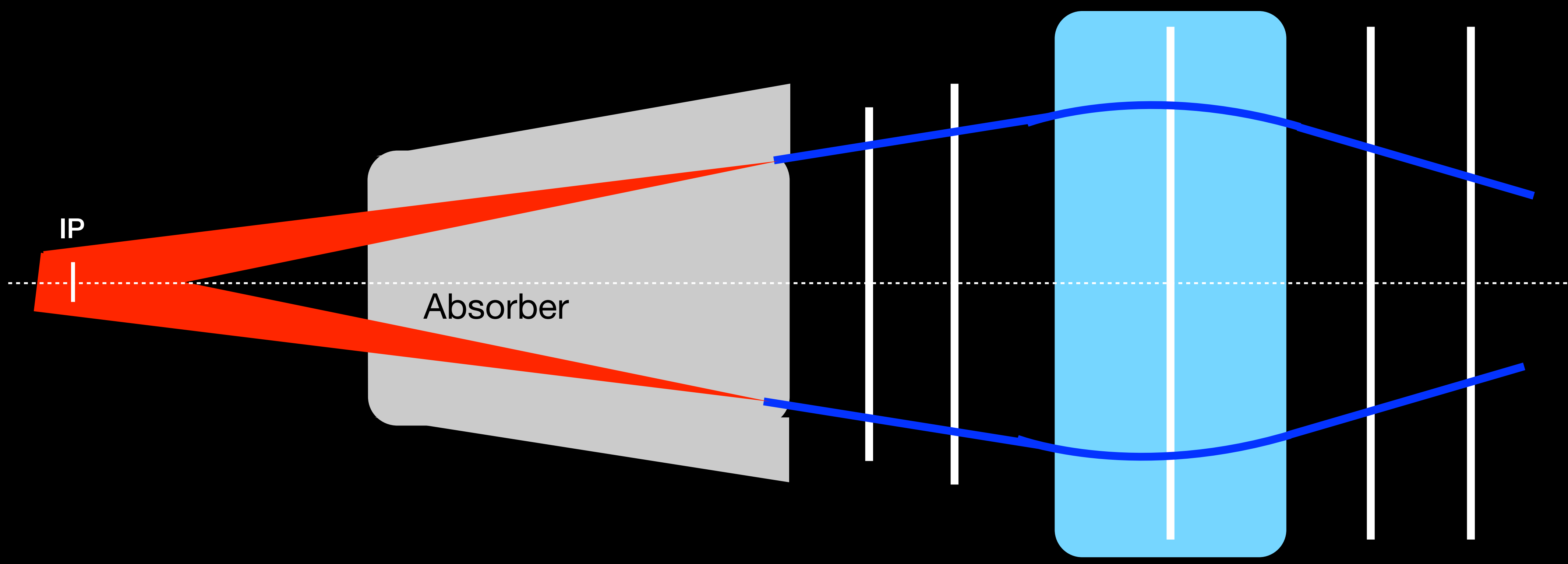
MFT STATUS AND PLANS

R. Tieulent for the MFT Collaboration
Institut de Physique Nucléaire de Lyon

MFT PHYSICS OBJECTIVES

- In-medium charmonium dynamics, study dissociation and regeneration mechanisms
  - Measurements of prompt J/ψ and ψ(2S) production and nuclear modification factors R_{AA} down to zero p_T
- Thermalization of heavy quarks in the medium
  - Measurements of elliptic flow (v_2) for charm, beauty (semi-muonic and J/ψ decays) and prompt charmonium
- Medium density and mass dependence of in-medium parton energy loss
  - Measurements of charm, beauty (semi-muonic and J/ψ decays) p_T-differential production yields
- QCD phase transition and its chiral nature
  - Measurement of the QGP thermal radiation and the spectral shape of low mass vector mesons

THE MUON FORWARD TRACKER



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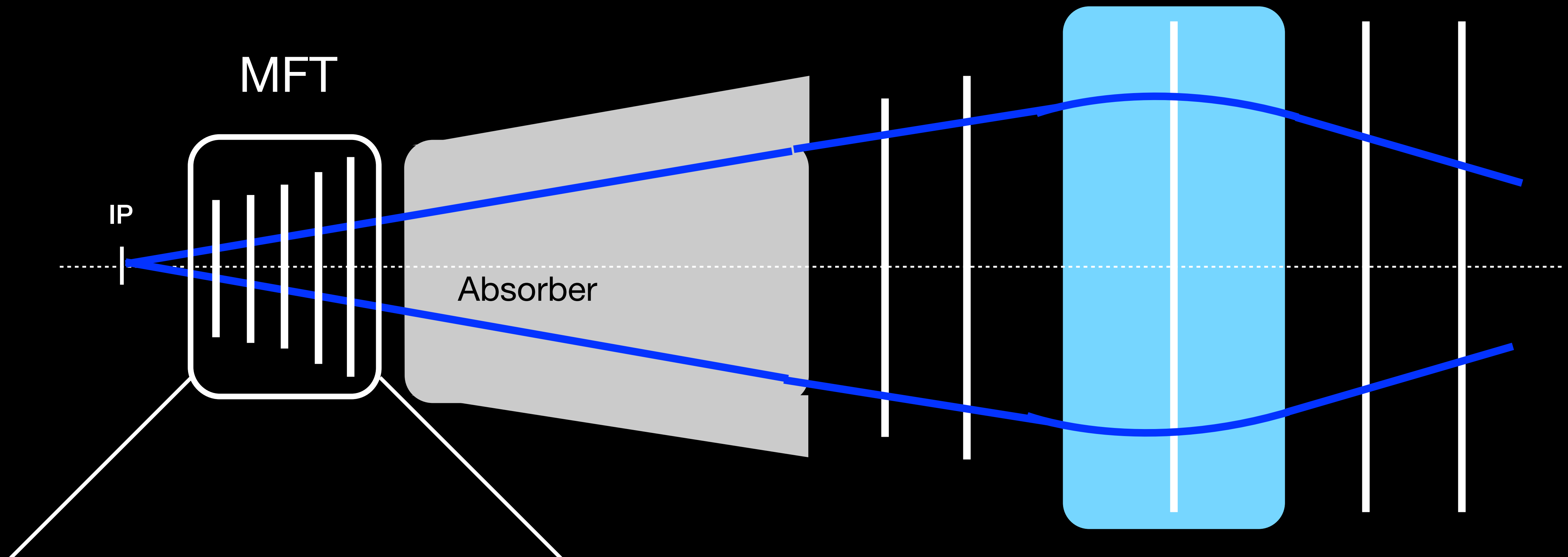
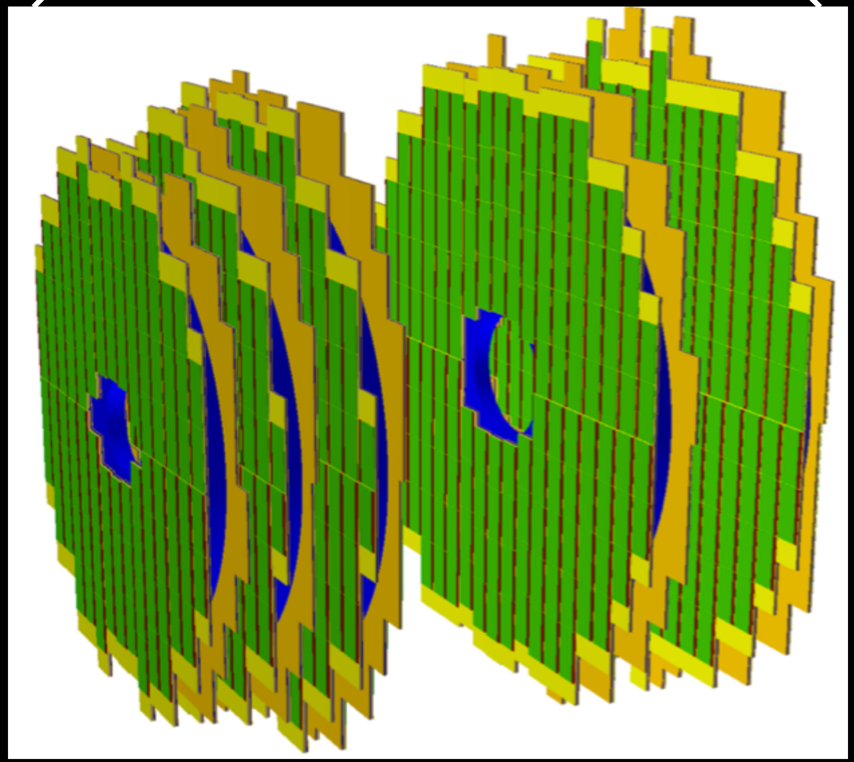




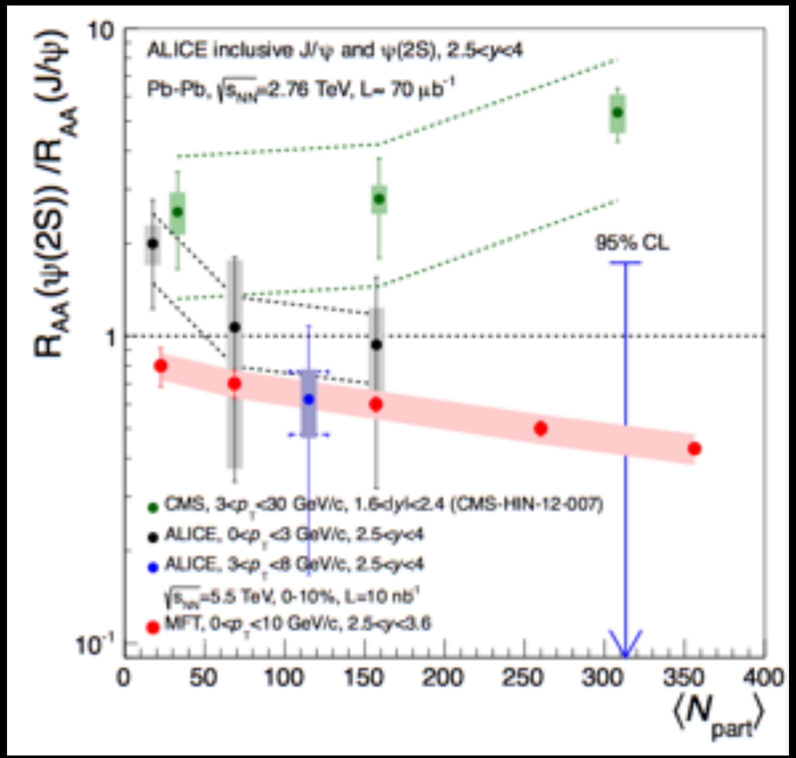
- 5 planes of silicon pixel sensors before the hadronic absorber
- Provides enough pointing accuracy to
  - Separate muon from B/D mesons,
  - Separate prompt/non-prompt J/Ψ,
  - Reduce background from π/K decays.

