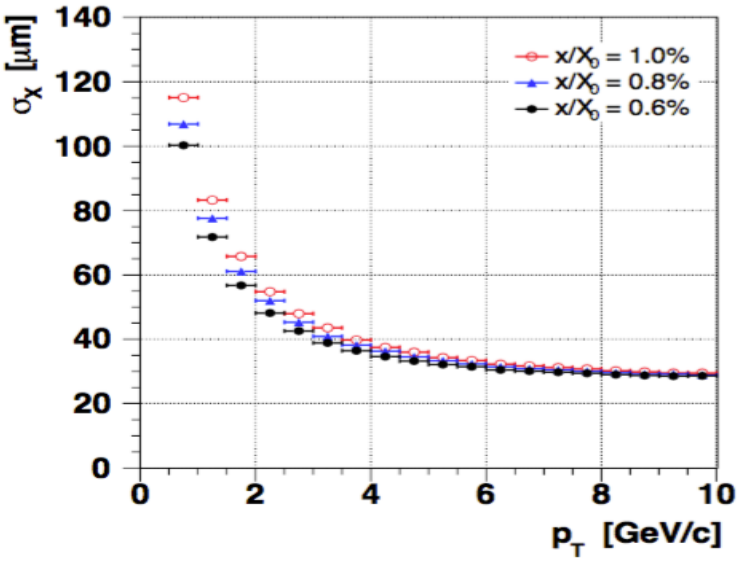
MFT Principle

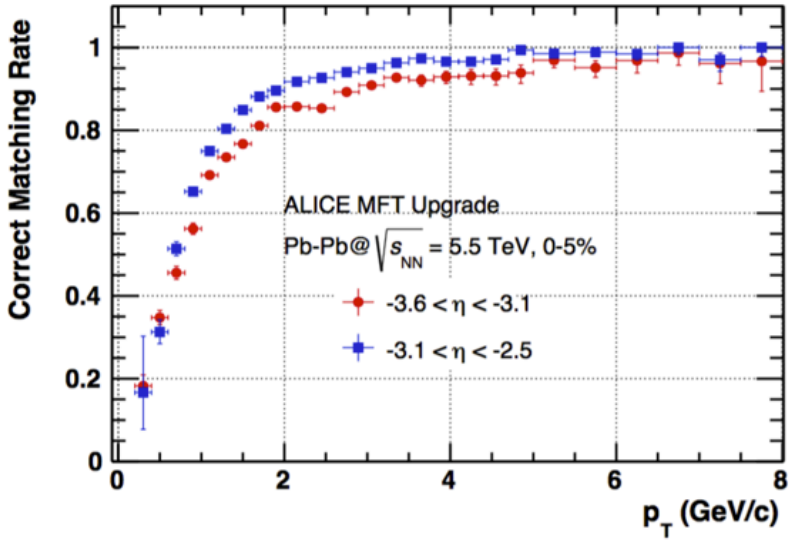
High resolution muon vertexing for the ALICE muon spectrometer



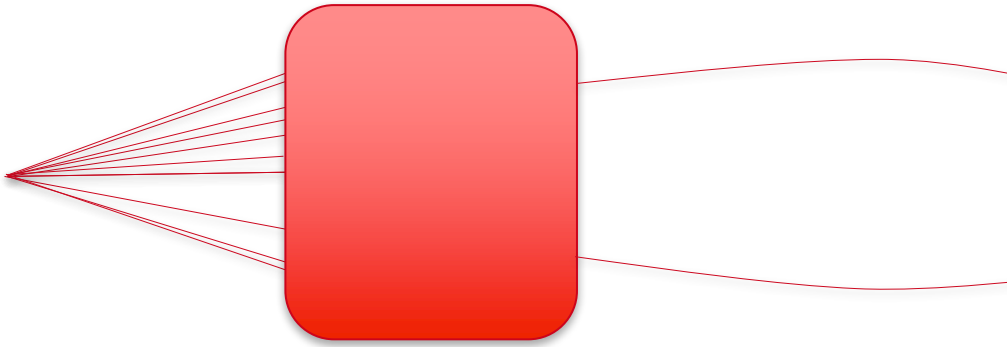
Upgraded ALICE tracking capabilities

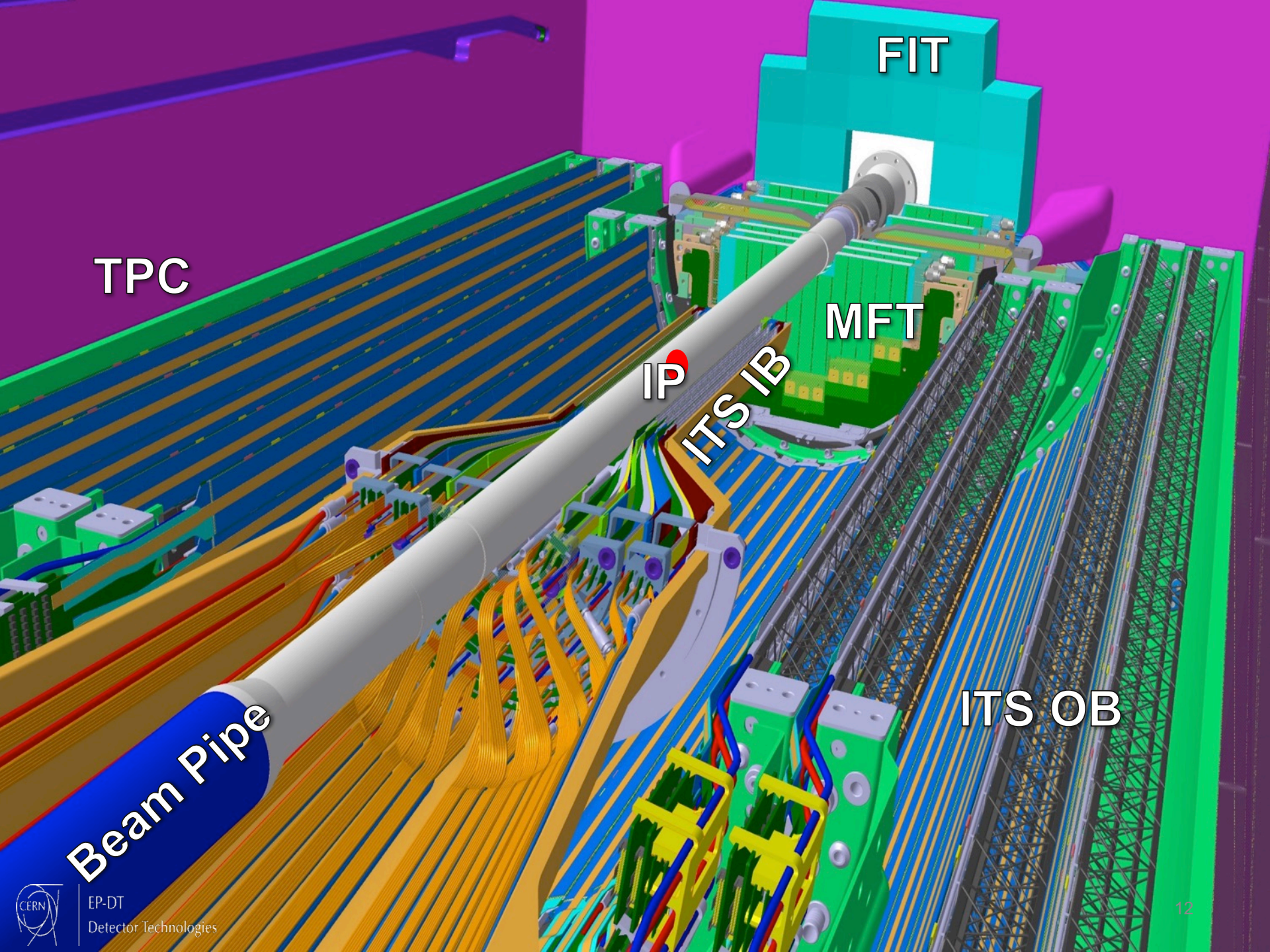
Muon Spectrometer (2.5<η<3.6) MFT+Muon





Displacement beauty decays in z (for any p_T, even for p_T=0) due to the rapidity boost.



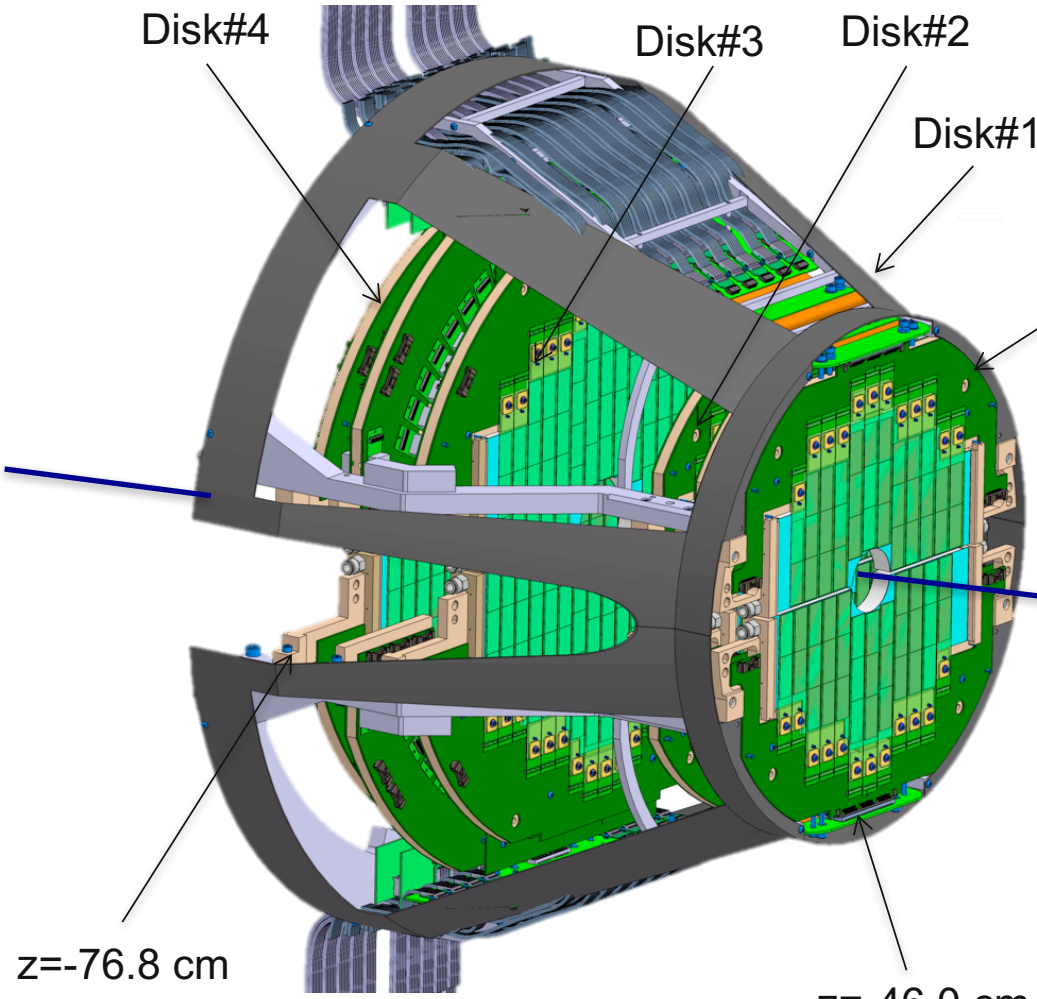

FIT
TPC
MFT
IP
ITS IB
ITS OB
Beam Pipe

MFT design goals

- Vertexing for the Muon Spectrometer at forward rapidity
  - 5 detection disks, O(5 μm) spatial resolution
  - 0.6% of X_0 per disk
  - $-3.6 < \eta < -2.45$
  - Disk#0 at z = -460 mm, R_{in} = 25 mm (limited by the beam-pipe radius)
- Good matching efficiency between MFT and Muon Spectrometer
  - Disk#4 at z = -768 mm (limited by FIT and the frontal absorber).
- Fast electronics read-out
  - Pb-Pb interaction rate ~50 kHz, pp interactions ~200 kHz.
  - Integration time and dead-time < 20 μs

MFT layout

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



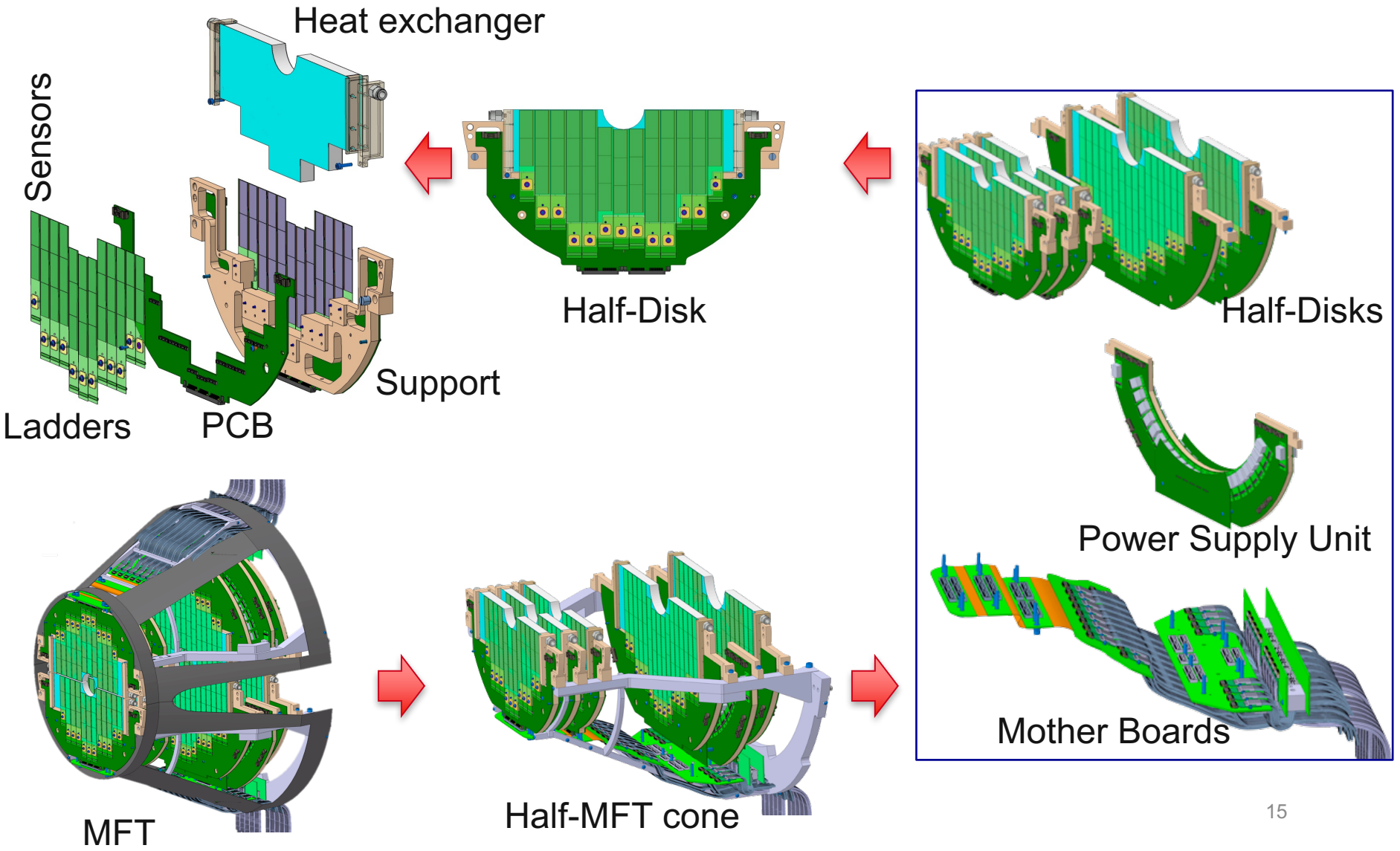
10 Half-disks
2 detection planes each

MFT doses
< 300 krad
< 2x10^{12} 1 MeV n_{eq}/cm^2

$-3.6 < \eta < -2.45$

IP region

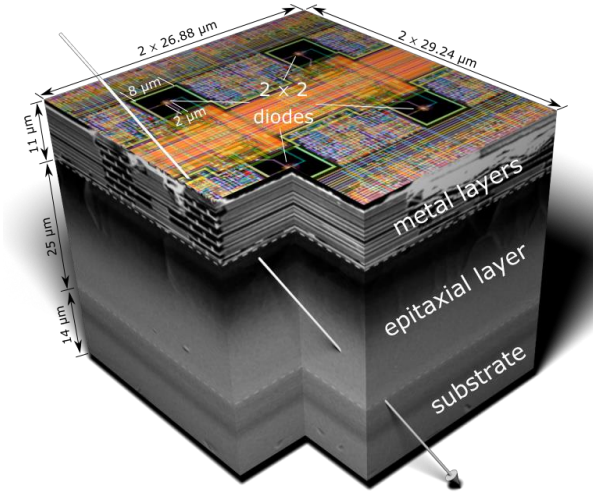
MFT layout

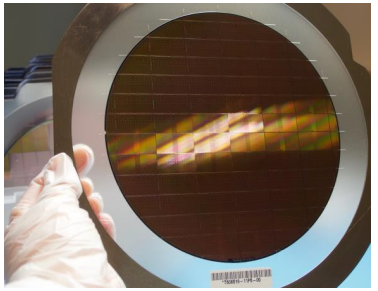

Heat exchanger
Sensors
Ladders
PCB
Support
Half-Disk
Half-Disks
Power Supply Unit
Mother Boards
MFT
Half-MFT cone

