A Large Ion Collider Experiment

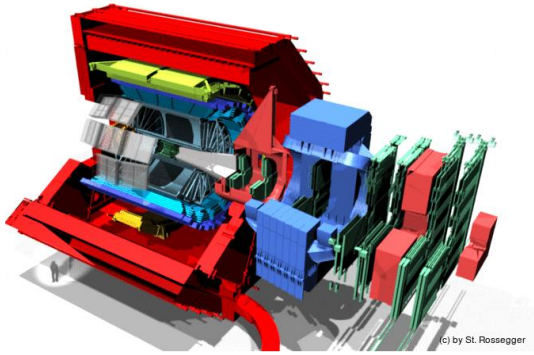
The ALICE Upgrade

W. Riegler, ECFA HL-LHC Experiment Workshop, Oct. 21st, 2014

ALICE Upgrade Strategy

Goal:

- High precision measurements of rare probes at low $p_{T,}$ which cannot be selected with a trigger. Target a recorded Pb-Pb luminosity $\geq 10\ nb^{-1}$ ➡ 8×10^{10} events to gain a factor 100 in statistics over the Run1+Run2 programme and
- Significant improvement of vertexing and tracking capabilities



Detector:

- Read out all Pb-Pb interactions at a maximum rate of 50kHz (i.e. $L = 6 \times 10^{27}\ cm^{-1}s^{-1}$) upon a minimum bias trigger
- Perform online data reduction based on reconstruction of clusters and tracks
- Improve vertexing and tracking at low p_T ➔ New Inner Tracking System (ITS)

ALICE Upgrade

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

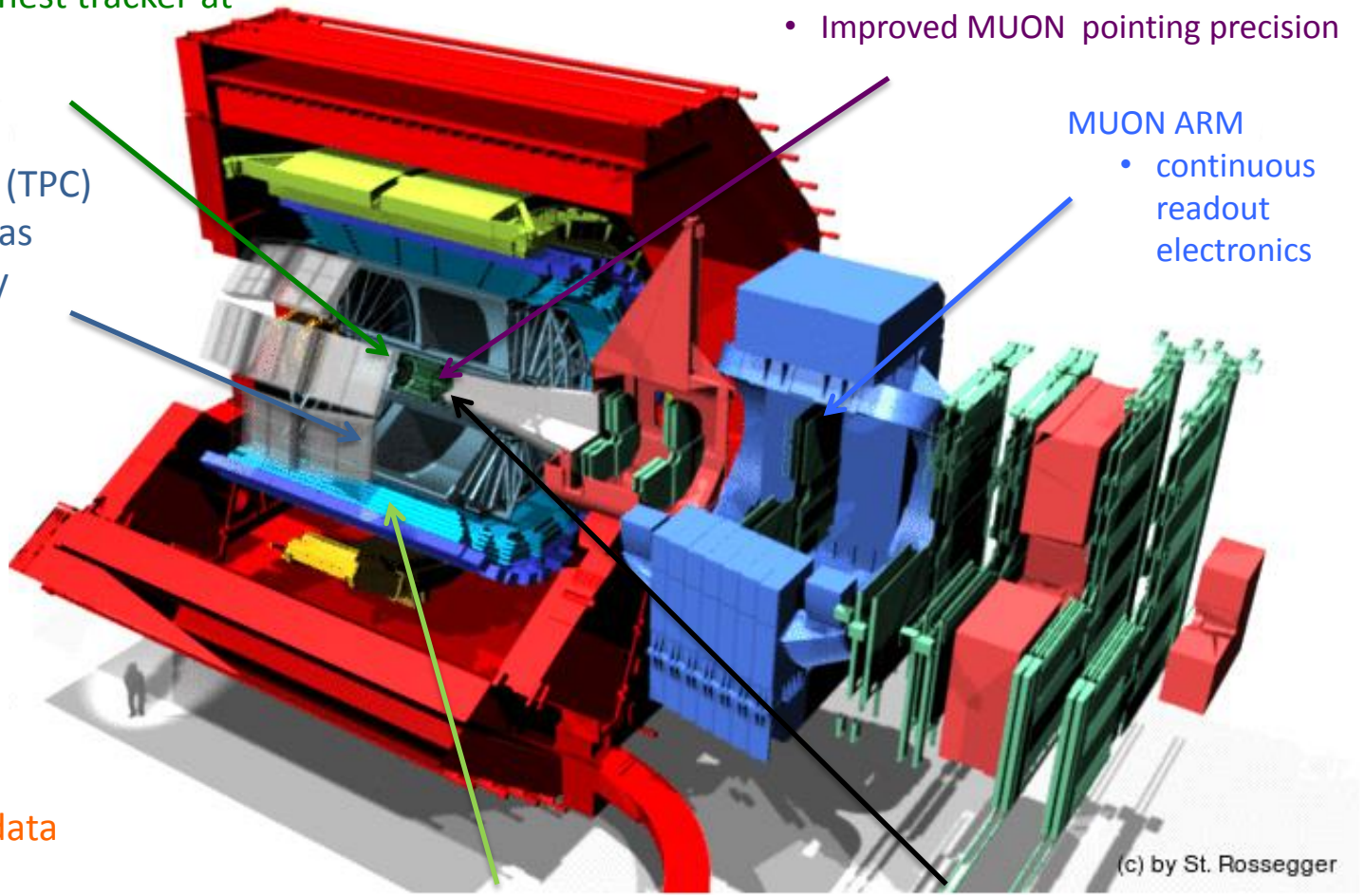
Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- New Micropattern gas detector technology
- continuous readout