NEW ACCESSIBLE MUON PHYSICS CASES

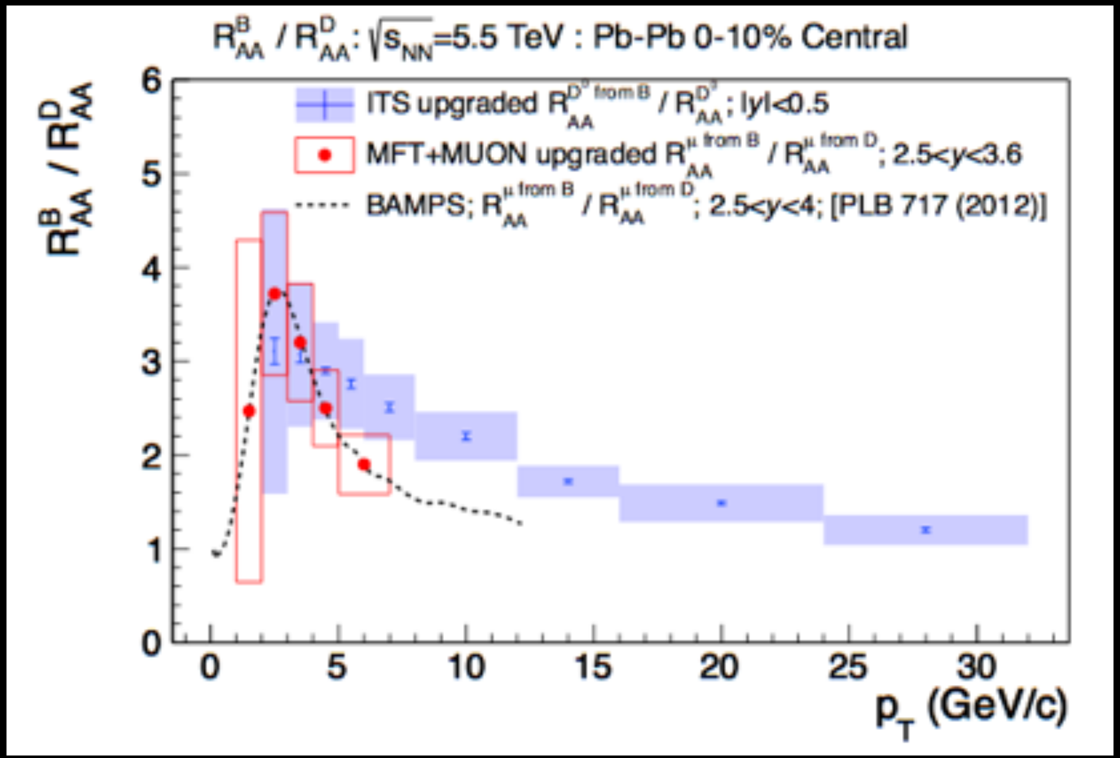
p_T coverage and expected errors for current ALICE-MUON accepted programme and with the extended programme proposed ($L=10\ nb^{-1}$)

Topic	Observable	MUON upgrade	MUON + **MFT** upgrade
Heavy flavour	$\mathbf{R_{AA}}$ (J/ψ from B)	unmeasurable	$p_T>0$; 10% (to be improved “à la LHCb”)
	$\mathbf{v_2}$ (J/ψ from B)	unmeasurable	Evaluation in progress
	μ decays from *c*-hadrons	unmeasurable	$p_T>1$; 7%
	μ decays from *b*-hadrons	unmeasurable	$p_T>2$; 10%
Charmonia	$\mathbf{R_{AA}}$ (prompt J/ψ)	unmeasurable	$p_T>0$; 10%
	$\mathbf{v_2}$ (prompt J/ψ)	unmeasurable	Evaluation in progress
	ψ’	$p_T>0$; 30%	$p_T>0$; 10%
Low Mass	Low Mass spectral func. and QGP radiation	unmeasurable	$p_T>1$; 20%

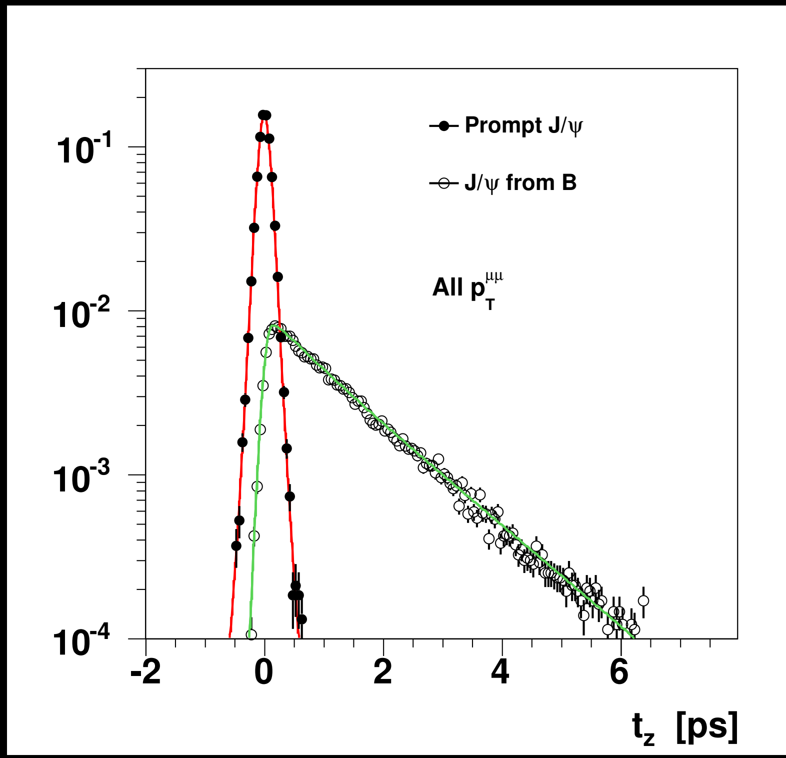
MFT PHYSICS PERFORMANCES



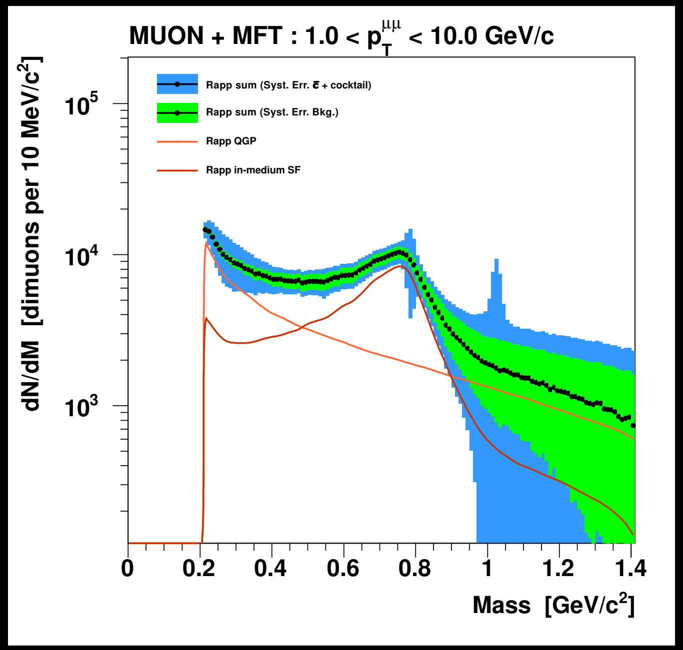
Ψ(2S) / J/Ψ



$R_{AA}(B)$ / $R_{AA}(D)$



B→ J/Ψ



Low Mass

- Physics Performances detailed in Addendum to the ALICE LoI (https://cds.cern.ch/record/1592659)
- New complete simulation with latest detector setup on going: first results to be added in the TDR final version

MFT DESIGN GOALS

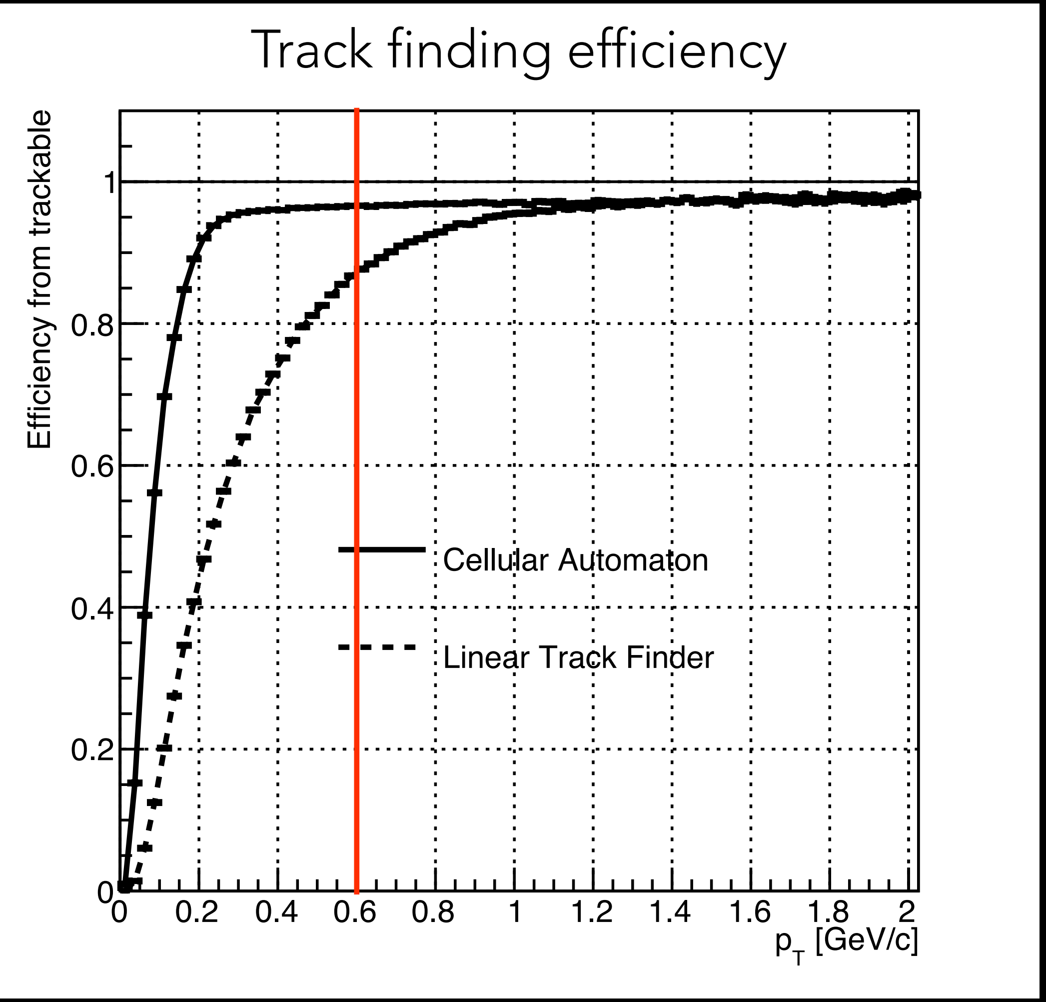
- Vertexing for the ALICE Muon Spectrometer at forward rapidity
    - 5 detection disks of silicon pixel sensors O(25 μm x 25 μm)
    - 0.6% of X_0 per disk
    - $-3.6 < \eta < -2.45$ (~75% of the MUON acceptance)
    - Disk#0 at z=-460 mm, R_{in}=25 mm (limited by the beam-pipe radius)

- Good matching efficiency between MFT and MUON
    - Disk#4 at z=-768 mm (limited by FIT and the hadronic absorber)

- Fast electronics read-out
    - Pb-Pb interaction rate ~50 kHz, and pp interactions at 200 kHz

MFT STANDALONE TRACKING

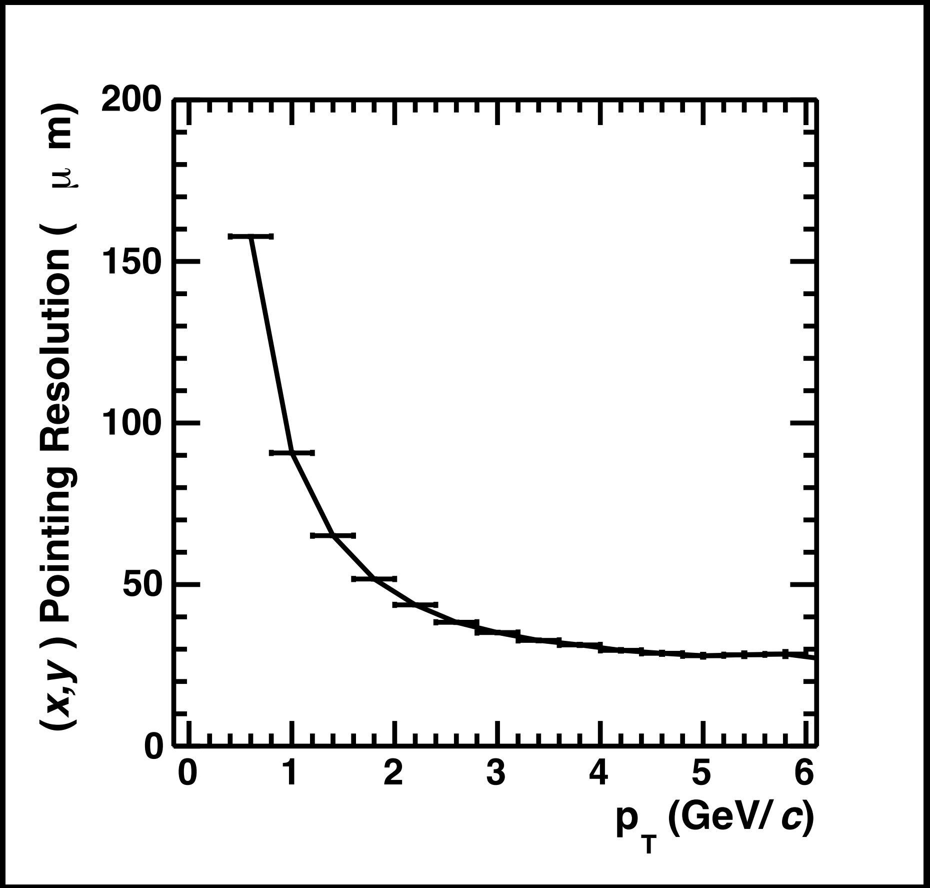
- Two standalone tracking algorithms have been implemented
- Cellular Automaton algorithm:
  - Good efficiency (>95%) down to p_T~0.2 GeV/*c*
  - Needed for charge particle multiplicity, reaction plane measurements, correlation studies.
- Linear Track Finding algorithm:
  - Optimizing the MUON/MFT matching efficiency