ALPIDE pixel sensor (ITS Upgrade and MFT projects)

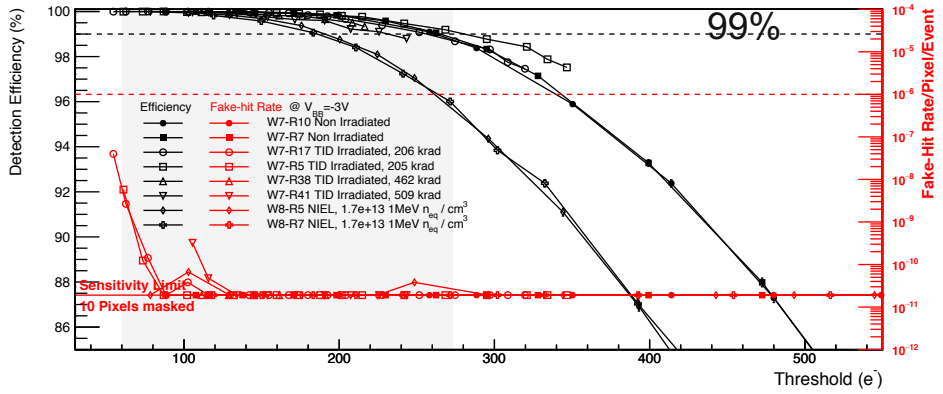
CMOS Monolithic Active Sensors (MAPS), TowerJazz 0.18 μm technology

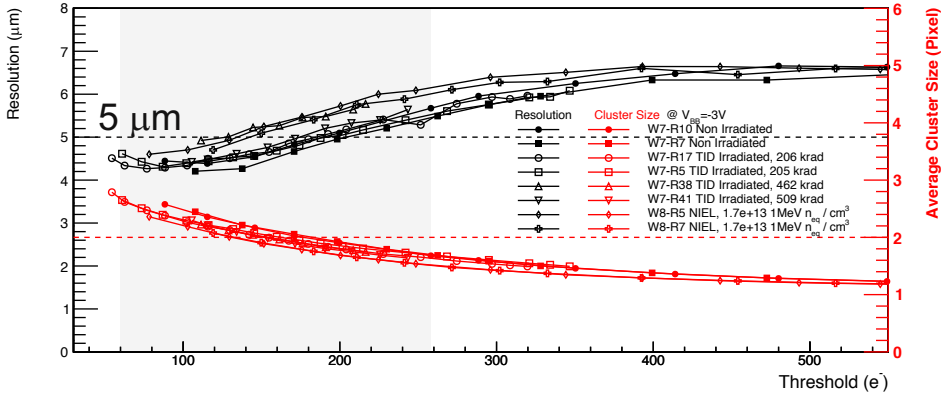
- Sensor Size 15 mm x 30 mm. Pixel pitch 29 μm x 27 μm.
- Event time resolution <4 μs
- Low power consumption ~40 mW/cm^2
- Expected radiation load in ALICE Run3 and Run4 <300 krad, <2.0x10^{12} 1MeV n_{eq}/cm^2
- Spatial Resolution 5-6 μm





ALPIDE
Production started
December 2016
End March 2018

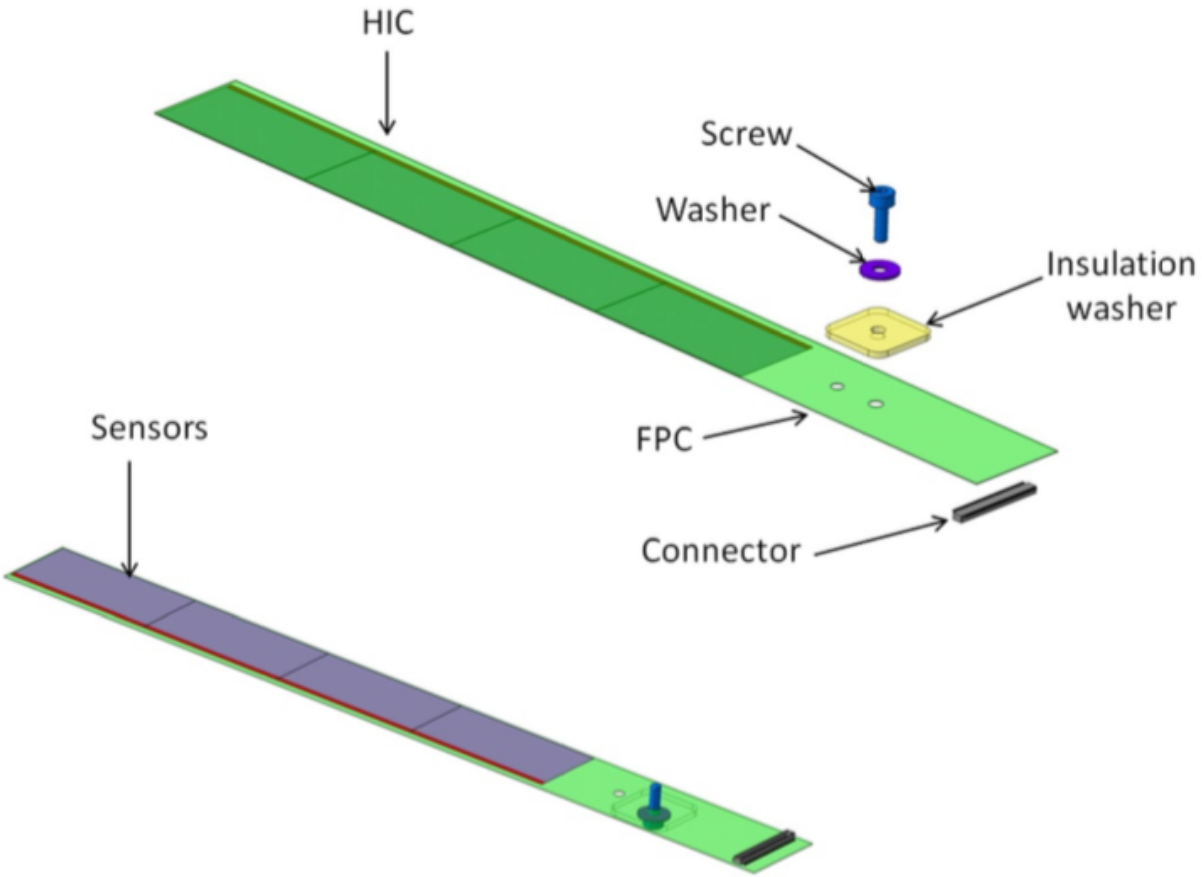




MFT ladder

The base element of the MFT detector

- ✓ Provide interconnection between sensor chips and the outside world
- ✓ Transport data to the detector periphery and slow control to the chips
- ✓ Provide proper power supply and reverse back bias to the chips
- ✓ Ensure adequate stiffness for handling and assembly
- ✓ Provide interconnection with the disk
- ✓ Protect and insulate sensor chips



Design requirements

- Material budget: ~2 x 0.15% X/X_0 (*heat exchanger ~0.3% X/X_0; disk 0.6% X/X_0*)
- Geometry:
  - ALPIDE chip: 15x30 mm^2, thickness 50 μm
  - Ladder width: 16,9 mm
  - Ladder length: 99.65 mm, 129.80 mm, 159.95 mm, 190.10 mm depending on the number of chips
- Positioning tolerances
  - Sensor position precision: 5 μm
  - Gap between adjacent chips: 150 μm
  - Gap between adjacent ladders: 200 μm
- Types and quantities: 4 types
  - 2-chip ladder: 32
  - 3-chip ladder: 136
  - 4-chip ladder: 96
  - 5-chip ladder: 16

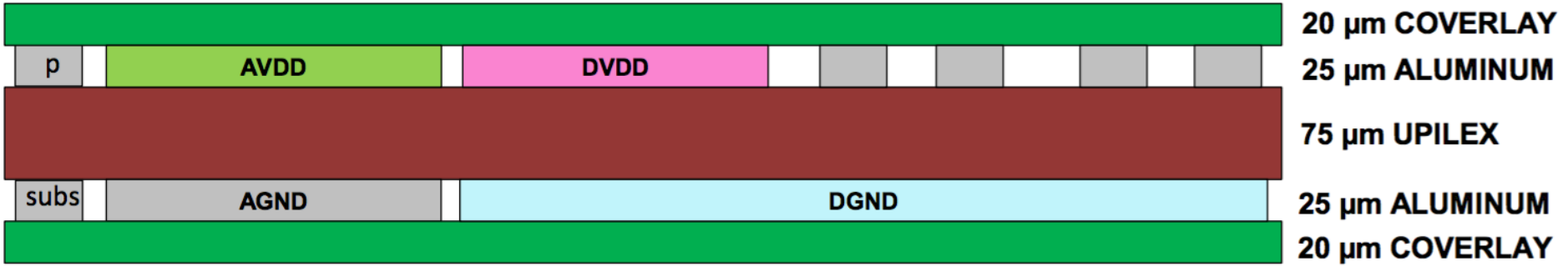
  } 1 full MFT

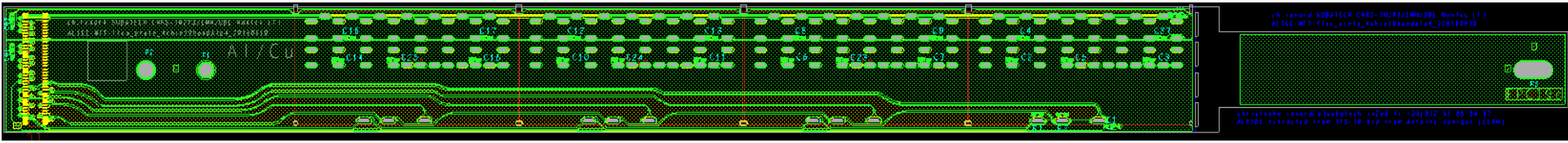
  - Total number to be produced (1 MFT + ½ MFT + 20% spares + 20% assembly yield): 604
- Power dissipation: <50 mW/cm^2
- Operation conditions: T < 30° C , non-uniformity < 5° C
- Radiation conditions: 300 krad; $2x10^{12}$ MeV n_{eq}/cm^2
- Handling and assembly: qualification and gluing on disk (heat exchanger)

Flex Printed Circuit

From ALPIDE chip to Hybrid Integrated Circuit (HIC)

- Chips are interconnected to a Aluminum Flexible Printed Circuit (FPC)



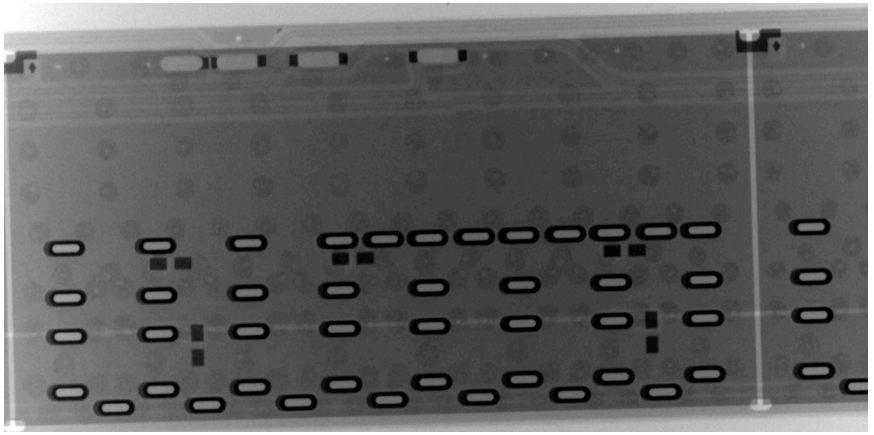


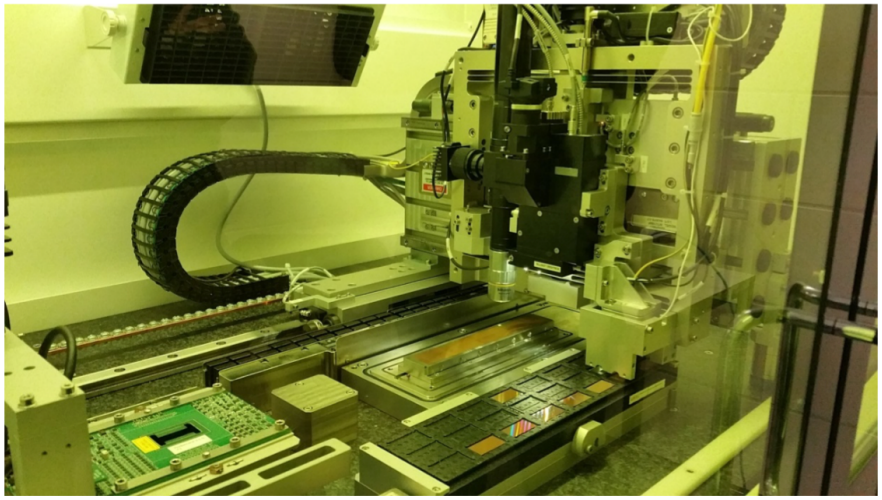
- It ensures data, slow control, reverse back bias and power supply from/to the chips
- Choice of Al and thickness: minimize material budget and voltage drop (impedance 100 Ω)
- Cu-FPC is the back-up solution

HIC gluing

Sensors gluing on FPC

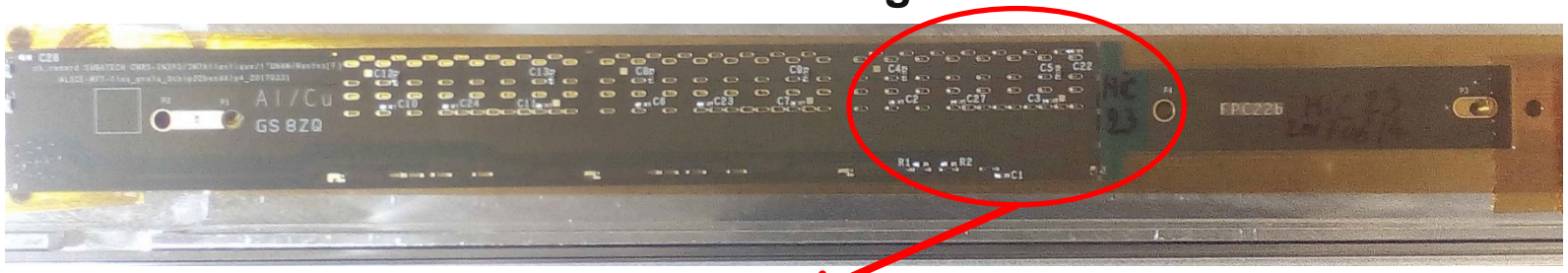
- ✓ R&D finished. Intensive work during the last year.
- ✓ Many tests done for plenty of key parameters: Cu/Al, glue thickness, wedge thickness, glue type, …
- ✓ ALICIA7 Module Assembly Machine has been installed at CERN-DSF January 18th 2017

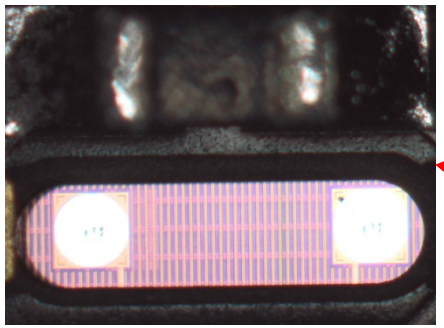


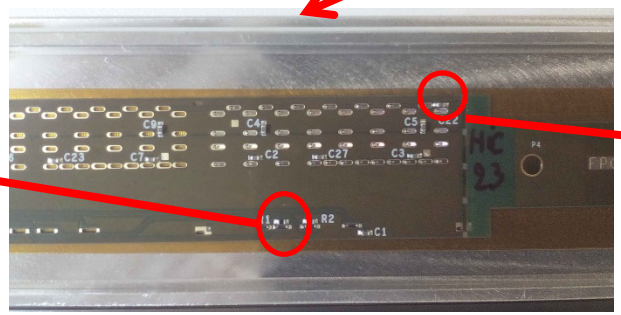


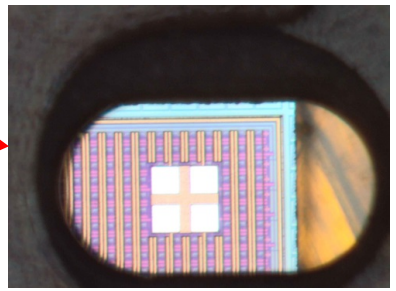
First wire-bonded MFT ladder

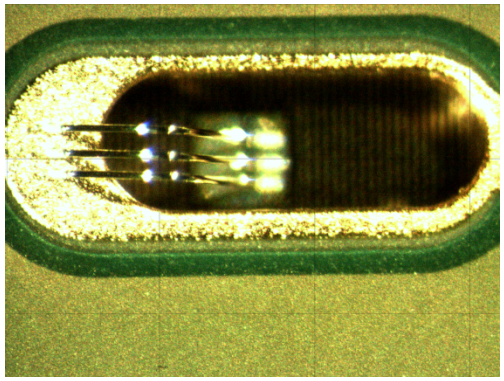
In collaboration with the CERN bonding lab









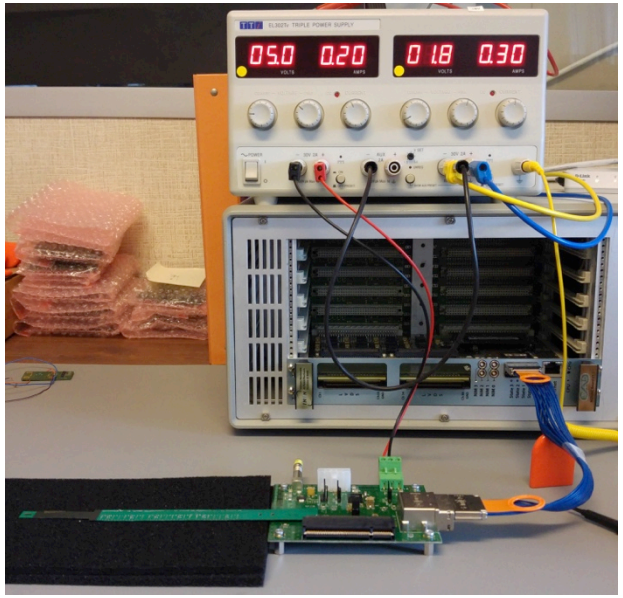


- ✓ Fruitful exchanges with the CERN bonding lab to optimize the process: cleaning, inspection, jig …
- ✓ First wire bonded MFT ladder. Major achievement
- ✓ Production of new prototypes ongoing

MFT ladder tests and qualifications

Three MFT ladder benches available

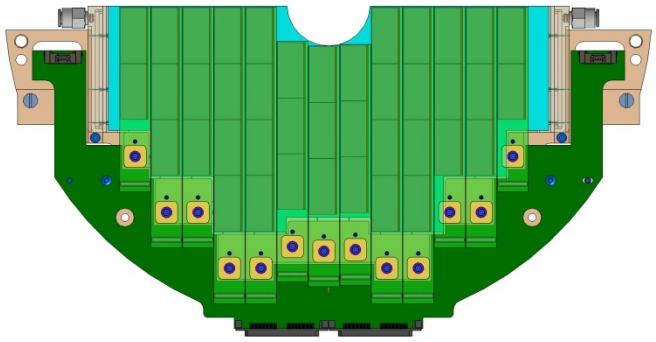
- ✓ HIC test bench (based on MOSAIC acquisition card) **fully operational**
- ✓ MFT ladder is read as ITS-IB stave
  - ✓ No master/slave protocol
- ✓ Study the response of several HIC assembly with (pALPIDE3 chips)
- ✓ Definition of the qualification process:
  - ✓ Parameters to be tested
  - ✓ Operational threshold and margins
  - ✓ Automatic filling of the QA database
- ✓ Test of first wire-bonded MFT ladder



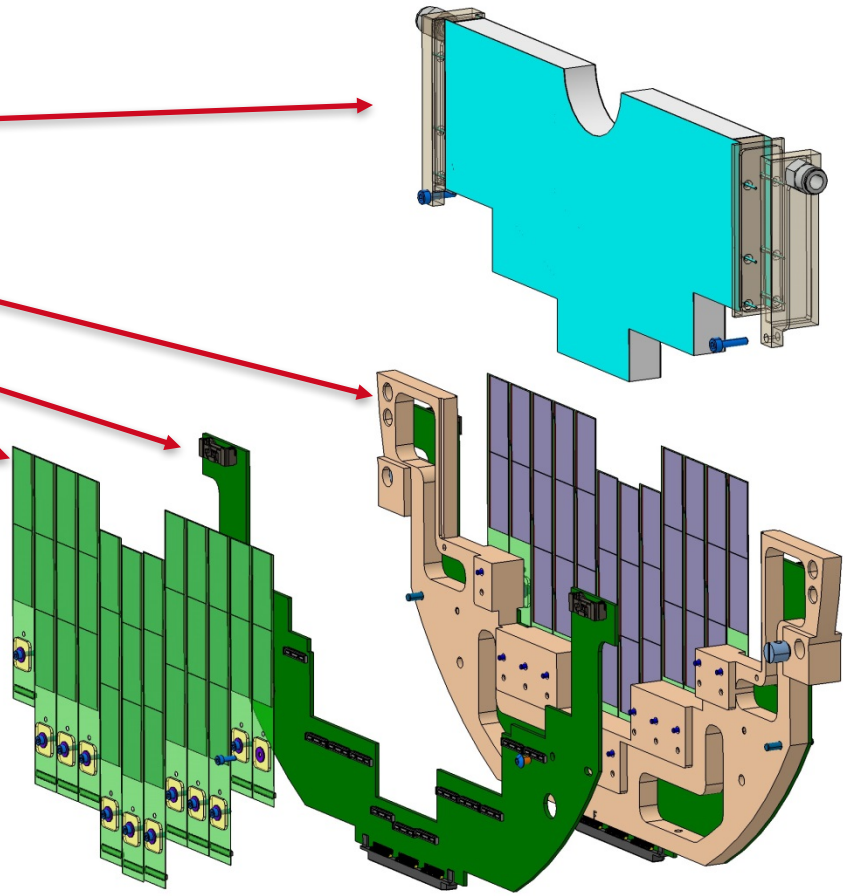
Disk structure

- Structure of disks:
  - Heat exchanger
  - Disk support
  - PCB
  - Ladders
  - Mechanical elements

Disk 00 and 01 are strictly identical



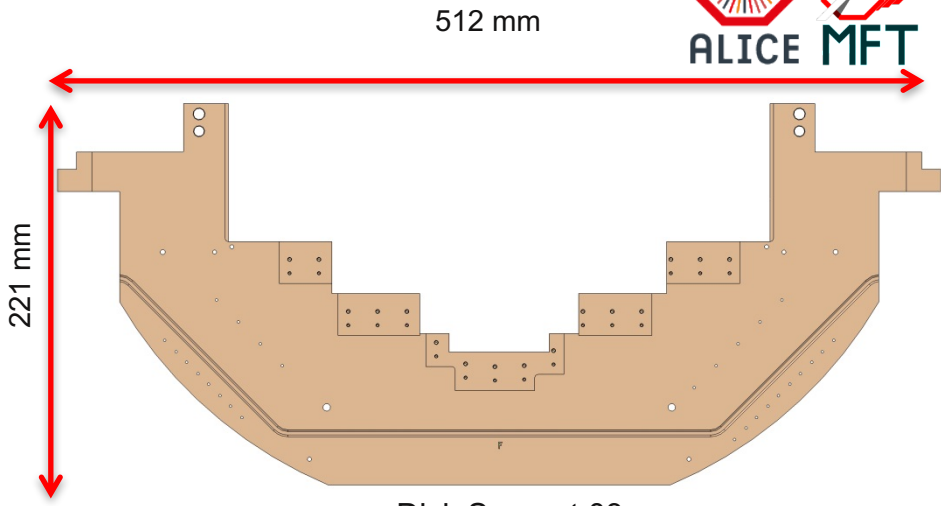
Disk 02



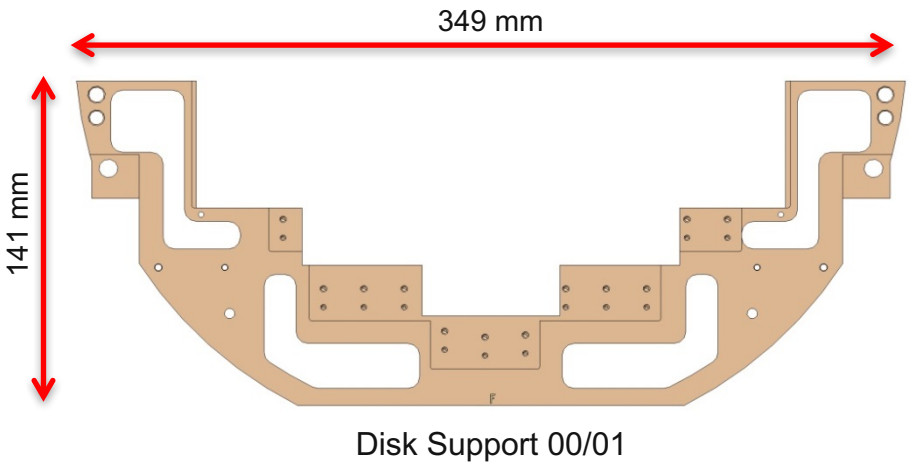
Exploded view of Disk 00/01

Disk support

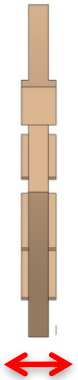
- Design goal :
  - Provide mechanical support to all elements
  - Provide housing and precise positioning of all components



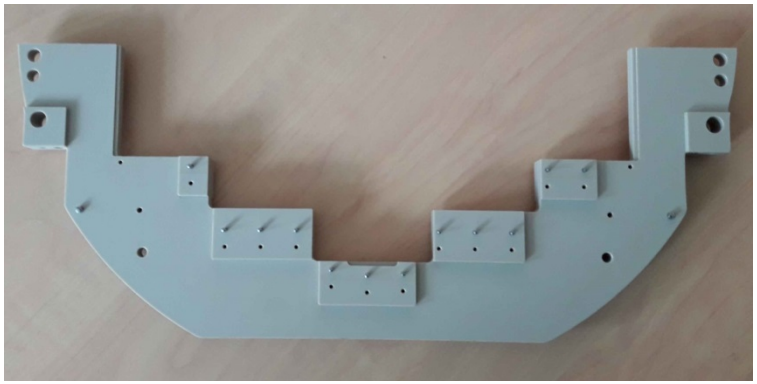
Disk Support 03



Disk Support 00/01



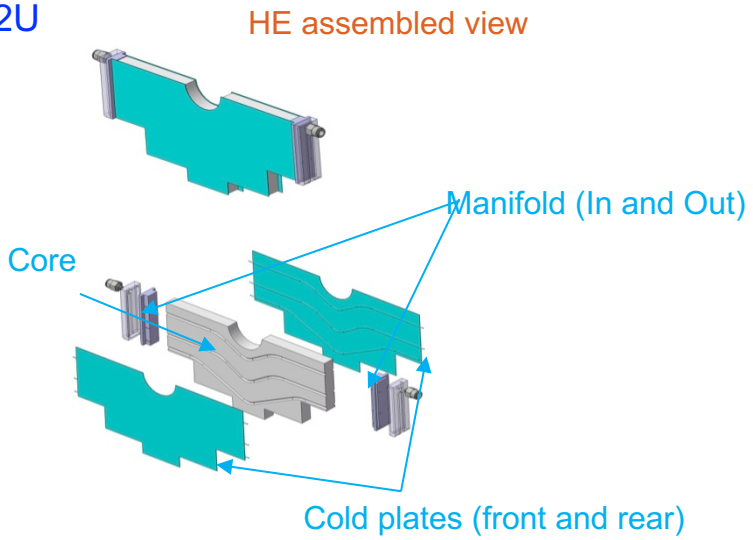
Thickness : 8mm / 14,1mm

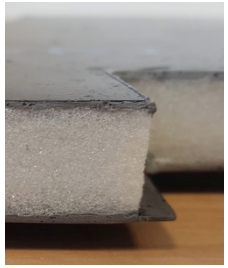


Last prototype of Disk Support 00/01

Heat Exchanger layout

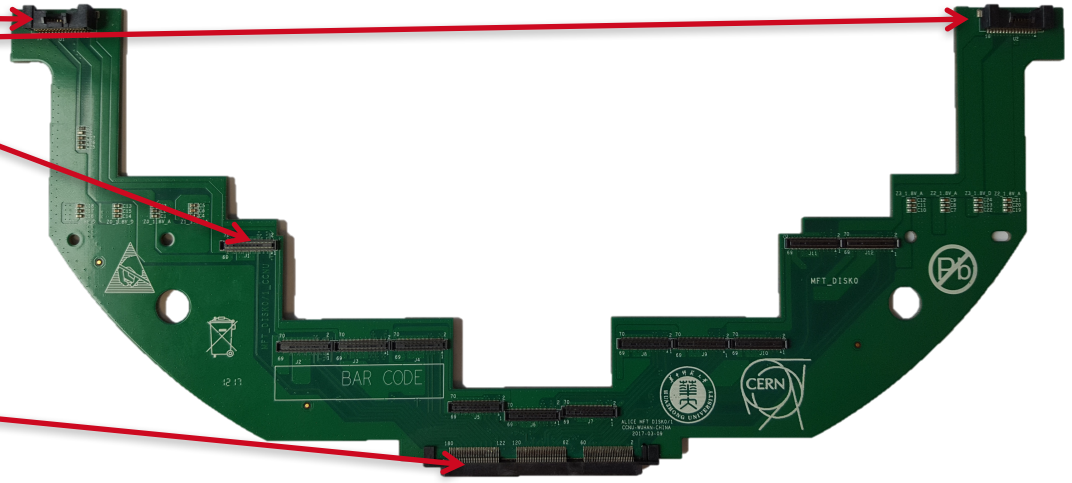
- Cold plates (cooling and rigidity)
  - Composite material (M55J for prototypes, K13D2U for production)
  - Embedded water pipes: polyimide, ⌀ 1 mm
  - Same design for front and rear
- Core (rigidity)
  - Rohacel 31 foam (light material)
  - Foam machined with gutters around water pipes
- Manifold (water repartition, mechanical fixation)
  - Plastic material (PEEK)
  - Two glued elements
  - Standard connectors (Legris)
- Cold plates, core and manifold are glued together to built a sandwich
- Material budget below 0.3% of X_0