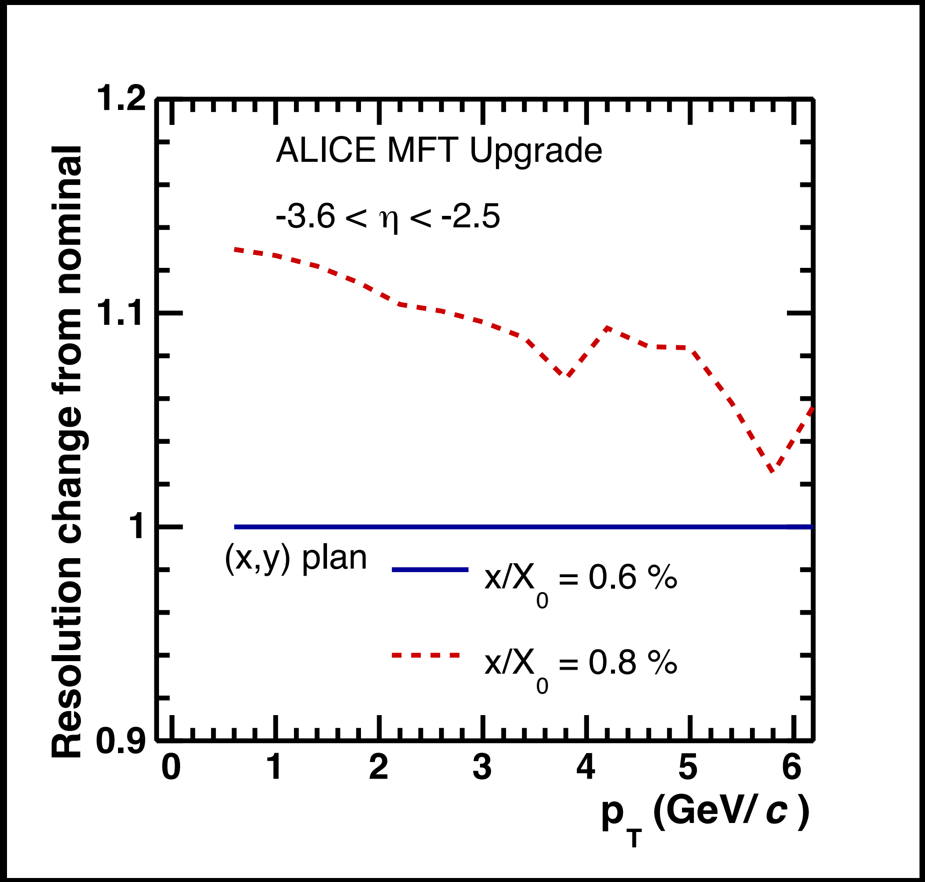


Hadronic absorber cut
p>4 GeV/*c* ($p_T \gtrsim$ 0.6 GeV/*c*)

IMPACT PARAMETER RESOLUTION

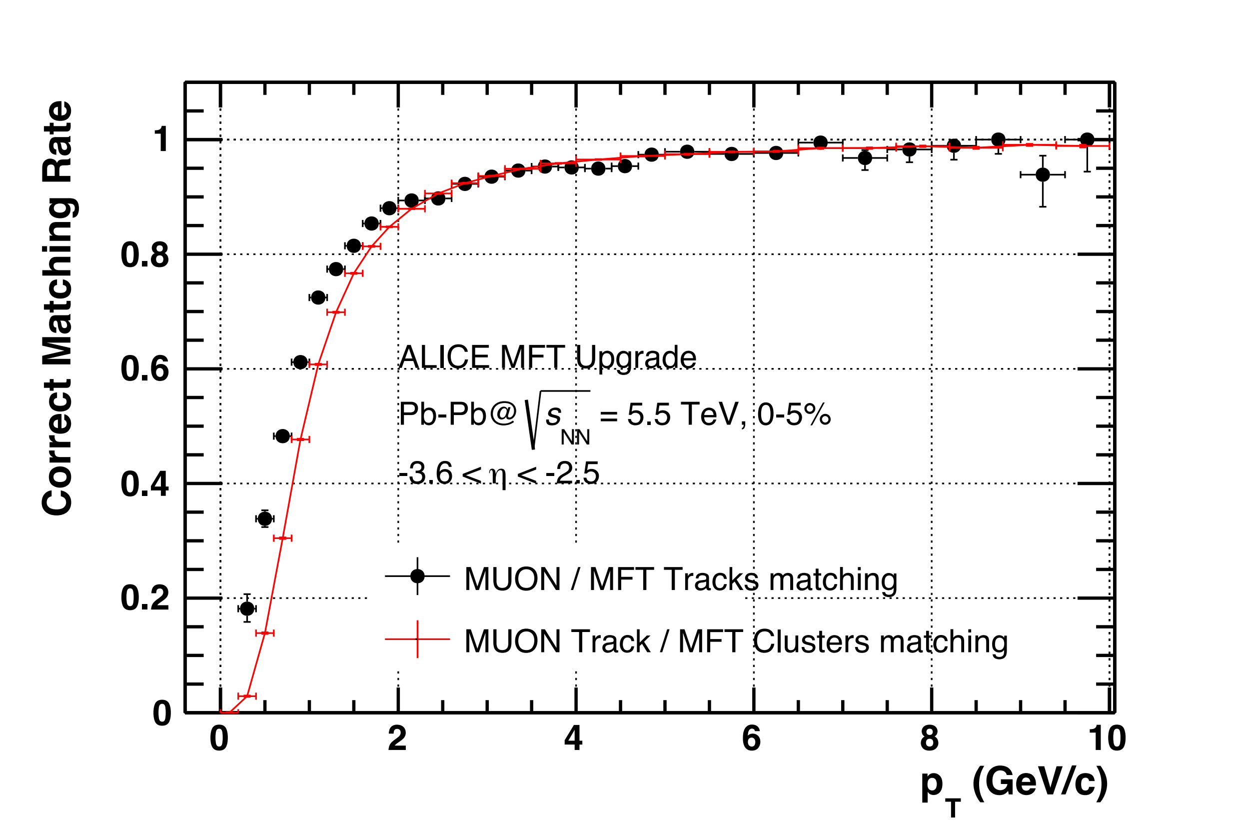
- Resolution below 100 μm for $p_T > 1$ GeV/c
- 10% worsening of the offset by increasing the material budget per disk from 0.6 to 0.8% of X_0

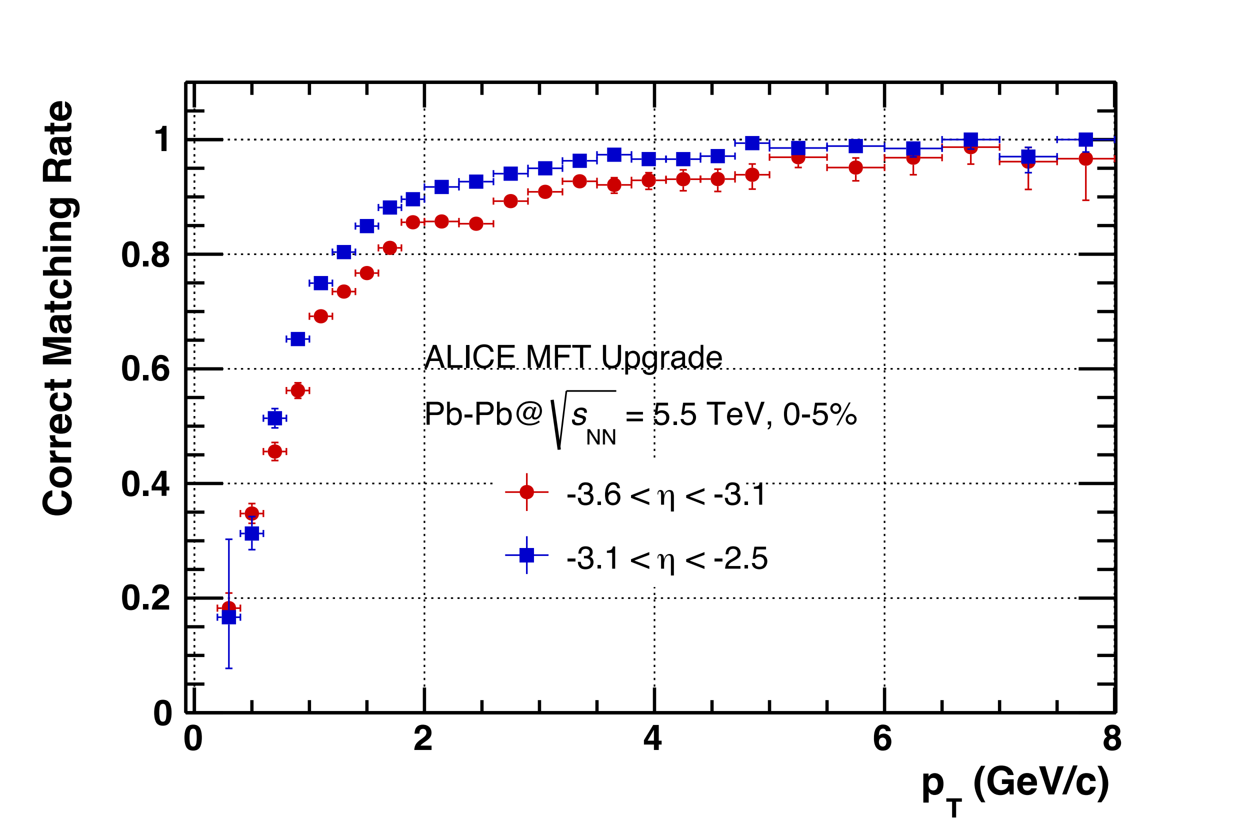




MUON / MFT MATCHING EFFICIENCY

- Two methods have been studied
  - MUON Track / MFT **Clusters** matching (developed in the LoI)
  - MUON Track / MFT **Track** matching (new in the TDR)
- Matching efficiency > 70% for p_T > 1 GeV/*c*