Disk Printed Circuit Boards (PCB)

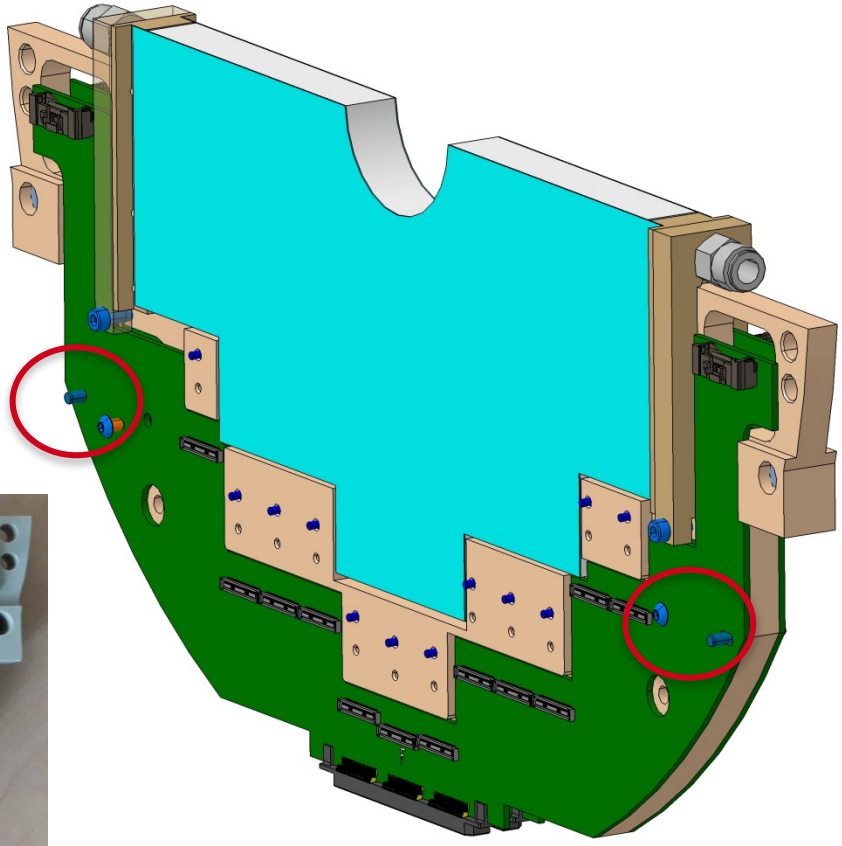
- ✓ Passive circuit,
- ✓ Ensure LV and BB
- ✓ Transmission of high speed signal (1.2 Gbit/s), clock and slow control
- ✓ Connected to the external world via de bottom connector
- ✓ Similar architecture for all the disk types
- ✓ To be used in the MFT signal integrity test



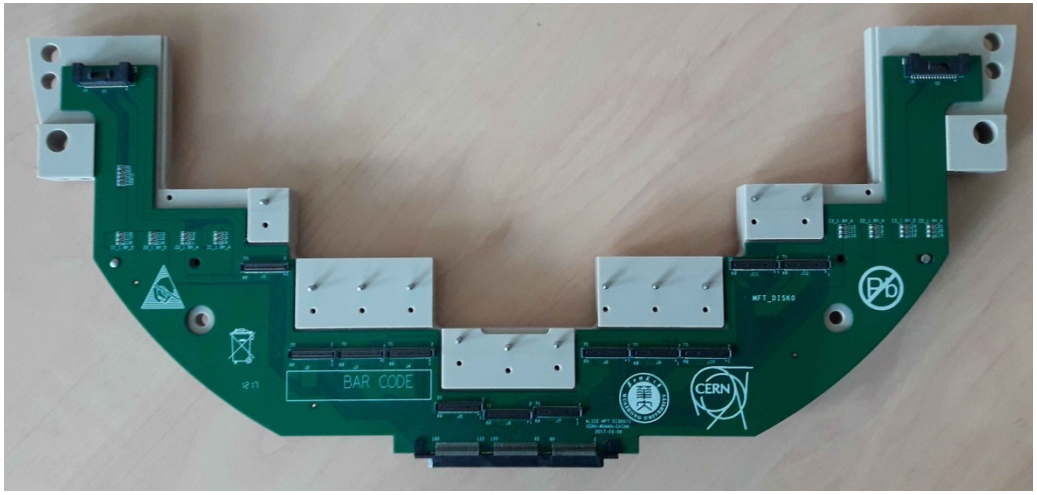
disk01 proto v2

Assembly PCB on Disk support

- PCB integration
  - 2 positioning pins
  - Locked by 2 screws for disks 00/01 and 02, 4 screws for disks 03 and 04
- Geometry control
  - Positioning accuracy of the PCB : ± 50 µm
  - Distance connector – HIC position pins : ± 50 µm
  - Distance between 2 connectors ± 25 µm



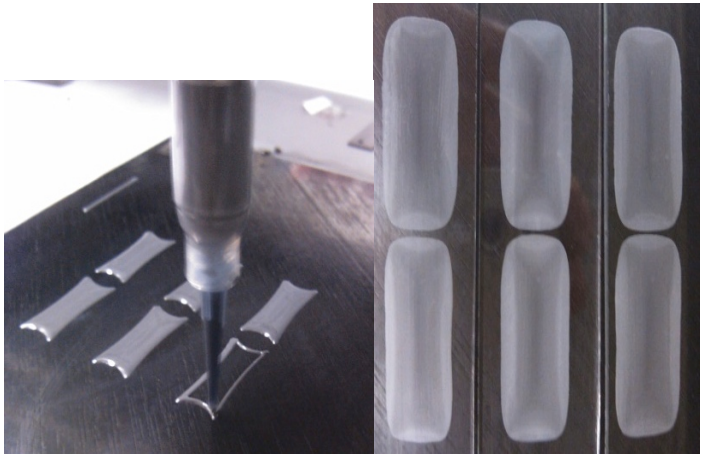
Disk 00/01

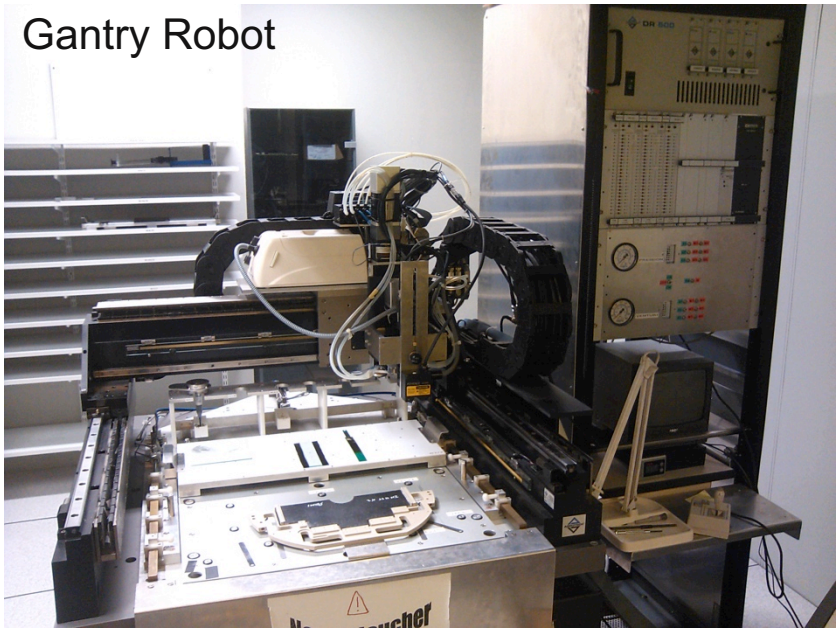


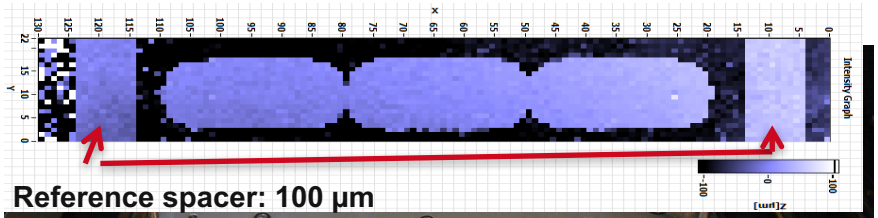
Disk 00/01 produced by CCNU-Wuhan

Disk assembly

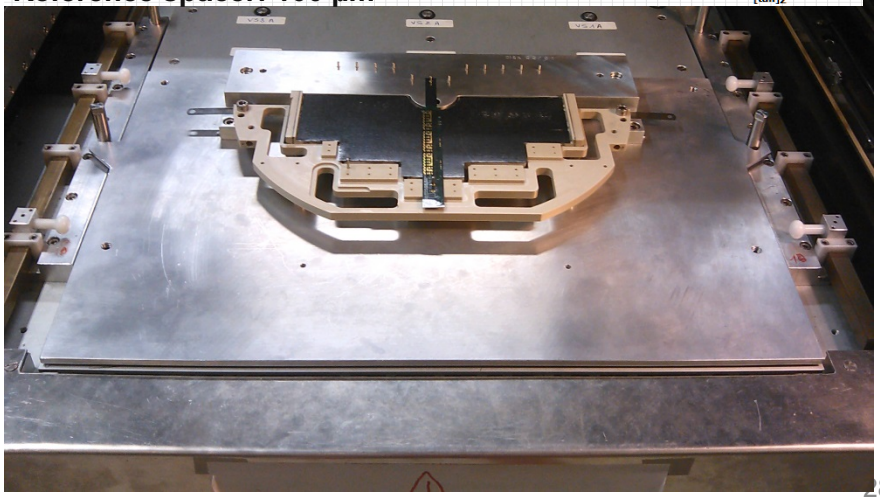
- Assembly tool installed on the Gantry @ IPNL
- Intensive R&D for the gluing process of ladder on disk
- Ladder are glued on heat-exchanger (SE 4445)
- Programming of robot displacement done





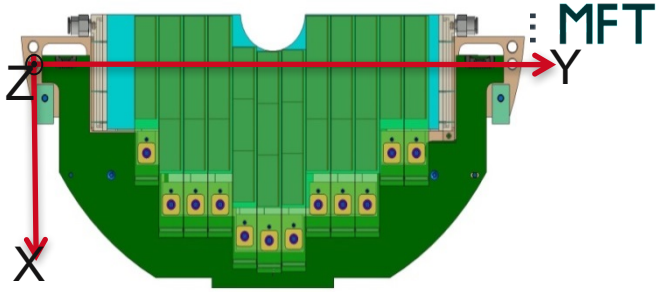


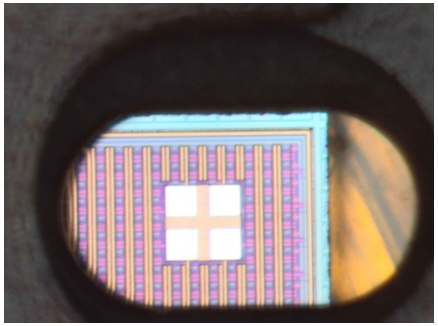
Reference spacer: 100 µm



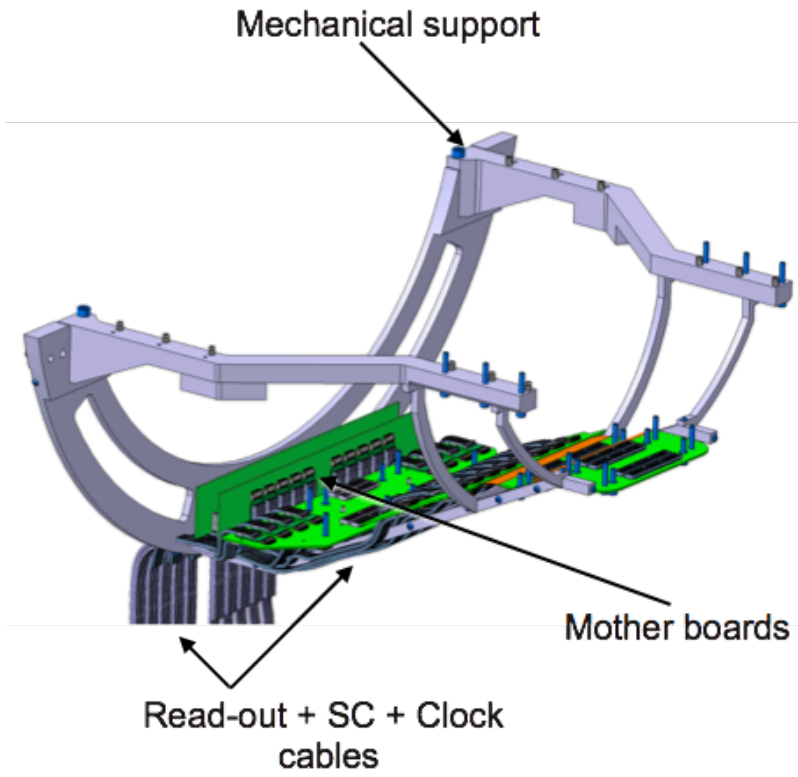
Sensor Survey on Disk

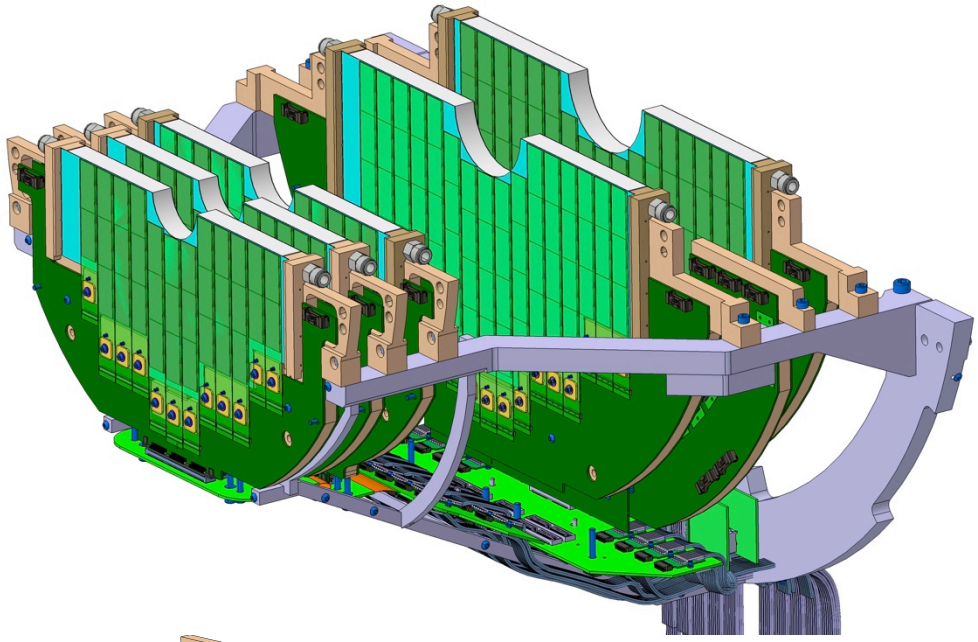
- Disk is installed in its assembly jig
- Assembly jig is aligned wrt the CMM coordinates
- Determination of the coordinate axis origin
- Disk alignment is checked wrt CMM coordinates
- Measurement of the sensor targets through the FPC openings
- Automatic storage of the measurement values in a text file (then transfer to the construction database)