MFT LAYOUT

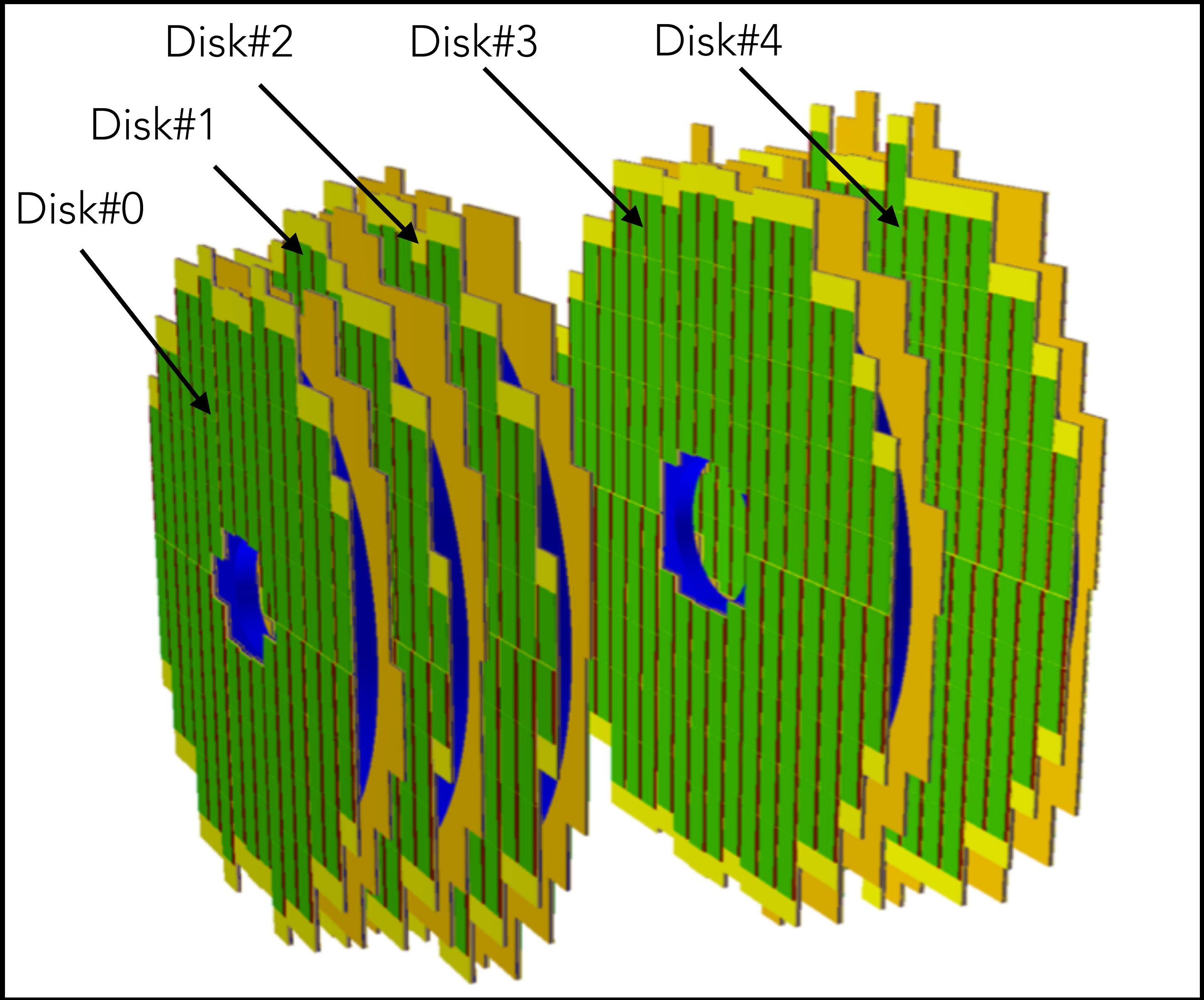
896 silicon pixel sensors (0.4 m^2) in 280 ladders of 1 to 5 sensors each

10 Half-disks: 2 detection planes each

$-3.6 < \eta < -2.45$

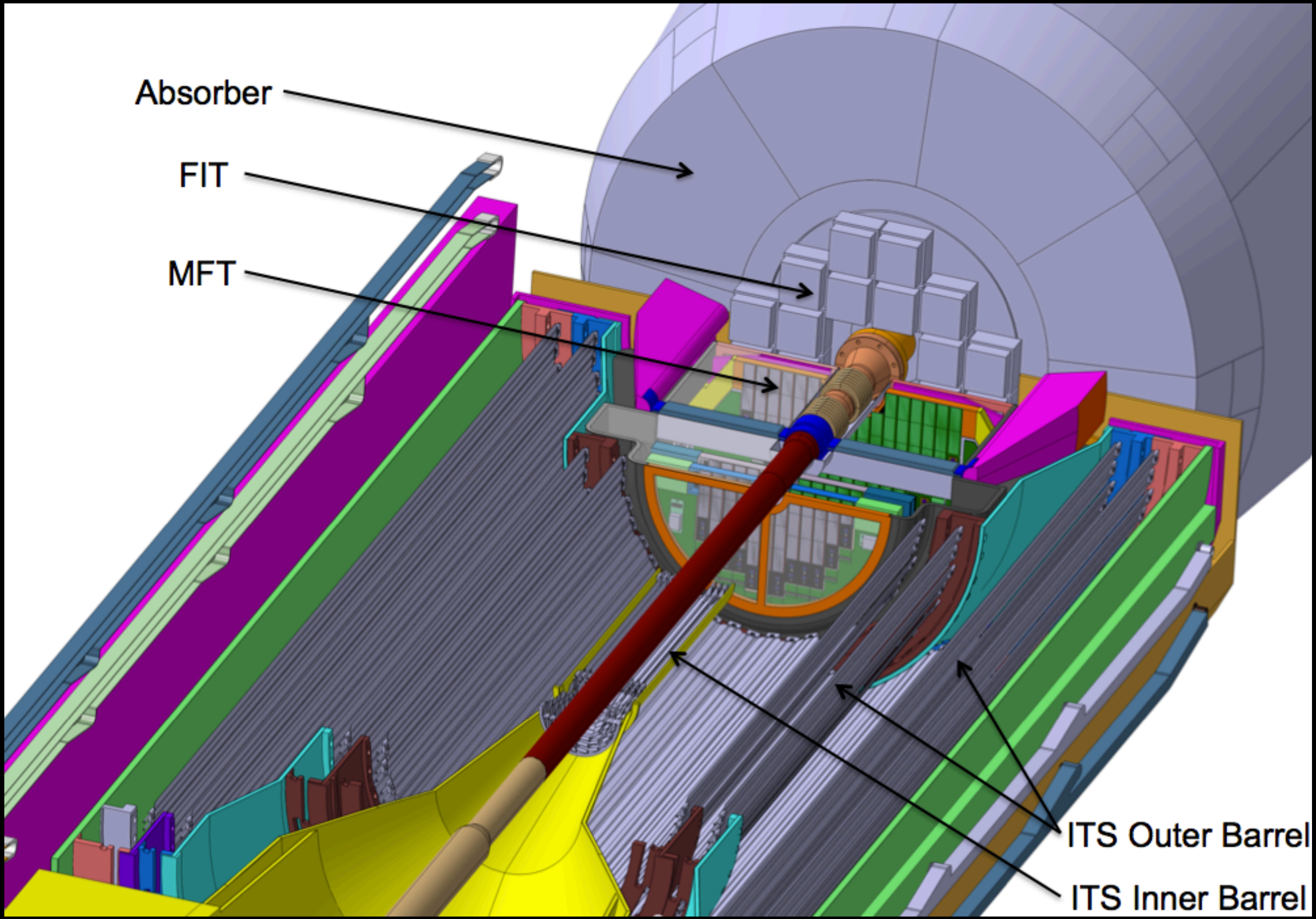
Doses seen by MFT

- < 400 krad
- < 6×10^{12} 1 MeV n_{eq}/cm^2
- 10-fold security factor
- Comparable to ITS inner barrel



5% of the ITS surface
Twice the ITS inner barrel

MFT ENVIRONMENT



JOINT MFT/ITS SILICON PIXEL SENSOR STRATEGY

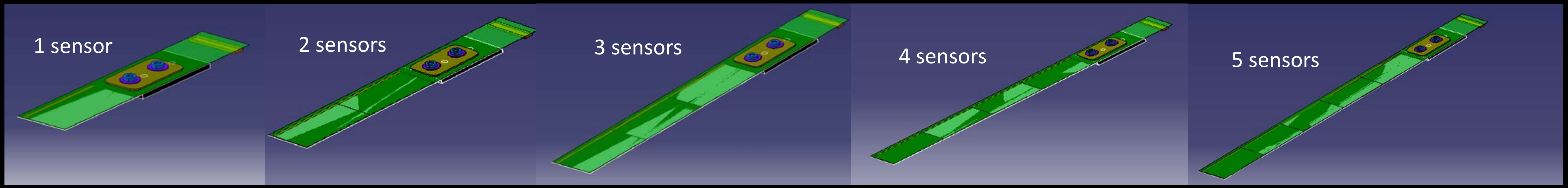
- Requirements of ITS inner-barrel and MFT are almost identical
  ⇒ Same pixel sensor

- ITS-MFT common sensor benefits
  - Minimize sensor cost and manpower resources
  - Similar flexible printed circuit
  - Same bonding technique (laser soldering)
  - Same read-out architecture

- ALPIDE sensor fits the requirements of the MFT detector
  - Pile-up is reduced due to the shorter integration time. Pile-up deteriorates MS-MFT matching efficiency (see MFT LoI)
  - Power consumption is below 50 mW/cm^2, easier integration of the MFT cooling system
  - CEA micro-electronics engineers joined the development team lead by CERN

- See ALPIDE performance results later today

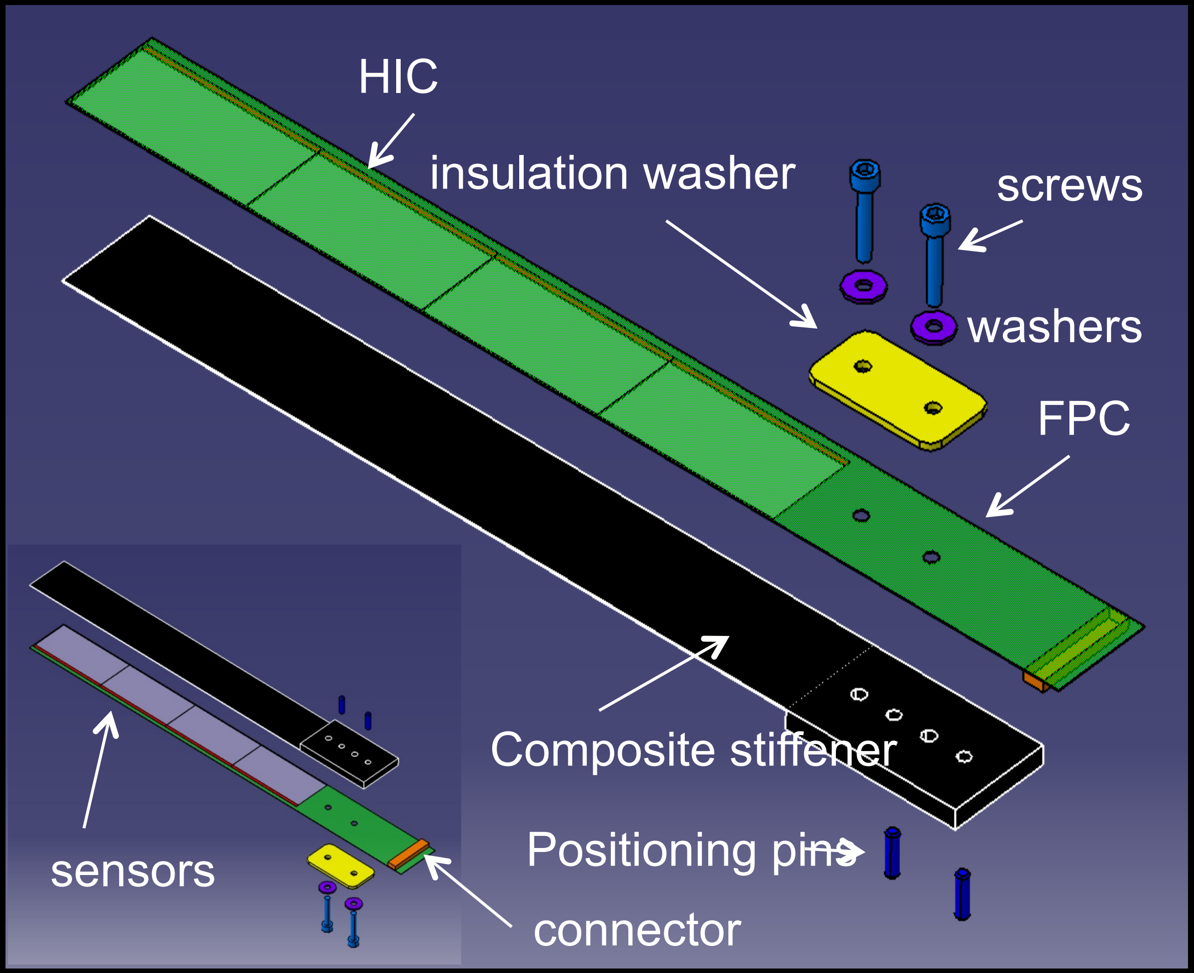
MFT LADDER DESIGN



Sensor(s) + Flexible Printed Circuit (FPC) = Hybrid integrated circuit (HIC) with 1 to 5 sensors each