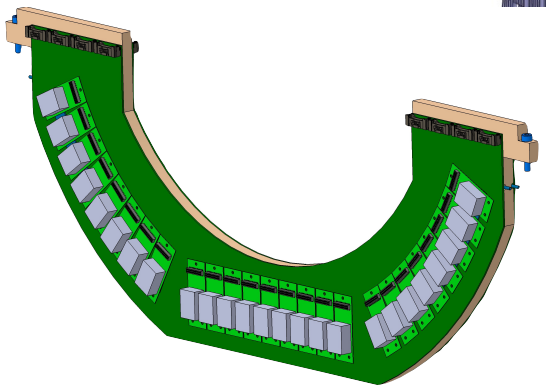




MFT Cone Elements







Power Supply Unit (PSU)

Cone design requirements: electronics

- Electronics functions
  - Transfer data signals from the chips to the outside world
  - Provide clock and slow control signals to the chips
  - Provide power (analog, digital, back bias) and ground to the chips
  - Transfer supplementary data from other sensors/devices (voltages, currents, temperatures)
- Electronics constraints
  - Preserve data signals continuity up to 1.2 Gb/s
  - Very limited space on disks to house DC-DC converters
  - Data from other sensors/devices (voltages, currents, temperatures) should be integrated to the main data flow

- Disks are connected to Mother Boards (as electronics cards in a crate)
- Data and slow control signals are transported via twinax cables
- Back bias, analog and digital power generation and latch-up detection are centralized in a Power Supply Unit
- Voltage, currents and temperatures are monitored by GBT-SCA, installed in a PSU-mezzanine

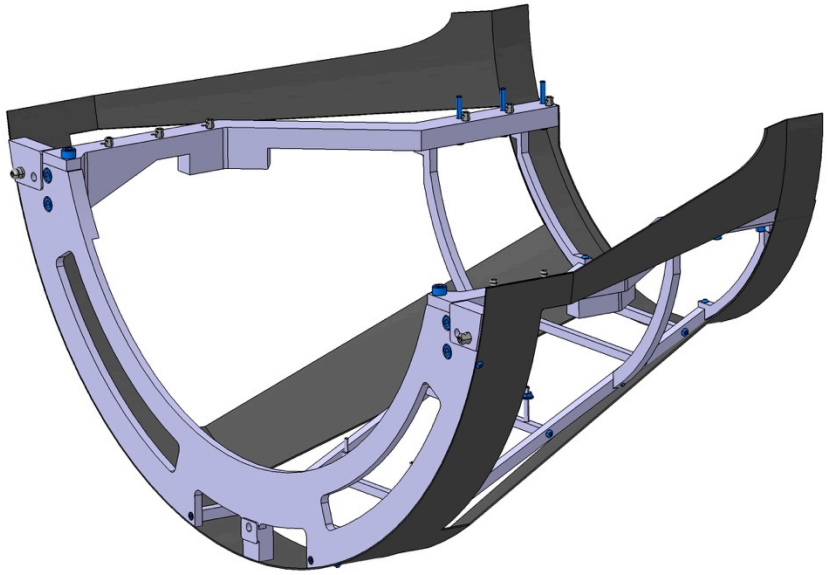
Cone design requirements: mechanics

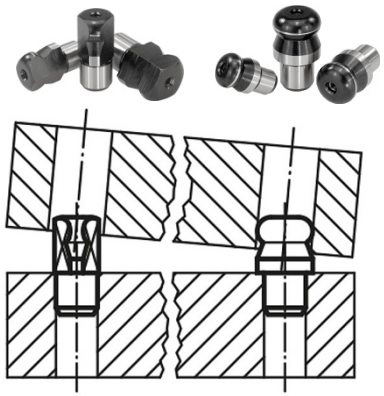
- Mechanical functions:
  - Provide housing, stability and positioning to the disks (and PSU)
  - Provide proper fixation and positioning to the barrel elements (patch panel and detector barrel)
  - Provide water cooling to the disks (and PSU)
  - Provide air ventilation inside the cone volume
- Mechanical constraints:
  - Disk position accuracy (with respect to the cone): < 100 μm
  - Maximum mechanical deformation of the cone structure: 100 μm
  - Vibrational response compatible with targeted position accuracy

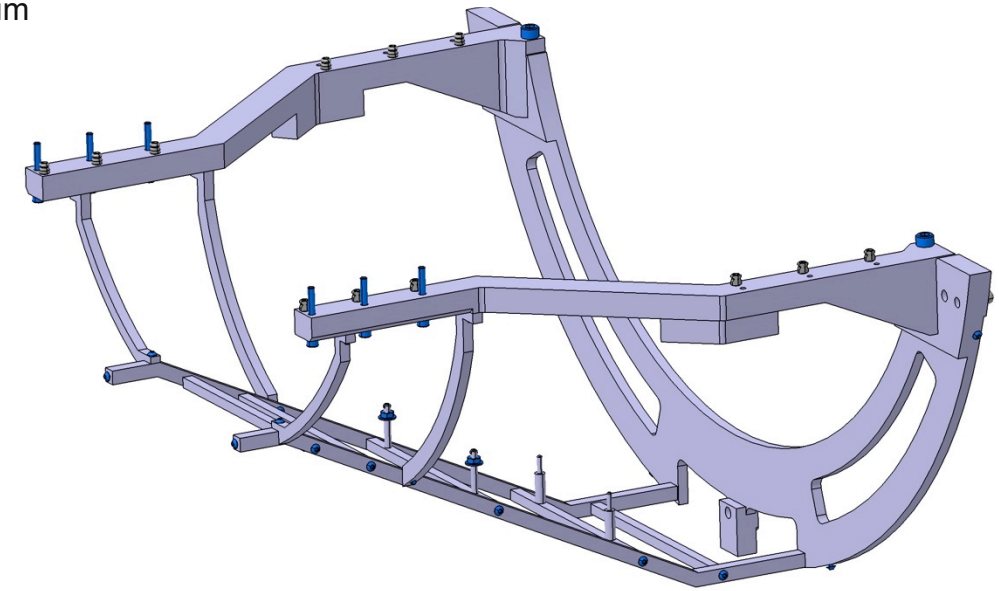
- Main mechanical element is a light skeleton (Aluminum): it provides rigidity and stability
- The skeleton houses all the active elements (Mother Boards and PSU) and services (power and data cables, water pipes, air ducts)
- Designed for easy assembly with possibility of fast interventions from the top

Cone skeleton layout

- Cone skeleton
  - Material: Aluminum Alloy 5083
    - High dimensional stability during and after machining
    - Possibility to have half-finished product with good precisions
      - Thickness tolerance : ± 100 µm
      - Transverse and longitudinal flatness <350 µm/m
  - Weight: ≈ 2,1 Kg
  - Positioning pins
    - Norelem 03108
    - Material: Stainless Steel
    - Very precise adjustment: ± 12 µm