HIC glued on Carbon plastic CFRP stiffener

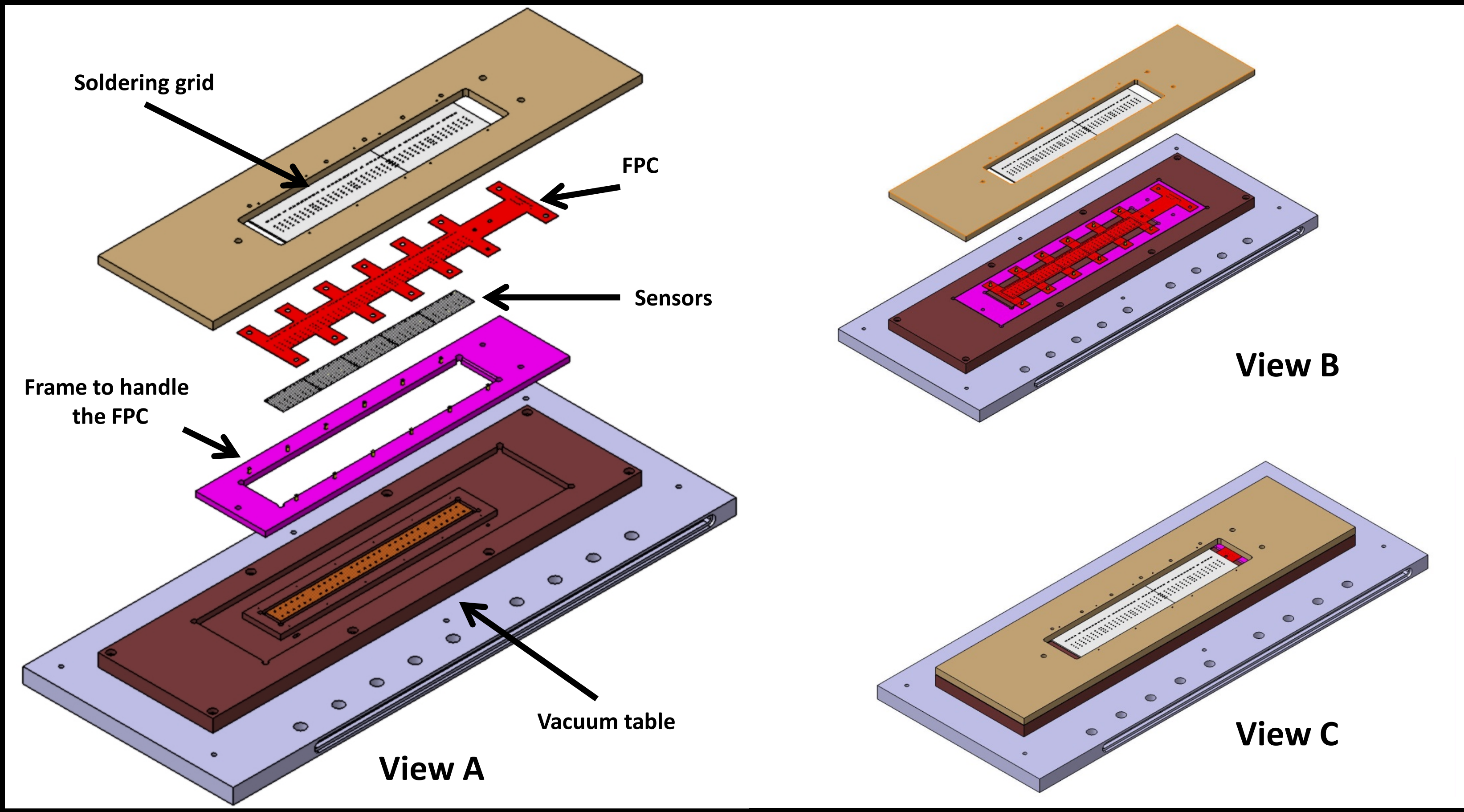
Mechanical characterization January 2015

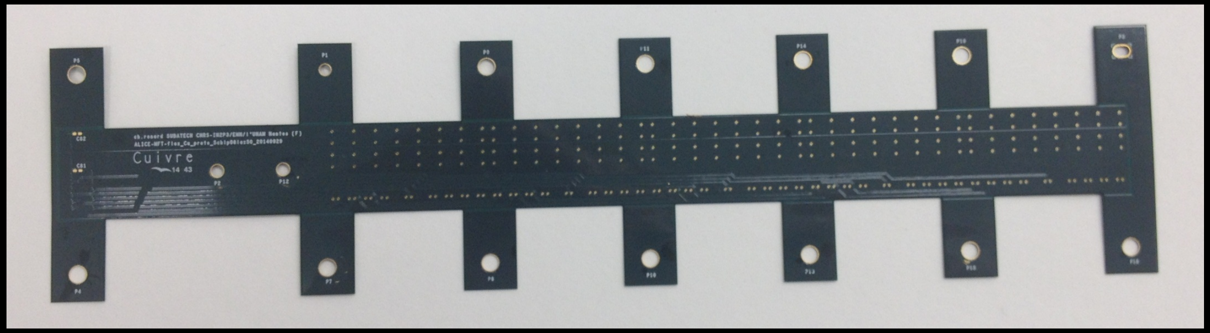


FLEXIBLE PRINTED CIRCUIT (FPC) HYBRID INTEGRATED CIRCUIT (HIC)

- Similar FPC to that of ITS inner barrel, but with 1 to 5 sensors each
- Polyimide with Al strips to minimise the material budget
- Laser soldering developed by ITS upgrade project
- Copper prototype realized
  - mechanical test (on-going)
  - laser soldering test (on-going)
- MFT worktable design/ prototyping on-going

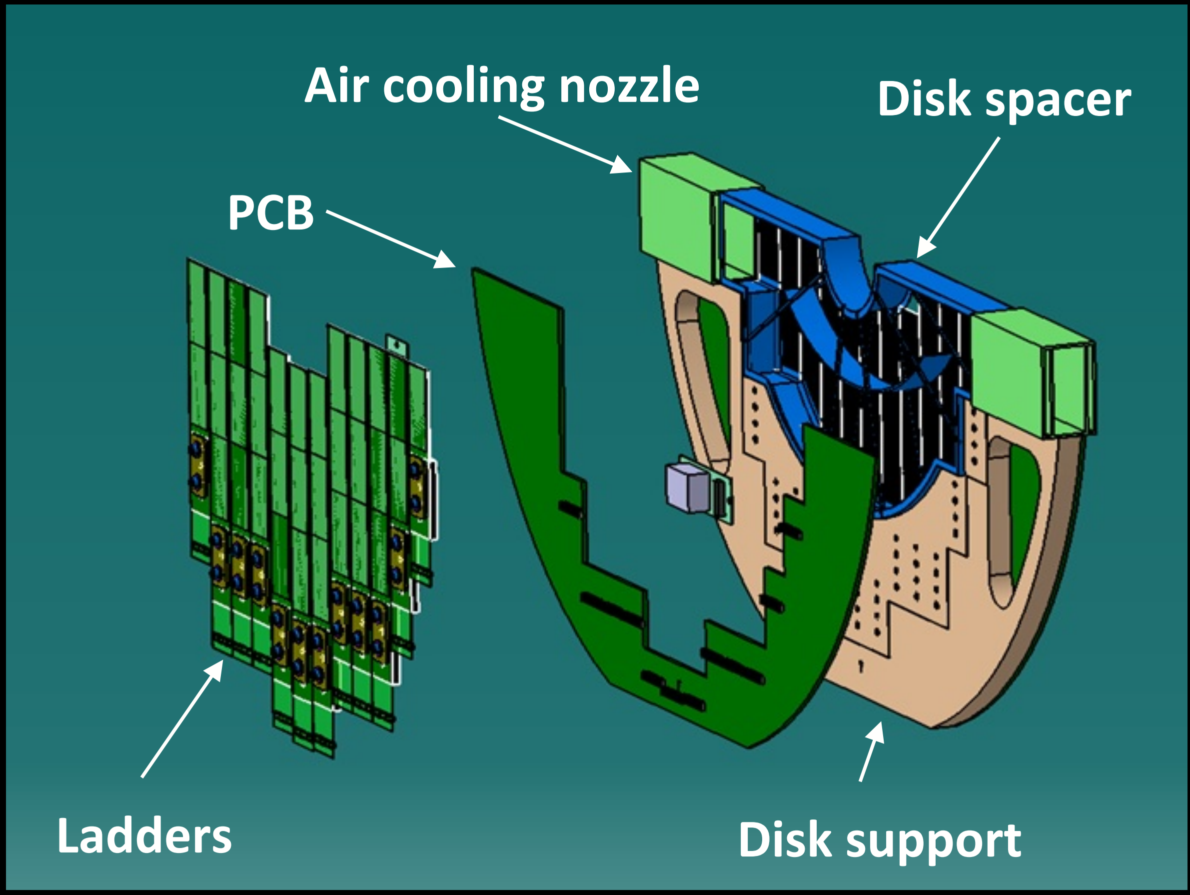
MFT Worktable

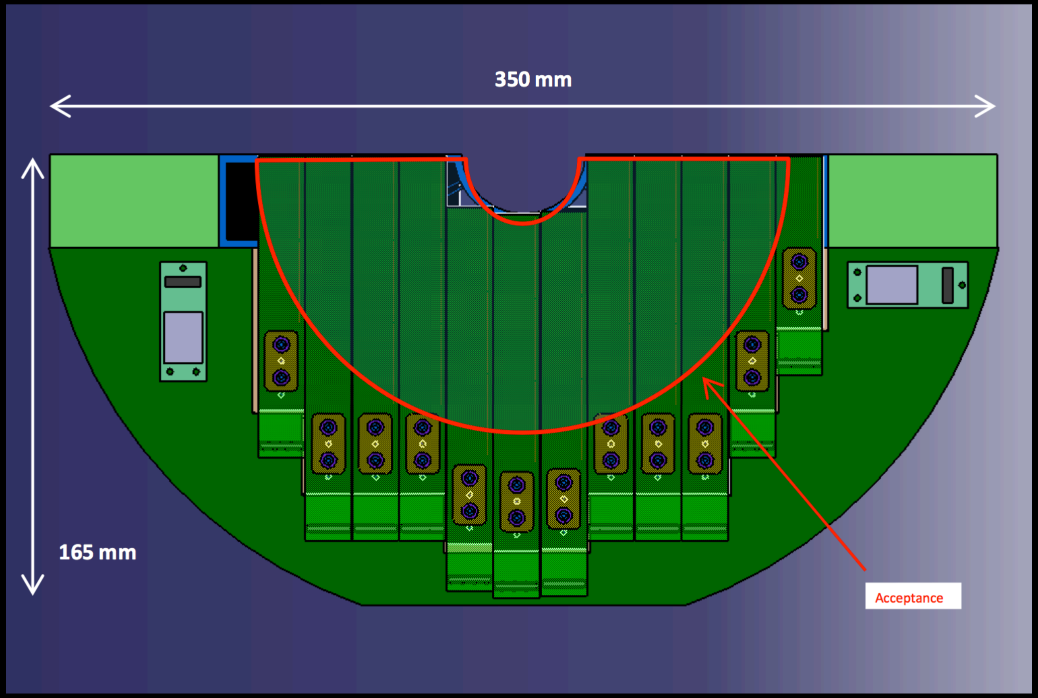




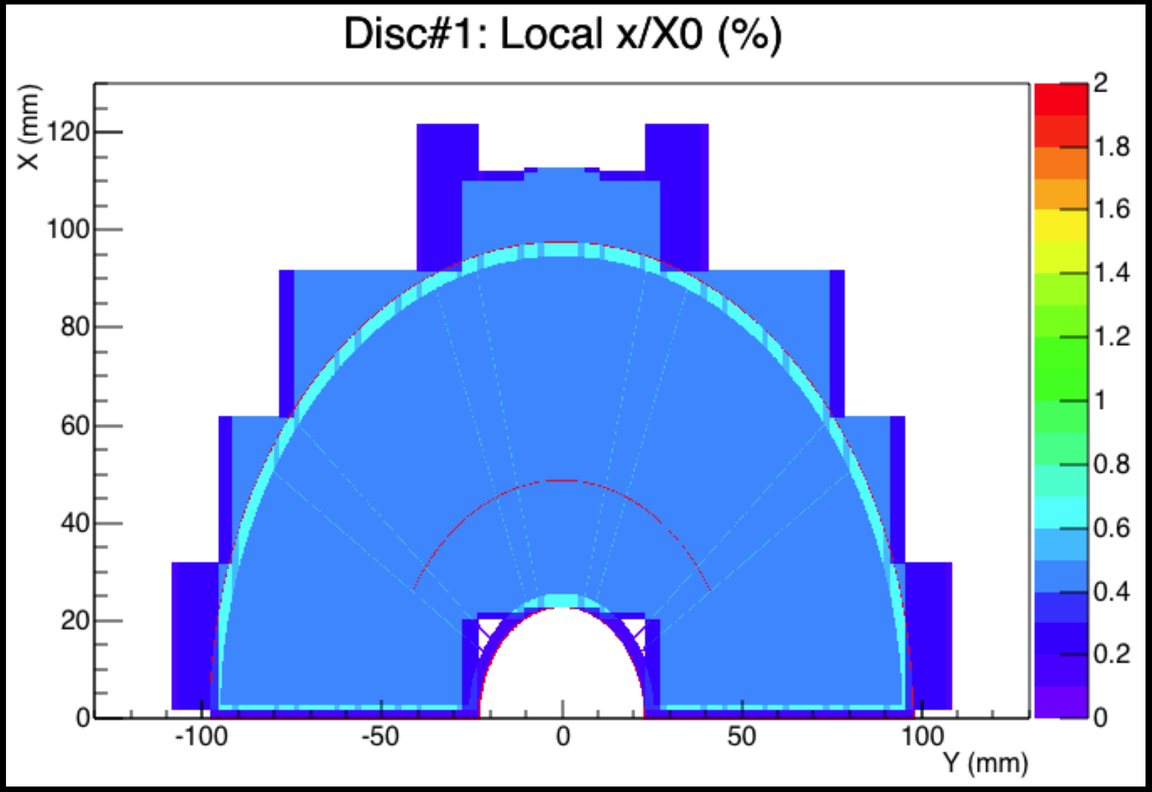
MFT HALF-DISK DESIGN

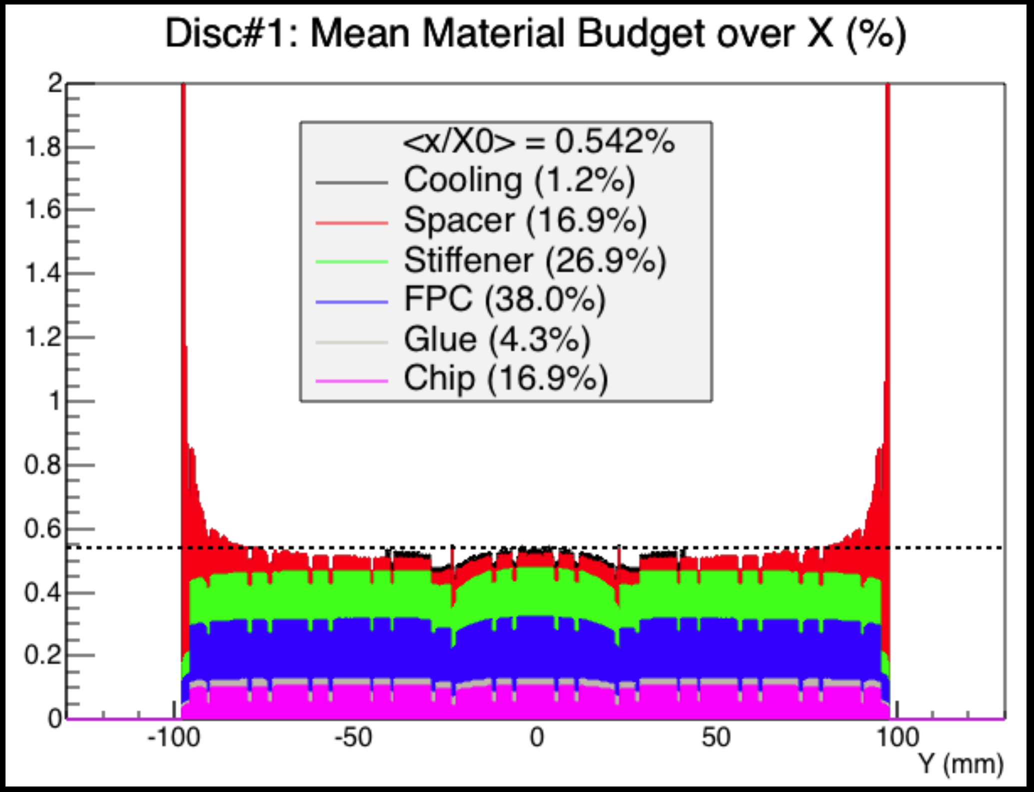
- Two detection planes (front/back)
  - Hermetic detector
  - Coverage around the beam pipe
  - Redundancy (50%)
- Two PCBs, containing the regulators, data, clock and slow control lines
- Half-disk support
- Half disk spacer
- Survey of each sensor positioning with respect to half-disk support markers





MATERIAL BUDGET PER HALF-DISK

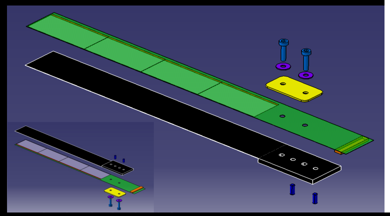


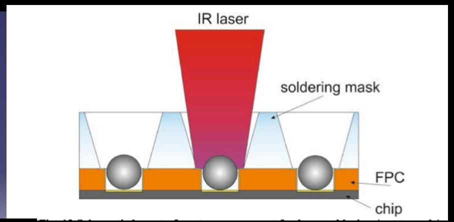


- FPC is the main contributor to the material budget (38%), followed by the stiffener (27%) and the disk spacer (17%)
- Silicon pixel sensors contributes to 17%
- Water cooling represents 0.08% of X_0 (15%), with “spikes” of 0.3% of X_0
- Material budget per disk below 0.6% of X_0

MFT LADDER ASSEMBLY PROCESS

- Preparation of the ladder elements
  - Common ITS-MFT sensors, FPC, carbon plastic stiffeners
  - Soldering of SMD components and connector on the FPC
- HIC Soldering (FPC and sensors)
  - common semi-automatic assembly system for ITS inner barrel and MFT at CERN
  - visual inspection and electrical tests

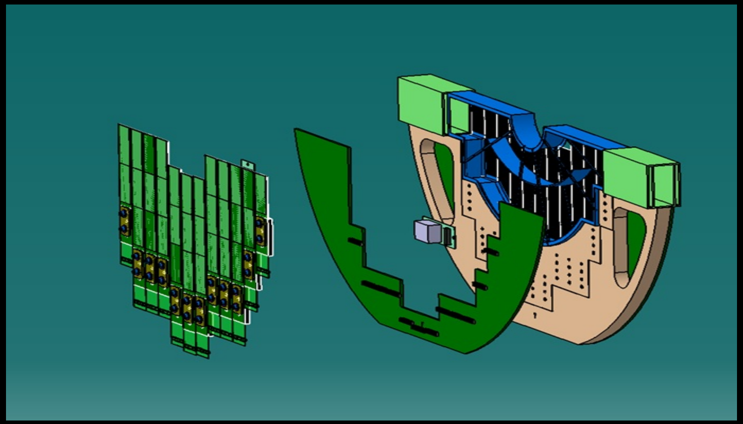




- HIC and stiffener gluing
- Qualification test
- Production of ladders
  - An MFT represents 280 ladders: 16, 36,120, 92, 16 ladders of 1 to 5 sensors respectively
  - 5 half-disk spares and 20% of ladder spares: total of 506 ladders
  - Duration of ladders production is estimated to 10 months (without margin)

HALF-DISK ASSEMBLY PROCESS

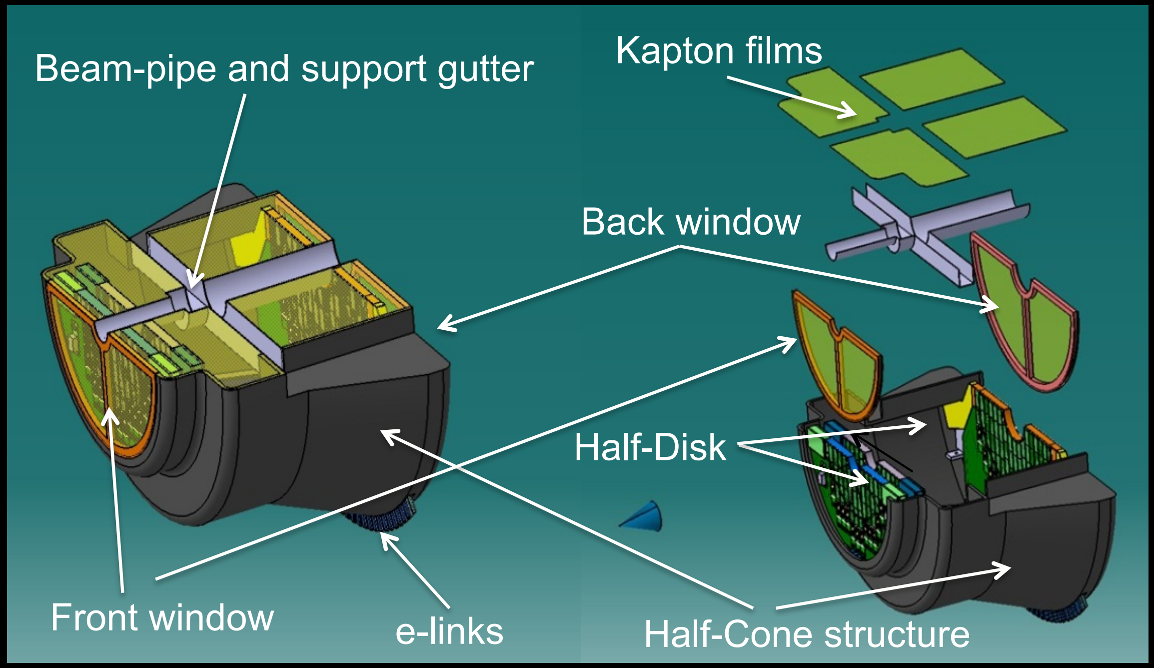
- Preparation of the half-disk elements
  - Ladders, half-disk support, half-disk spacer, 2 PCBs
- Positioning of the ladders on the half-disk
  - Positioning (0.1 mm precision) of ladders on the front and back planes
  - Gluing on the half-disk spacer
  - Electrical test



- Qualification tests
- Survey of the sensor positions with respect to the half-disk support
- Production of half-disks
  - MFT represents 10 half-disks + 5 spare half-disks
  - Duration of half-disk production is estimated to 3 months (without margin)

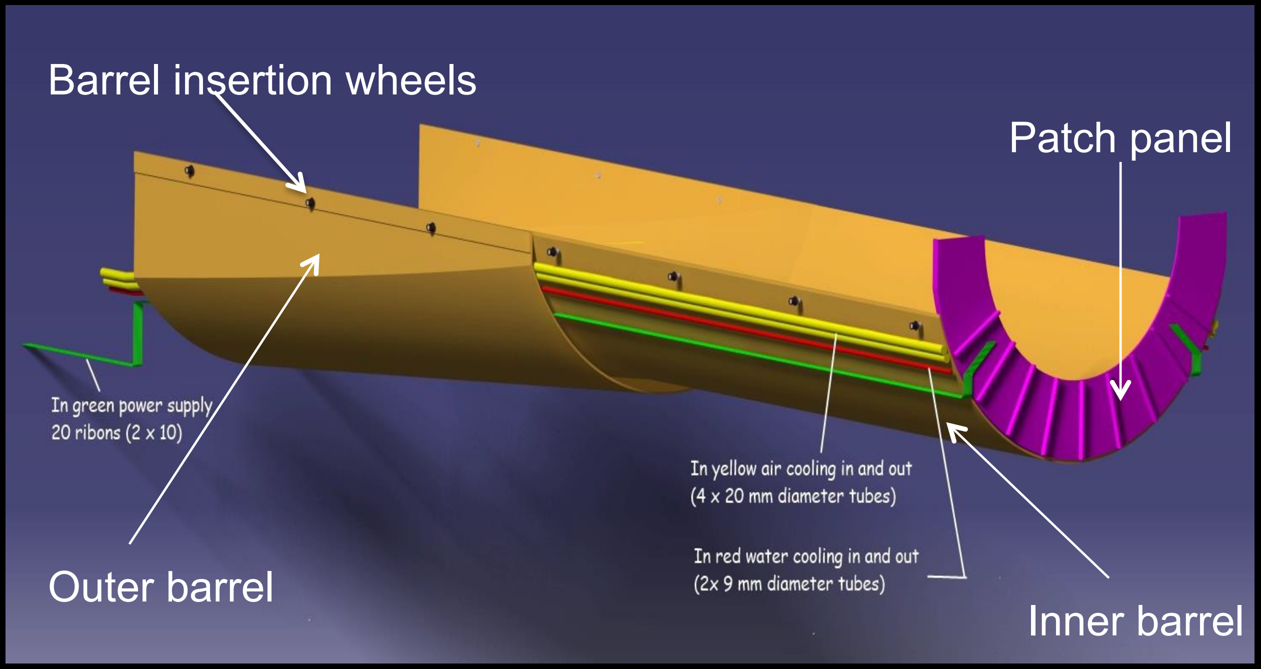
MECHANICAL STRUCTURES

Half-Cone



- 2 half-cones (Top / Bottom)
- Structure in carbon fibre
- Support half- disks, service distribution (water tubes, power supply), DCS, RO, SC cables