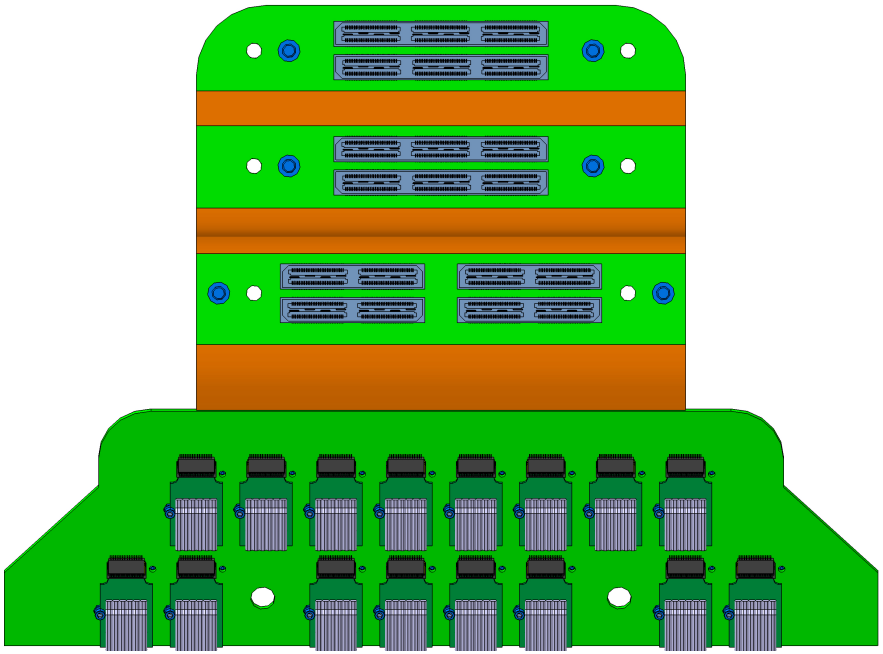


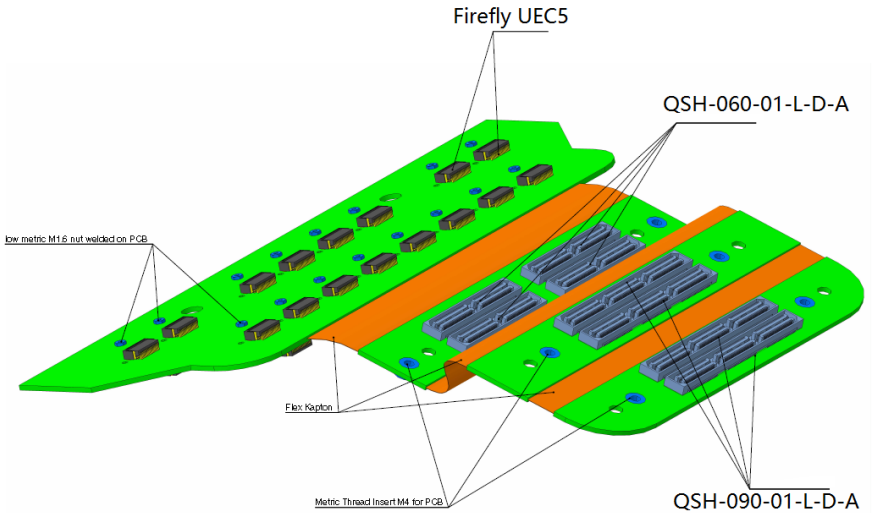


Mother Boards 012

MB012: Design almost ready. First prototype by the end of the summer

MB3-PSU and MB4 : Design started

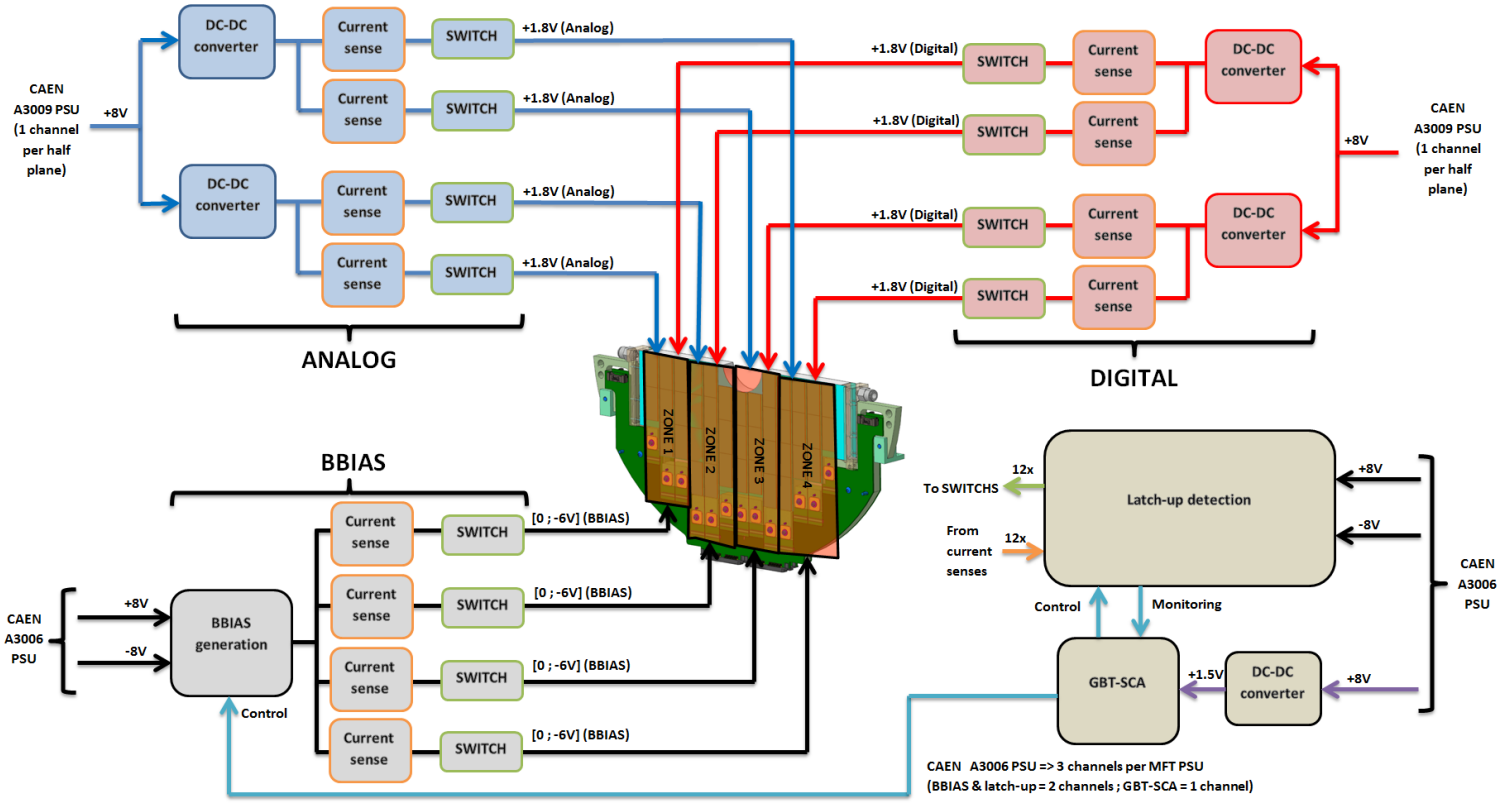




Layout MB012

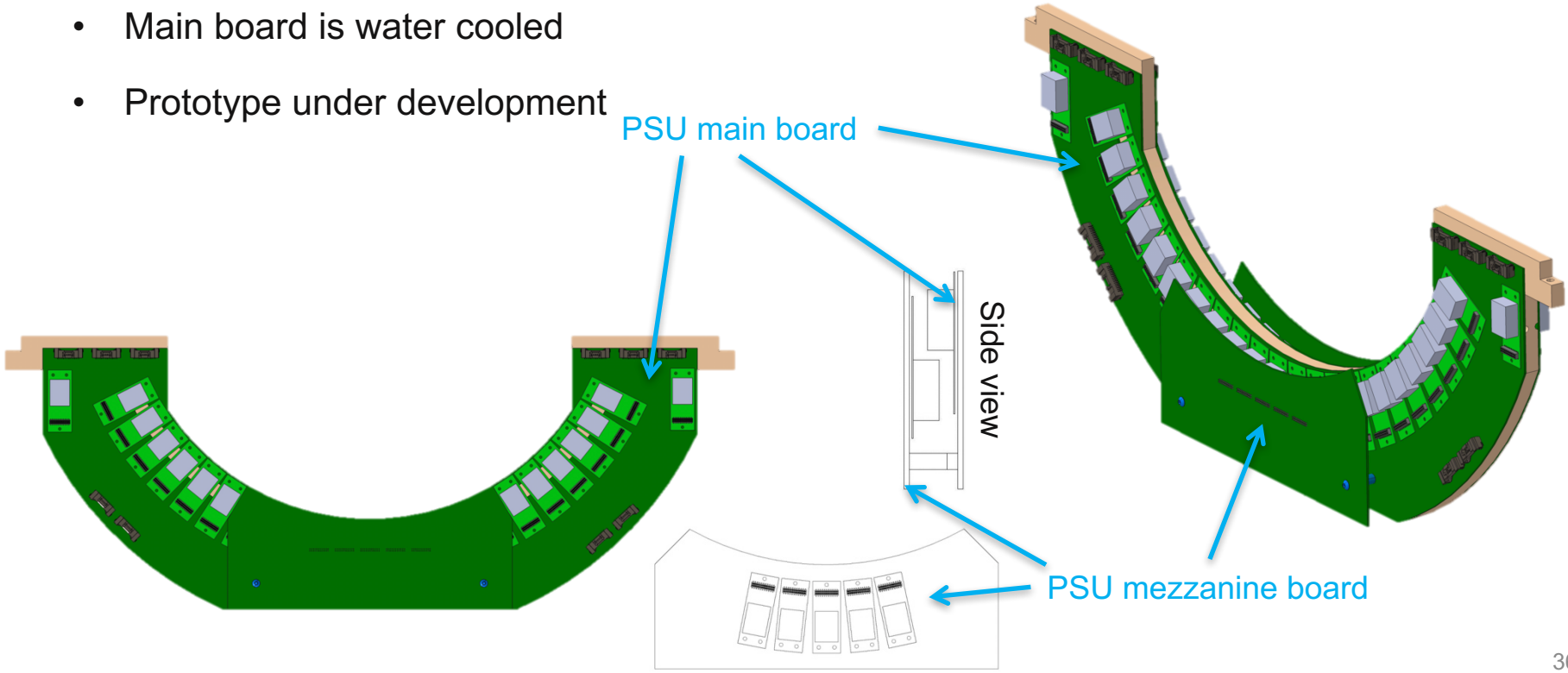
PSU: Electronics design and optimization

PSU to DISK 0-1-2 bloc diagram:



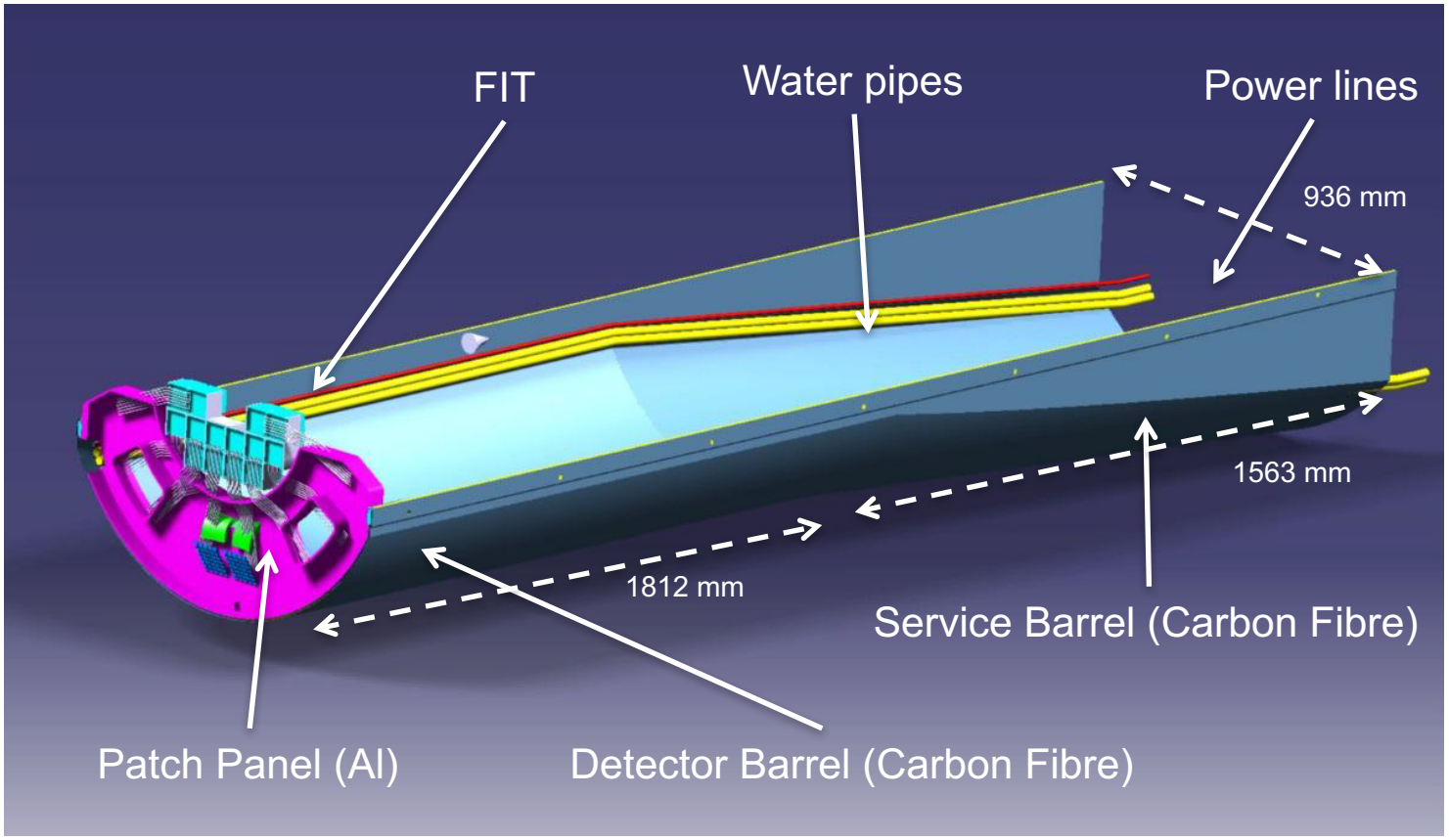
PSU Layout

- Main board with 24 DC-DC converters (to supply the power for all the disks) and electronic components (for latch-up, BBIAS generation…)
- Mezzanine board with 5 DC-DC converters and 5 GBT-SCA (one DC-DC converter per GBT-SCA)
- Main board is water cooled
- Prototype under development



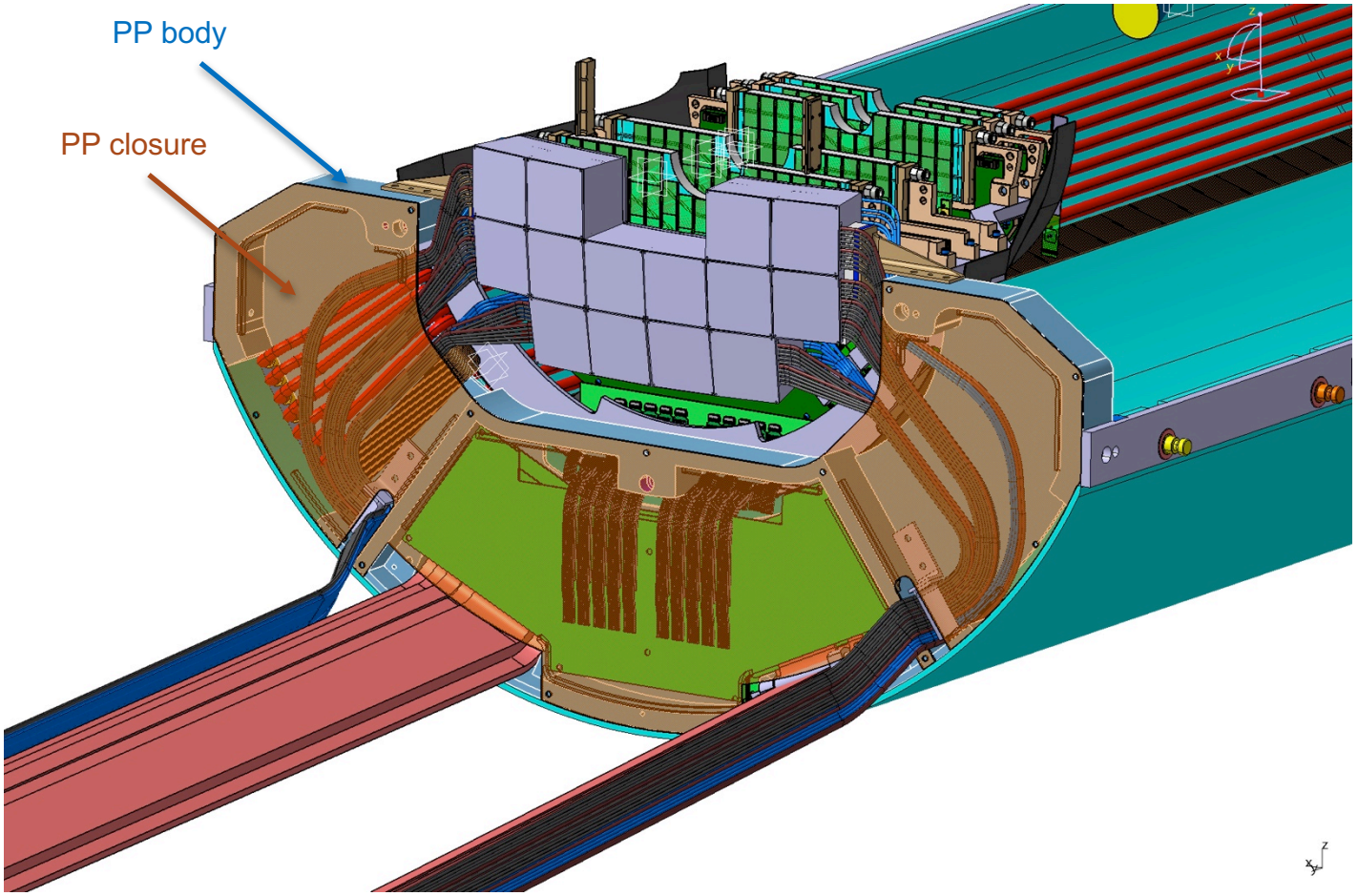
MFT Half-Barrel

Global layout of half barrel

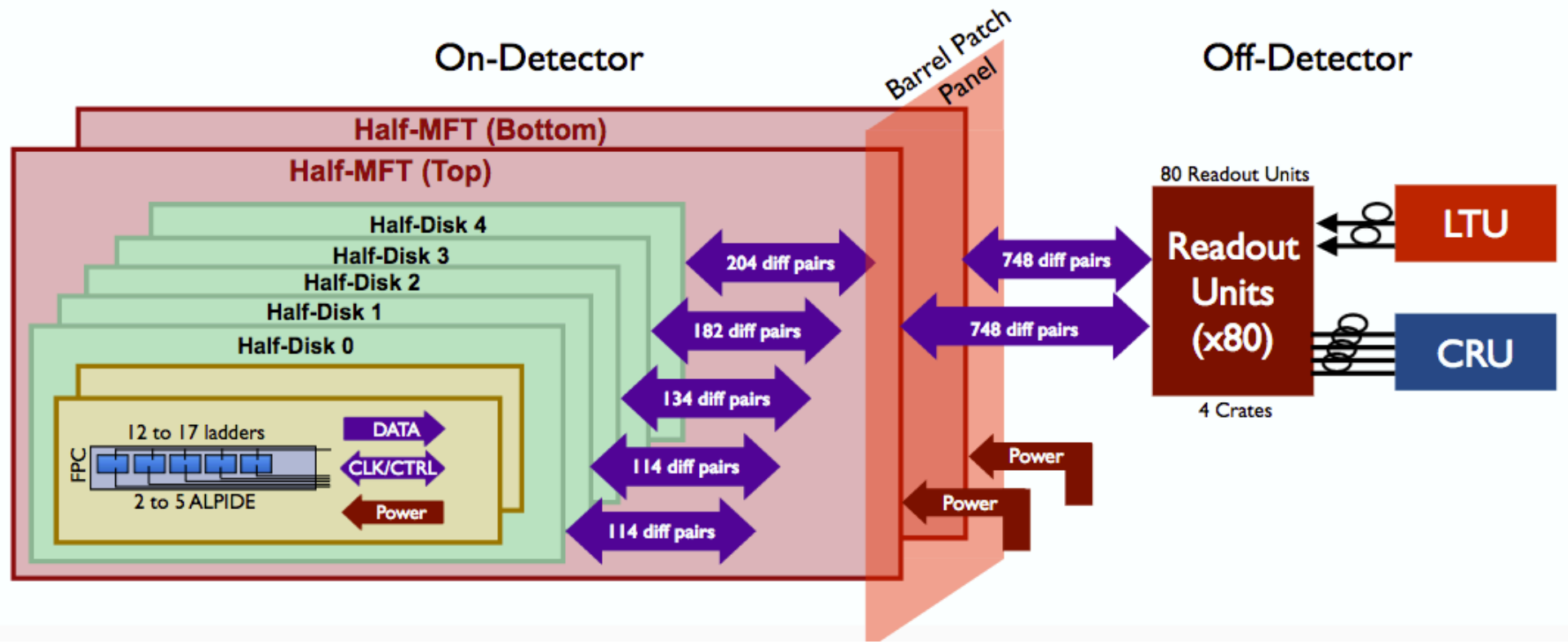


- Barrel function: MFT insertion and positioning
- Full scale mock-up built for integration studies

Patch Panel layout – Full rear view



MFT Readout Architecture

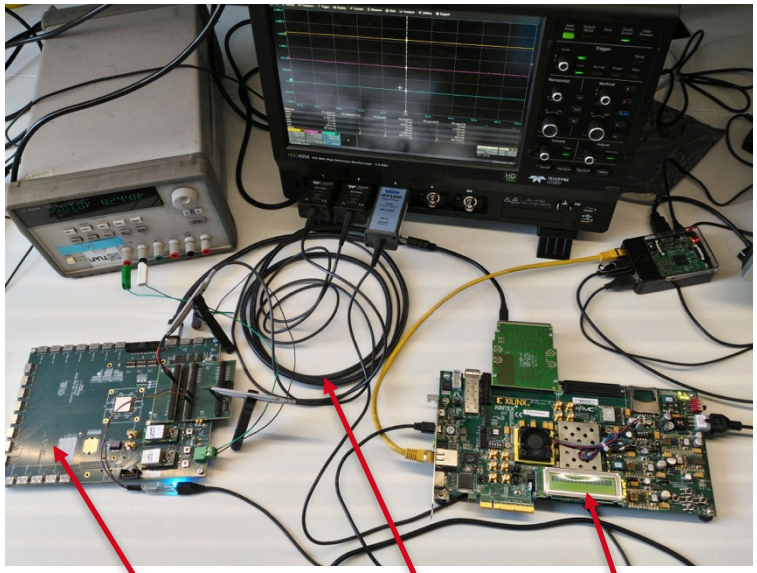


- Between 132-272 high speed data signals (1.2 Gb/s) per disk
- Between 96-136 clock and slow control signals per disk
- Total of 1496 twinax cables for read-out
- 80 concentrator boards (RU) ~ 6 m away, where TID about < 1 krad