Half-Barrel

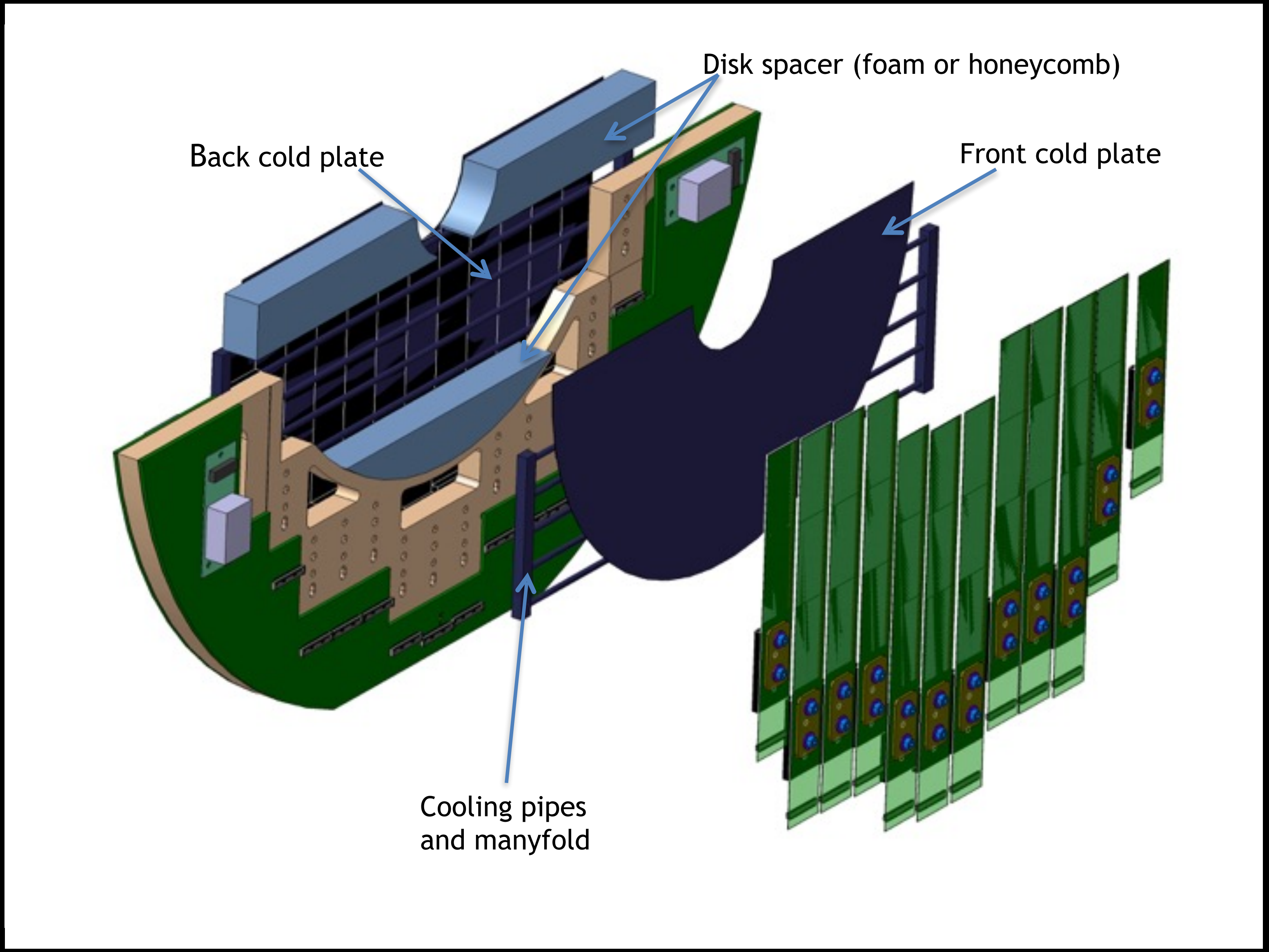


- Insertion tool of the MFT
- Supporting half-cone
- Routing services from A-side, and DCS, read-out cables from C-side

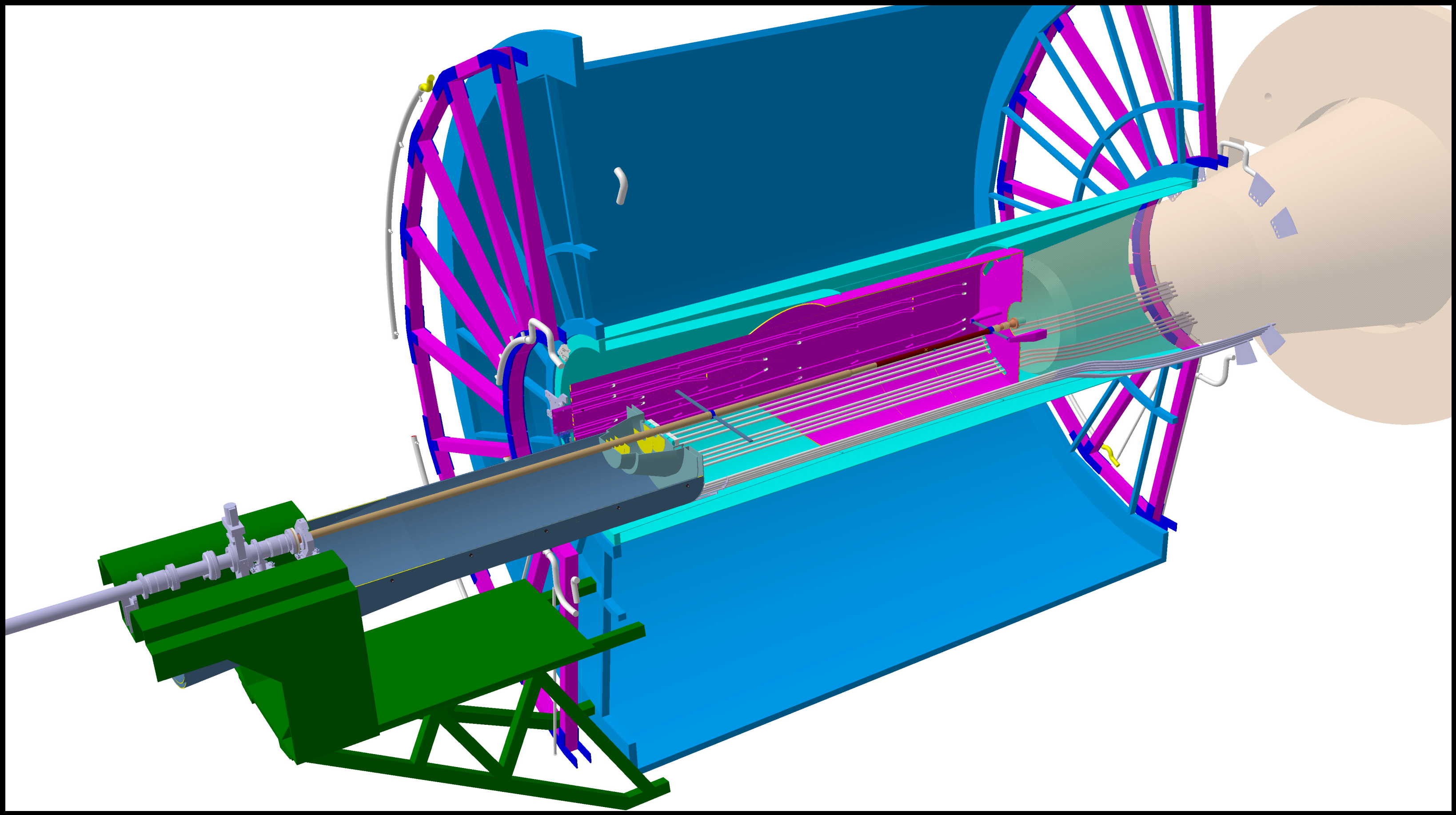
COOLING

- Water-cooling technic chosen (same as ITS)
    - Assumed 50 mW/cm^2 for the sensor
    - Polyimide pipes are foreseen for half-disk plane
    - Cold plate on the half-disk spacer

Water-cooling in the PCBs to Cool the DC-DC converters

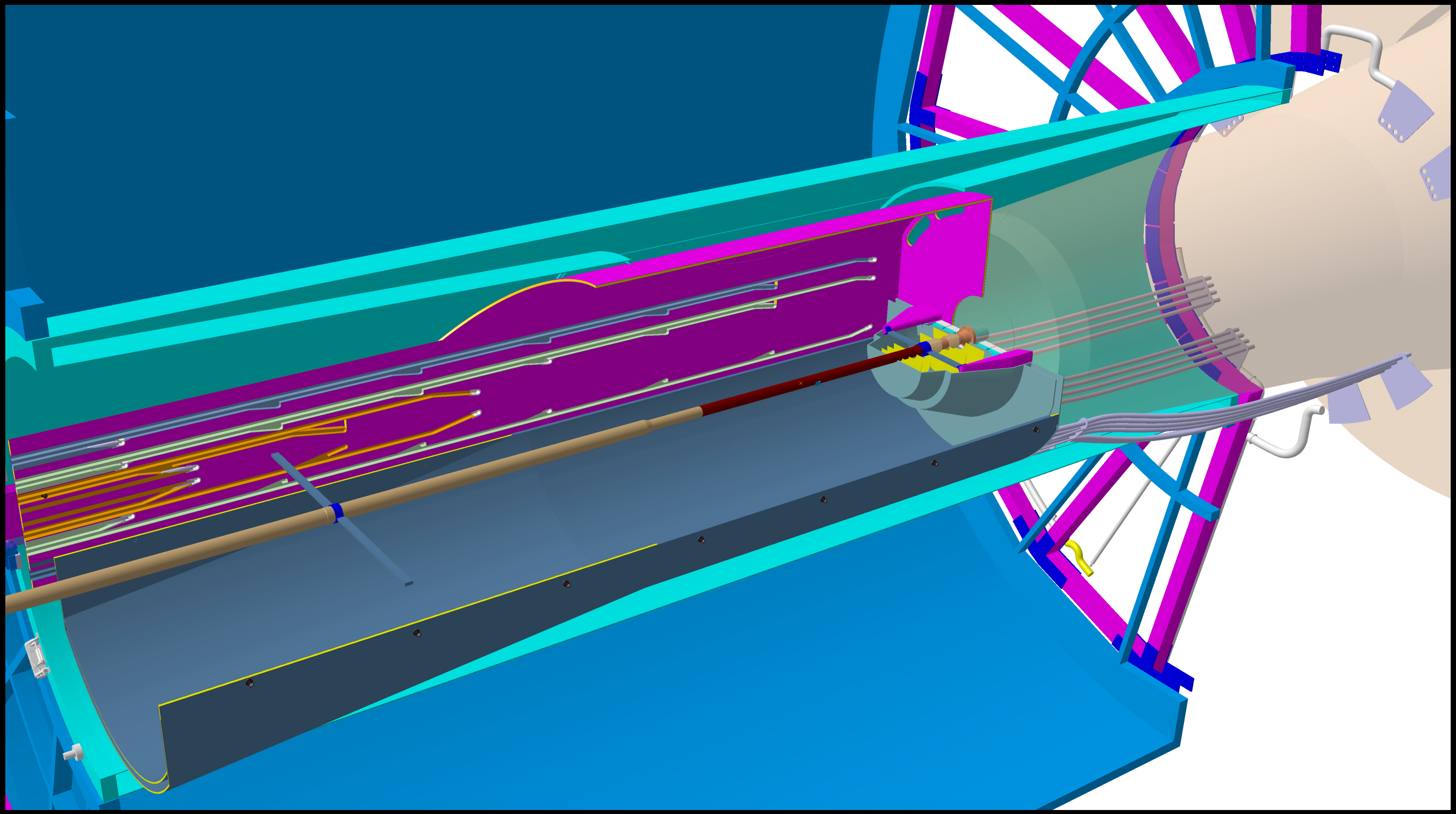


MFT INSTALLATION / REMOVAL



- MFT Installed before ITS
- Final position 3 m away from the parking location
- FIT installed in the MFT barrel
- Top and bottom
- Removal possible during a winter shutdown