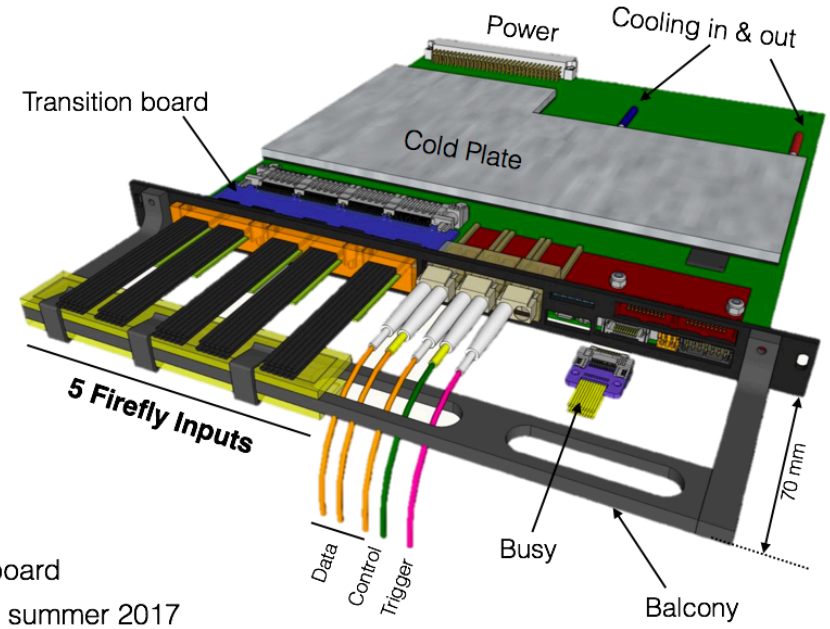
RU and GBT-SCA communication

Testbench and ongoing test

- Specific to MFT: PSU (GBT-SCA) ➔ RU
- Currently communicating with GBT-SCA access to GPIO and DAC values



Readout Unit v1



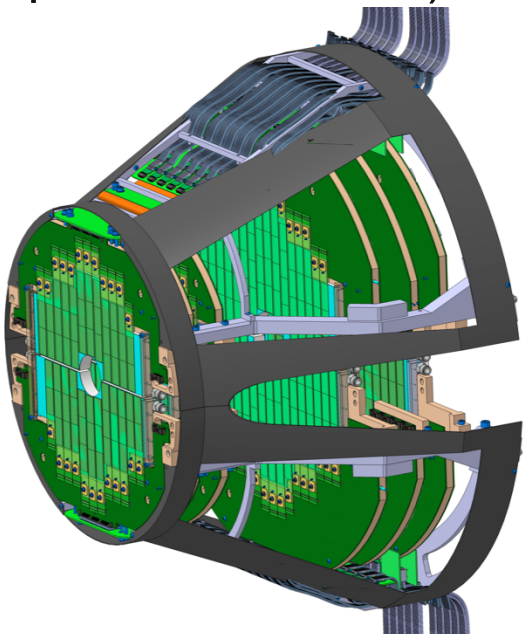
6U size board

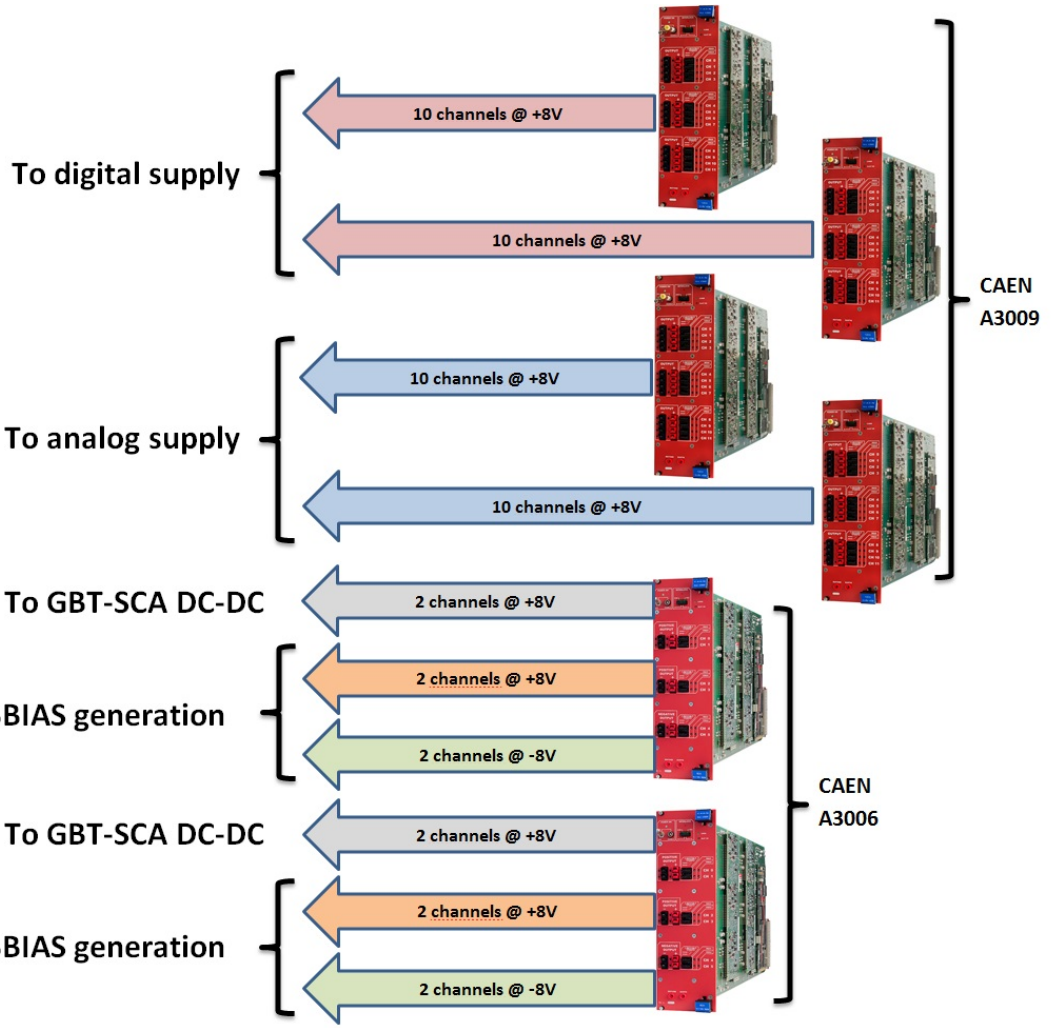
Available summer 2017

Total LV module/line needs

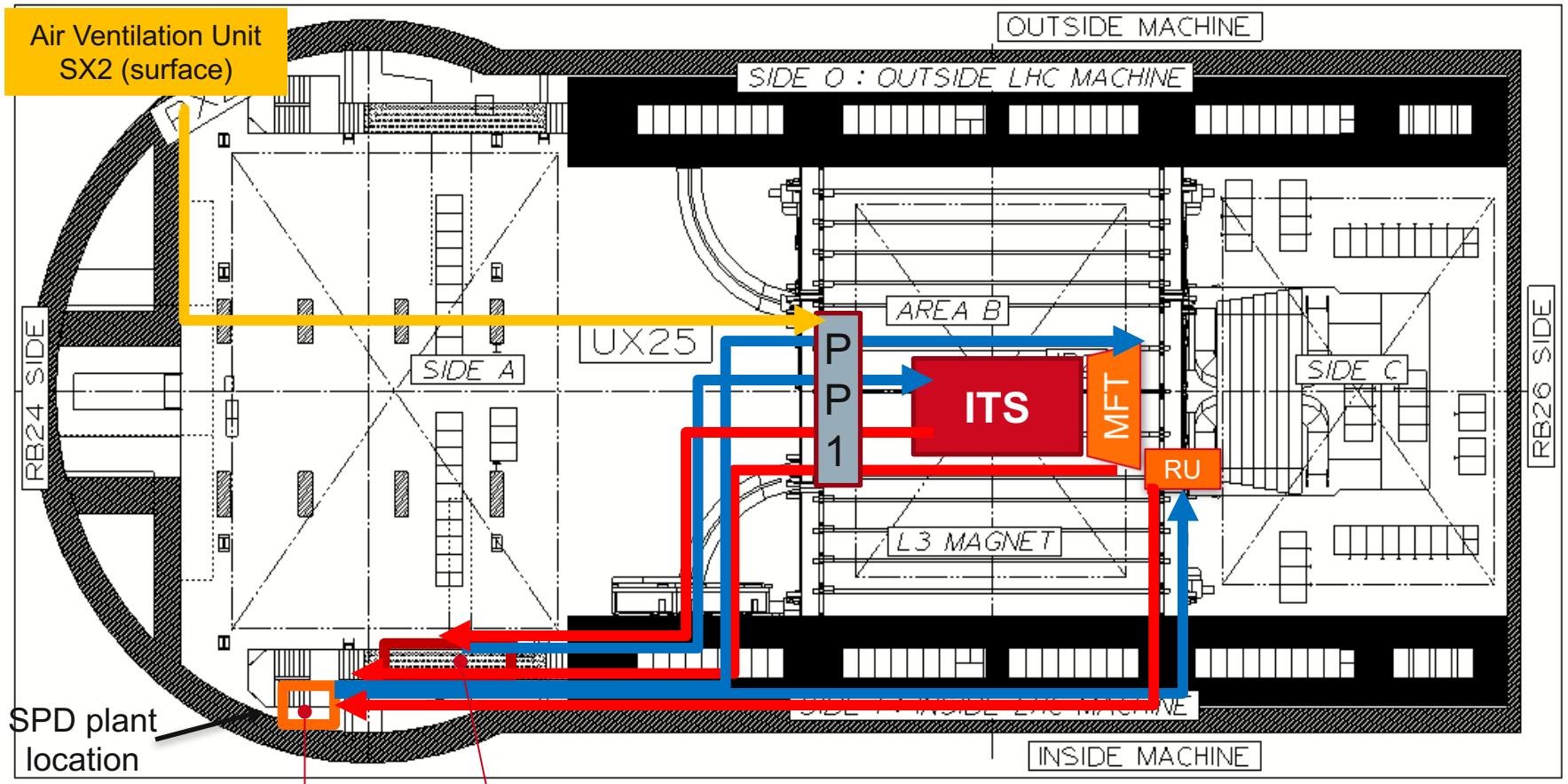
- 20 digital +8V (5 per MFT PSU)
- 20 analog +8V (5 per MFT PSU)
- 4 BBIAS +8V (1 per MFT PSU)
- 4 BBIAS -8V (1 per MFT PSU)
- 4 GBT-SCA +8V (1 per MFT PSU)

TOTAL = 104 LV lines
(52 power + 52 GND)



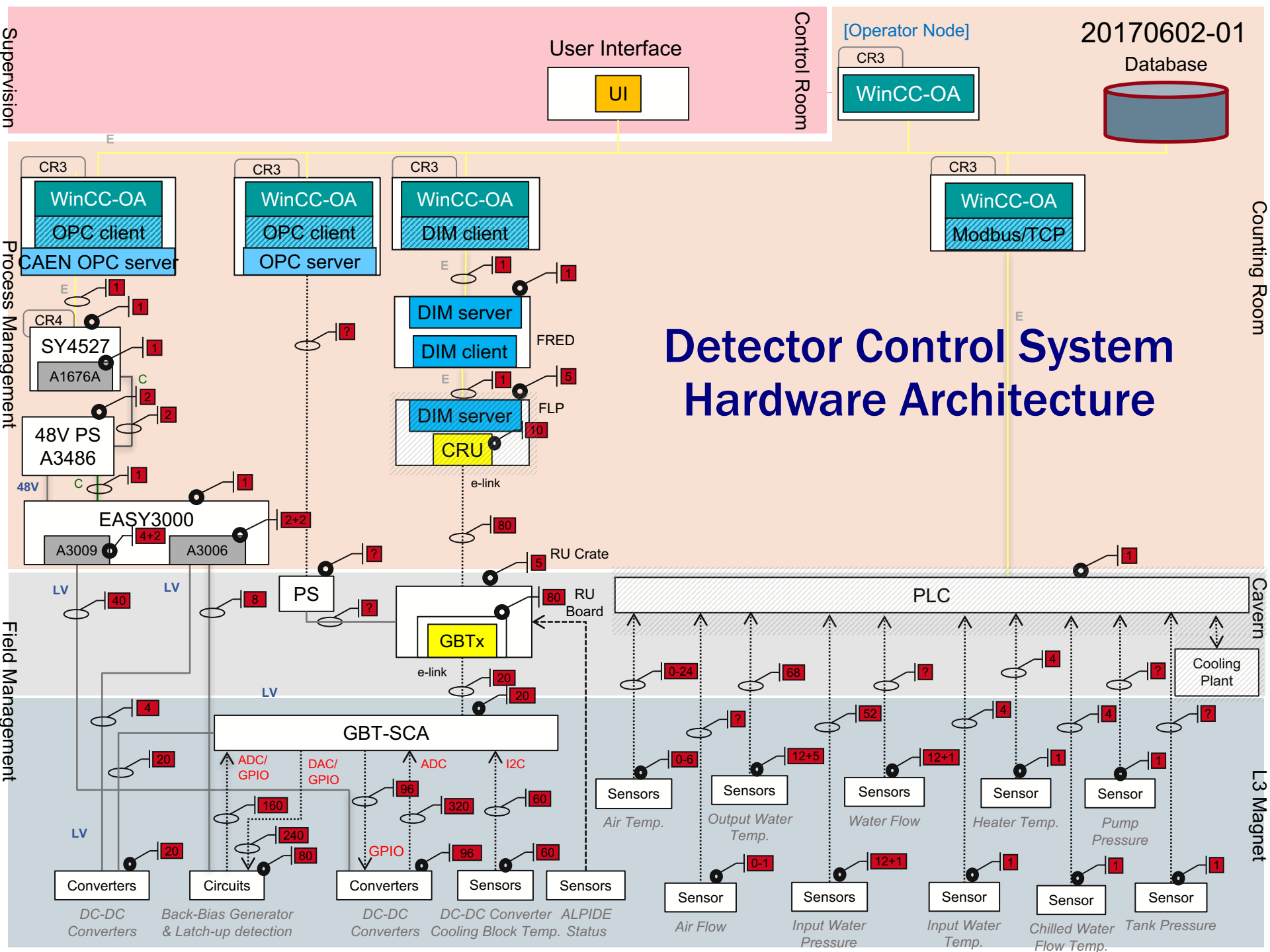


MFT Cooling system layout



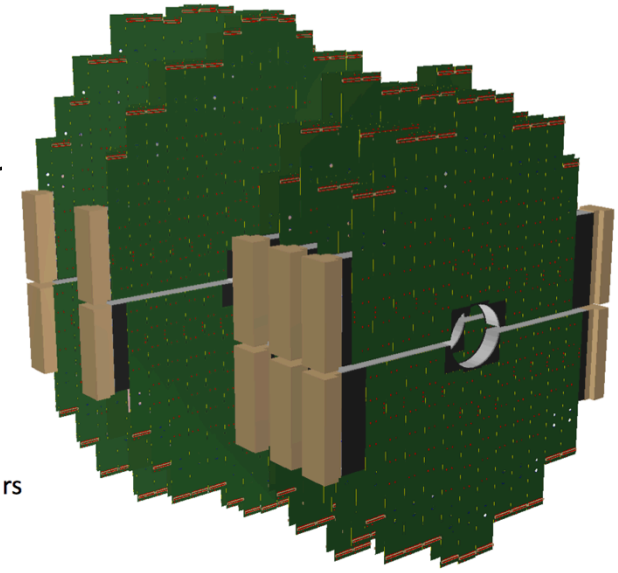
Cooling system requirement

	Sensors	RU Crates
Power dissipation (W)	< 500	< 2500
Pressure drop @ nominal flow (mbar)	< 300 mbar	< 300 mbar
Nominal flow (l/h)	~ 300	880
Temperature (°C)	17-20	17-23
Access	Side A	Side C
Maintenance	Long stops only	Possible during short stops