MFT INSTALLATION / REMOVAL



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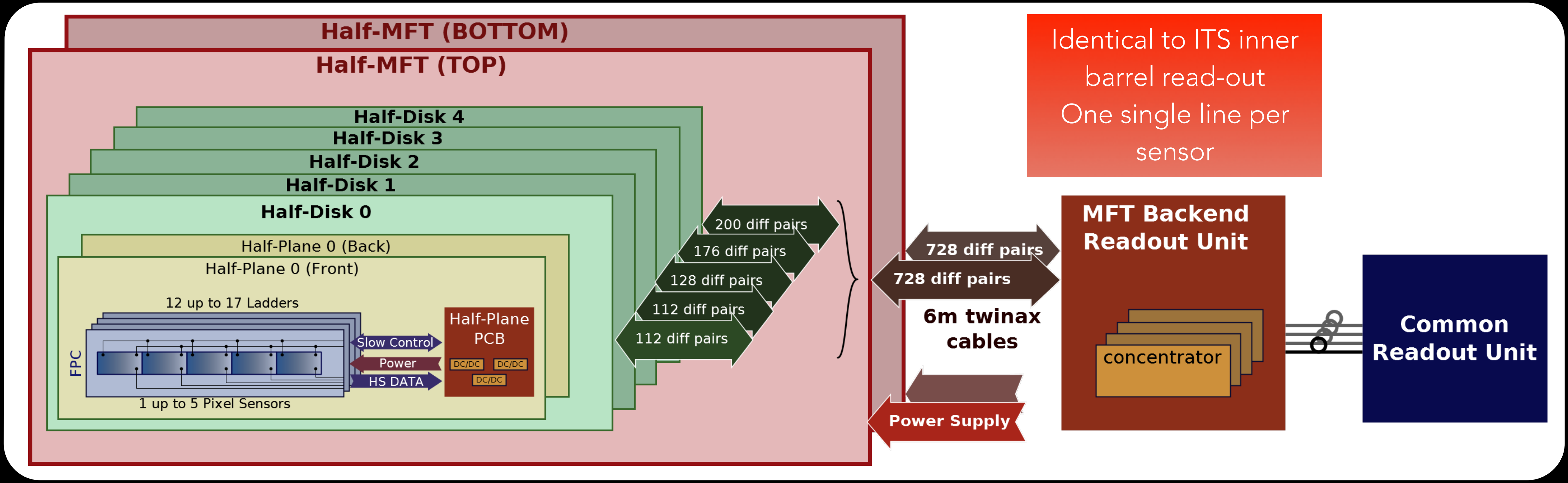
READ-OUT ARCHITECTURE

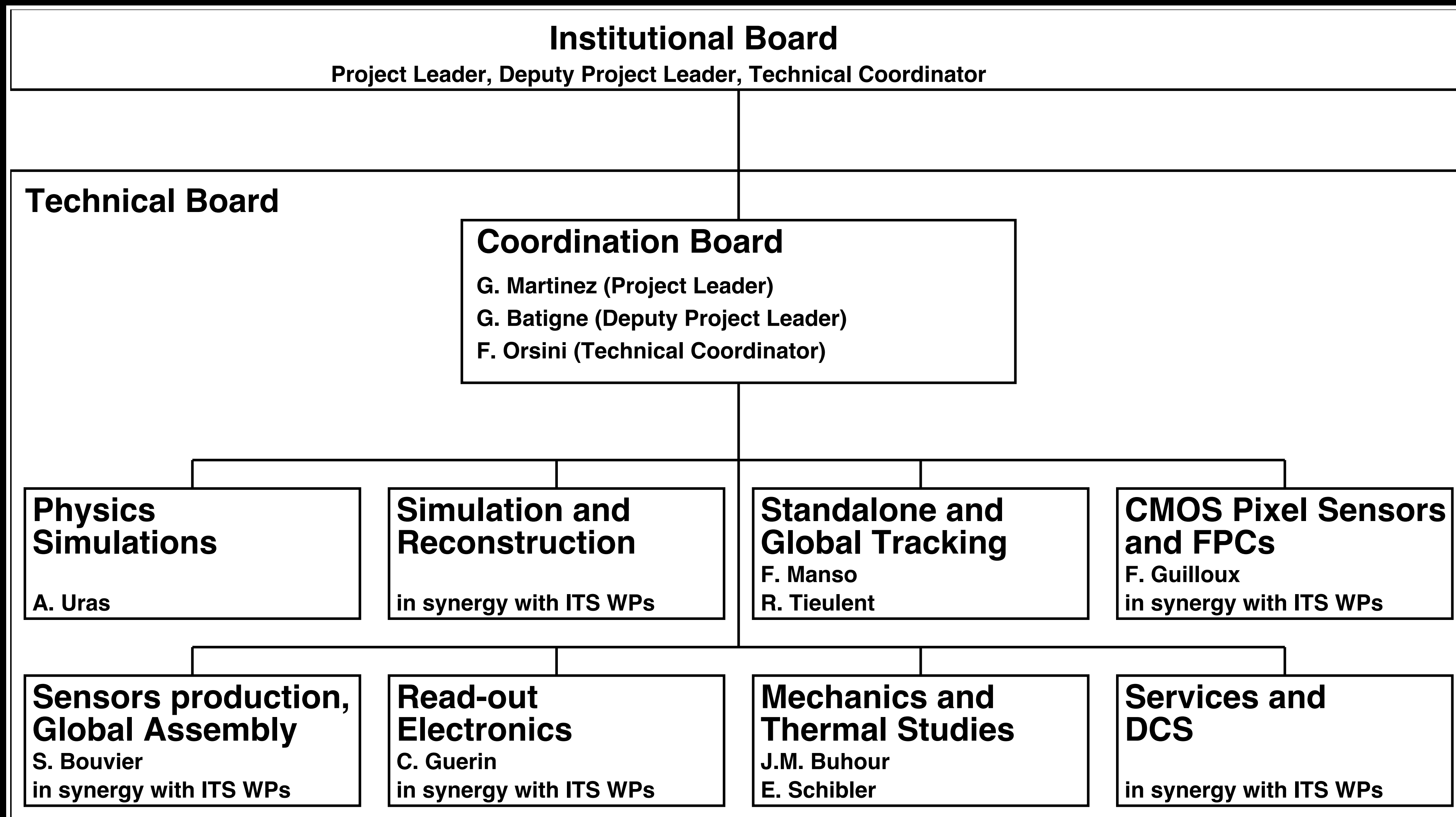


- Between 128-264 high speed data signals (1.2 Gb/s) per disk
- Between 96-136 clock and slow control signals per disk
  - Total of 1456 twinax cables for read-out
- Full MFT data throughput 57 Gb/s
- Concentrator board ~ 4 m away, where TID about 10 krad

SERVICES / HALF-BARREL

- Power supply (A-side)
  - 300 W for 896 sensors and 48 DC-DC converters on the PCBs
  - 20 Aluminium bus-bars, total section of 80 mm^2 (0.1 V drop)
- Readout and DCS cables (C-side)
  - 1 per sensor, Samtec AWG30 Twinax cable, 4 m “firefly”: 896 cables
  - 1 slow control and 1 clock cable per ladder: 560 cables
  - 116 cables for detector control system (voltage, current and temperature sensors)
- Cooling (A-side)
  - 8 water-pipes with a diameter of 5 mm

MFT ORGANIZATION



- CMOS pixel sensor is common to ITS and MFT
- FPC will be produced in same site than ITS FPC
- Readout is planned to be identical to ITS inner barrel readout
- Sensors assembly on FPCs: use of the same «semi- automatic machine » and laser soldering technique than ITS. Assembly will be performed at CERN

MFT COLLABORATION

Table 7.1: Institutes participating or planning to participate in the MFT Project.

Country	City	Institute
China	Wuhan	Central China Normal University (CCNU)
France	Clermont-Ferrand	Laboratoire de Physique Corpusculaire (LPC), Clermont Université, Université Blaise Pascal, CNRS/IN2P3
France	Nantes	SUBATECH, Ecole des Mines de Nantes, Université de Nantes, CNRS/IN2P3
France	Saclay	Commissariat à l'Energie Atomique, IRFU
France	Villeurbanne	Université de Lyon, Université Lyon 1, CNRS/IN2P3, IPN-Lyon
India	Kolkata, Aligarh	Saha Institute of Nuclear Physics and Aligarh Muslim University
Japan	Hiroshima	Hiroshima University
South Korea	Pusan, Yonsei	Pusan National and Yonsei Universities
Spain	Valencia	Instituto de Física Corpuscular
Peru	Lima	Pontificia Universidad Católica del Perú
Russia	Gatchina	Petersburg Nuclear Physics Institute
Thailand	Nakhon Ratchasima, Chachoengsao	Suranaree University of Technology and Thai Microelectronics Center

RESPONSIBILITY SHARING (UNDER DISCUSSION)

Pixel Sensors	
CMOS wafers	**IRFU, Suranaree Univ. of Technology**, *in synergy with ITS*
Thinning & dicing	**IRFU**, Suranaree Univ. of Technology, *in synergy with ITS*
Series tests	**Pusan National University, Yonsei University**, IRFU, *in synergy with ITS*
Ladders	
FPCs manufacturing & tests	**SUBATECH**
FPCs electronic components & tests	**SUBATECH**
Automatic assembly system for HICs	**SUBATECH, IRFU**, *in synergy with ITS*
Stiffeners manufacturing	**SUBATECH**
HICs and ladders assembly & tests	**IRFU, SUBATECH**, AMU, IPNL, LPC CL, PNPI, SAHA *in synergy with ITS*
Ladders qualification tests	**IRFU, IPNL**, LPC CL, SAHA, HIROSHIMA, LIMA
Disks	
Disk Spacers, support manufacturing	**SUBATECH**
Disks Assembly	**SUBATECH, IPNL, IRFU**, AMU, LPC CL, PNPI, SAHA
Disks Tests	**IRFU, IPNL**, LPC CL, SAHA, HIROSHIMA, LIMA
Shipments	**SUBATECH**
Global assembly	
Cone manufacturing	**SUBATECH**
Half MFT Assembly & test	**SUBATECH, IRFU, SAHA**, IPNL, PNPI, HIROSHIMA, LIMA
Services barrel, connections	**IPNL**
Integration in ALICE	
Insertion Tools	**IPNL**, SUBATECH
Barrel manufacturing	**IPNL**
Check-out in surface	**IPNL, IRFU, SUBATECH**
Installation in cavern	**IPNL, IRFU, SAHA, SUBATECH**

RESPONSIBILITY SHARING (UNDER DISCUSSION)

Readout electronics	
Printed Circuit Boards	**IPNL** , CCNU, IFIC
Data e-links	**IRFU, IPNL**, *in synergy with ITS*
Patch Panels equipped	**IPNL**
Optical fibers	**SAHA**, IPNL
Readout Units	**AMU, SAHA, IRFU, IPNL**, *in synergy with ITS*
Common Readout Units	**AMU,SAHA** *in synergy with ITS and ALICE Electronics coordination*
Services	
Power Distribution	**SUBATECH**, *in synergy with ITS*
Power Supplies	**SUBATECH**, *in synergy with ITS*
Power Regulations	**SUBATECH**, *in synergy with ITS*
Cooling & Ventilation Plants	**PNPI**, *in synergy with ITS*
DCS	**PNPI**, *in synergy with ITS*

CONCLUSIONS

- MUON physics will highly benefit from the addition of the MFT
  - Ψ' extraction down to zero p_T
  - J/Ψ from *b*-hadrons measurement
  - Open Charm/Beauty separation
  - Extract in-medium effects in Low Mass region

- TDR is under finalization
  - 1st collaboration round open until December 17th, 2014
    https://aliceinfo.cern.ch/ArtSubmission/node/871
  - Final document to be sent to LHCC second half of January 2015

- Contribution from Asia teams is under discussion