Supervision
Control Room
Process Management
Field Management
Counting Room
Cavern
L3 Magnet
User Interface
UI
[Operator Node]
CR3
WinCC-OA
20170602-01
Database
CR3
WinCC-OA
OPC client
CAEN OPC server
CR4
SY4527
A1676A
48V PS
A3486
48V
EASY3000
A3009
A3006
CR3
WinCC-OA
OPC client
OPC server
PS
CR3
WinCC-OA
DIM client
DIM server
DIM client
FRED
DIM server
CRU
FLP
e-link
RU Crate
RU Board
GBTx
e-link
GBT-SCA
ADC/ GPIO
DAC/ GPIO
ADC
I2C
GPIO
Converters
DC-DC Converters
Circuits
Back-Bias Generator & Latch-up detection
Converters
DC-DC Converters
Sensors
DC-DC Converter Cooling Block Temp.
Sensors
ALPIDE Status
CR3
WinCC-OA
Modbus/TCP
PLC
Cooling Plant
Sensors
Air Temp.
Sensors
Output Water Temp.
Sensors
Water Flow
Sensor
Heater Temp.
Sensor
Pump Pressure
Sensor
Air Flow
Sensors
Input Water Pressure
Sensor
Input Water Temp.
Sensor
Chilled Water Flow Temp.
Sensor
Tank Pressure
Detector Control System
Hardware Architecture

WP9: Physics

- ✓ Geometry description in AliROOT constantly updated and detailed
- ✓ Migration to O2/ALPHA: workflow is defined ar tools are under development
- ✓ MFT O2 Goals end 2017:
  - ✓ MFT Geometry
  - ✓ Implementation of Active Volumes
  - ✓ First MFT MC simulation in O2/ALPHA
- ✓ Preparation for commissioning should start this year : alignment, calibration, clustering, standalone tracking
- ✓ Implementation of the MUON-MFT matching algorithm in O2
- ✓ More manpower is needed in this WP



rs

Conclusion

- ✓ R&D phase is in its final step and MFT is already in its construction phase (Sensors)
- ✓ All Engineering Design Reviews passed
- ✓ Production Readiness Reviews scheduled to start this fall 2017
- ✓ 2017/2018 will be the “production years”: enormous effort is needed by all teams!

Backups

Physics Performance of the Upgraded ALICE

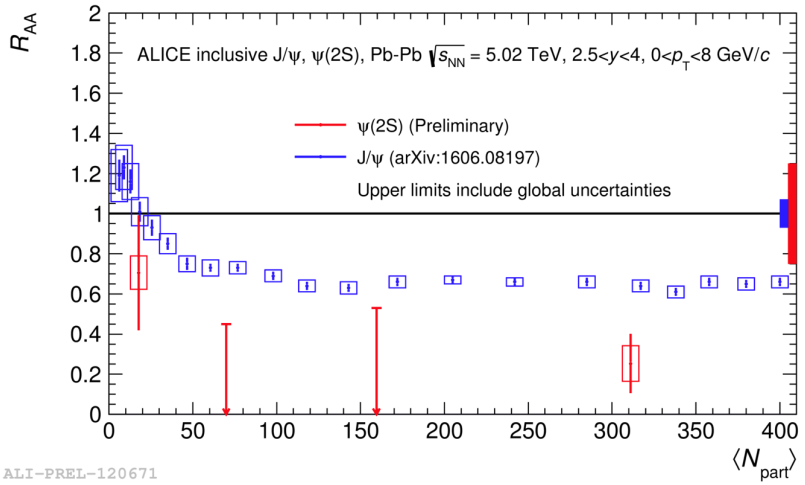
ψ(2S) 2.5<η<4.0

Completing the charmonium potentials for the study QGP at the LHC

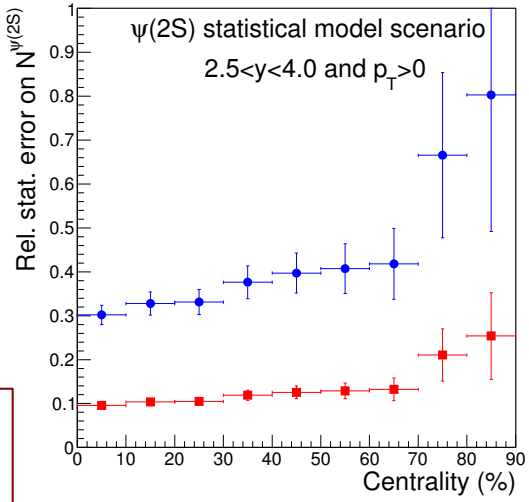
With ITS and MFT: Prompt Decay separation and better S/B

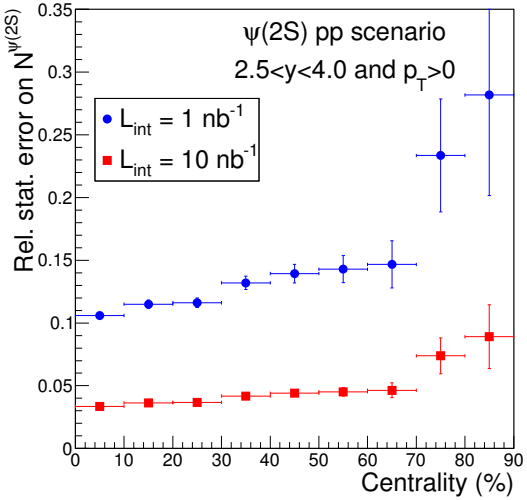
Discrimination between models becomes possible. Recombination time : at hadronisaton or in the QGP?

p_T, y and centrality dependence



Present measurement

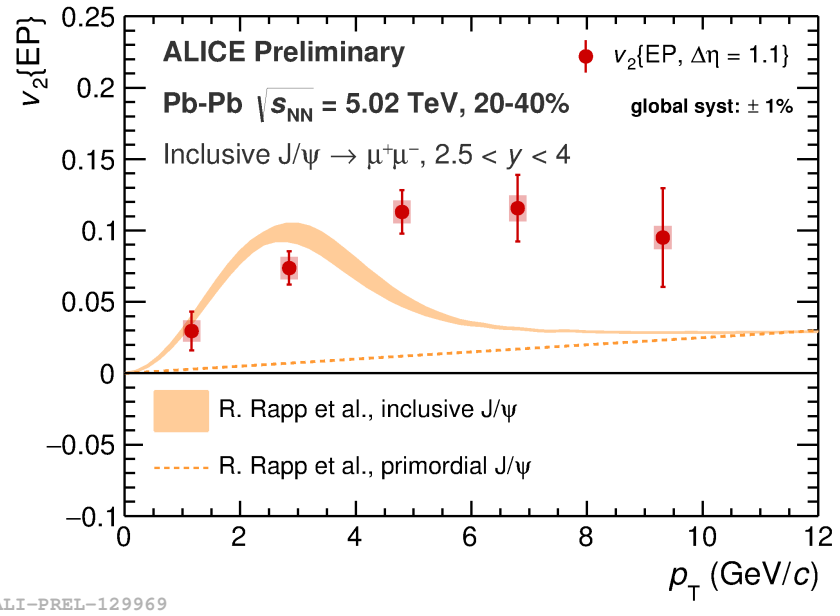




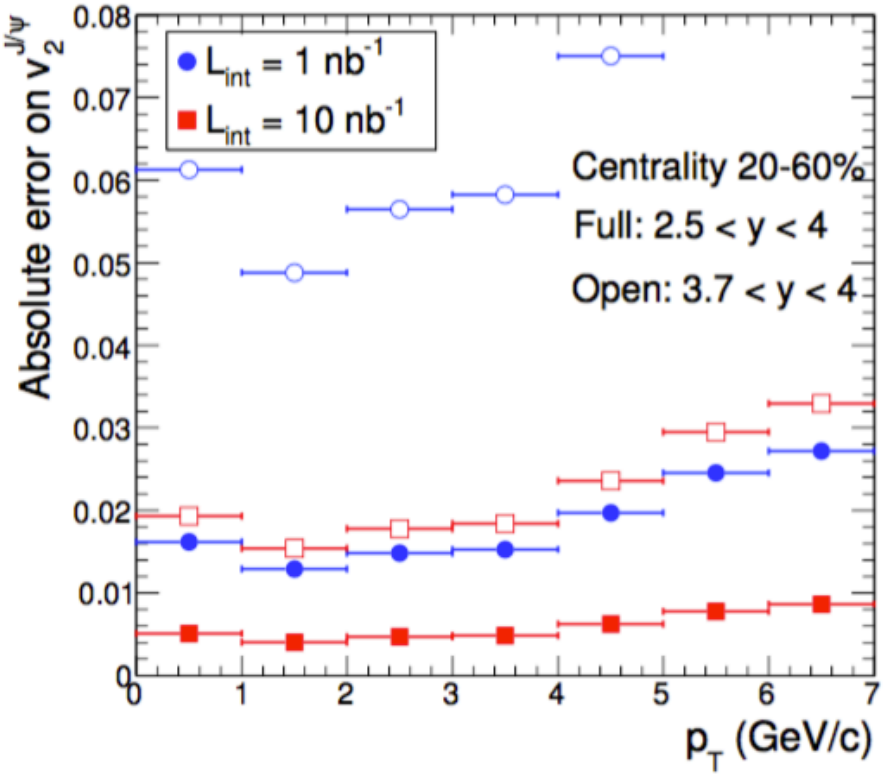
Future precision

Physics Performance of the Upgraded ALICE

J/ψ elliptic flow 2.5<η<4.0



Present measurement

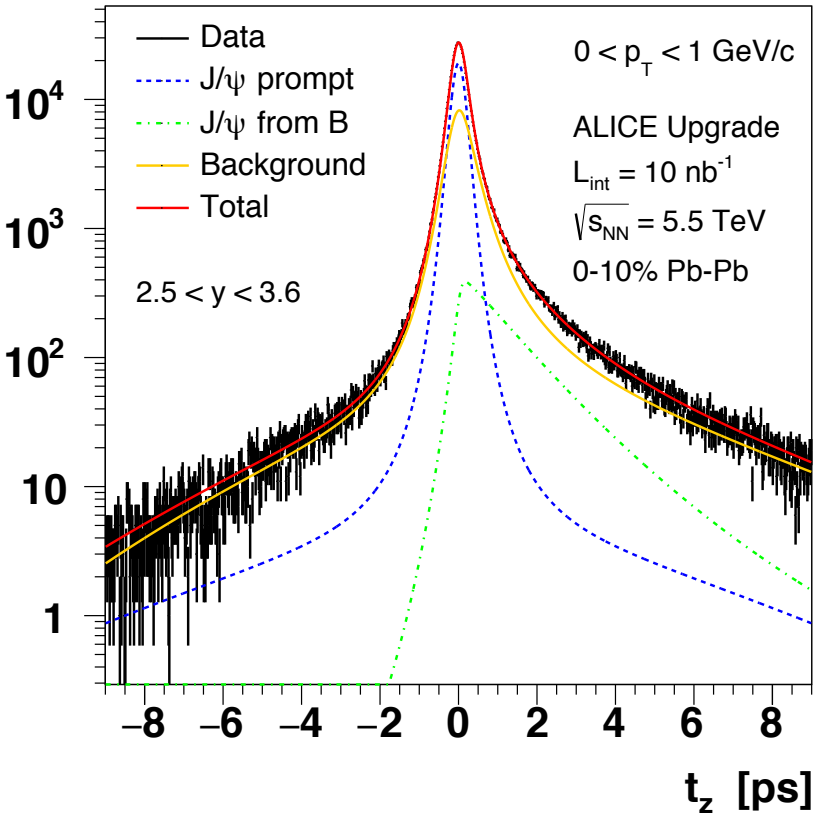


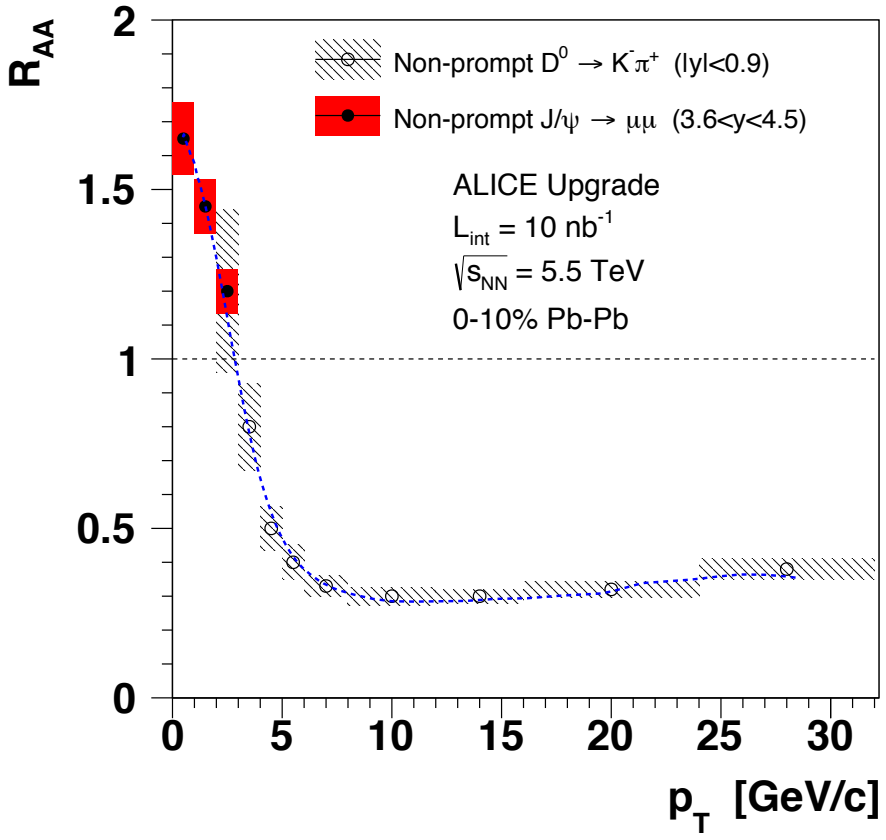
Future precision

With ITS and MFT: Prompt - Decay separation

Physics Performance of the Upgraded ALICE

Beauty measurement in the golden J/ψ channel





Down to p_T=0, displacement ensured by the rapidity boost