New Central Trigger Processor (CTP)

Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate



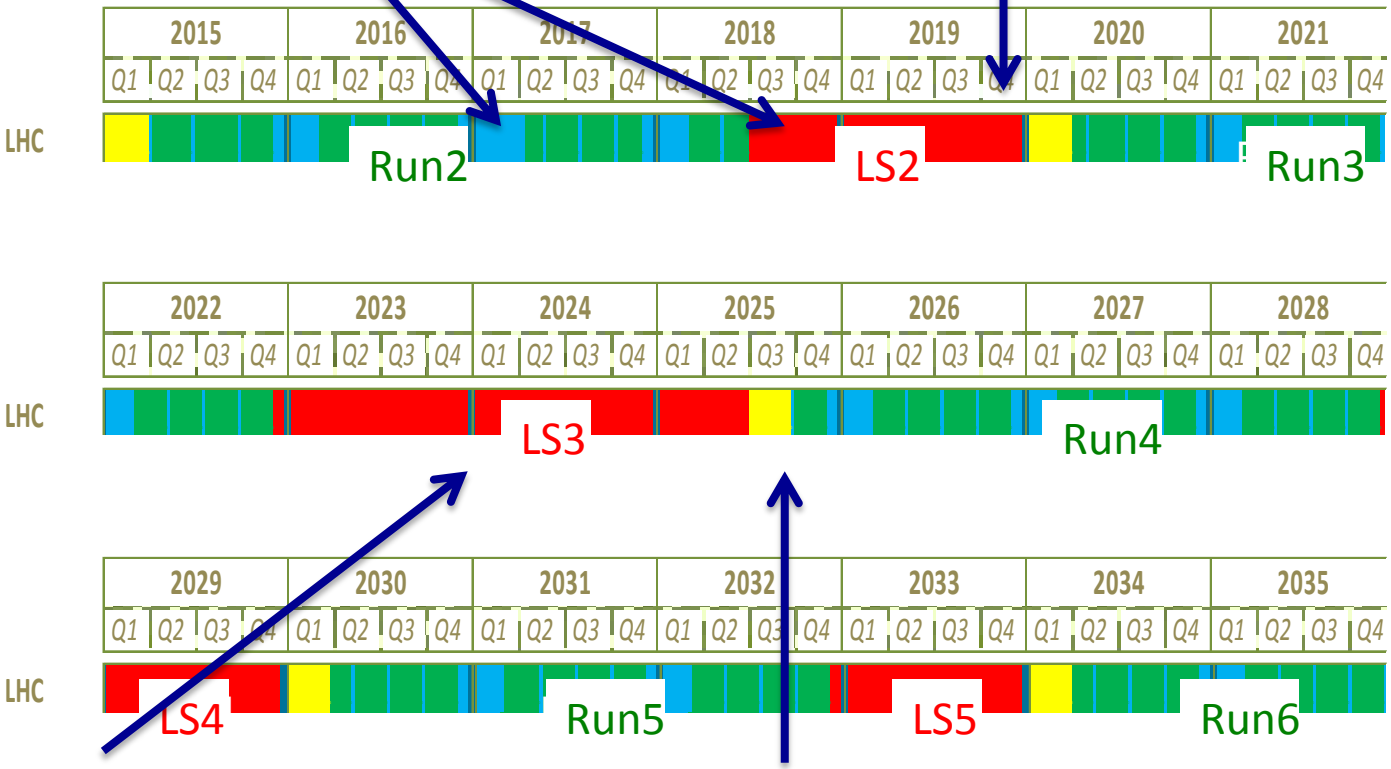
TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

Long Term Schedule

PHASE I Upgrade
ALICE, LHCb major upgrade
ATLAS, CMS ‚minor' upgrade

Heavy Ion Luminosity from 10^{27} to 7 x10^{27}



PHASE II Upgrade
ATLAS, CMS major upgrade

HL-LHC, pp luminosity from 10^{34} (peak) to 5 x10^{34} (levelled)

ALICE will operate beyond LS3 in the HL-LHC era

Vacuum in Long Straight Sections around P2

Vaccum pressure in LSS around ALICE of 2.3×10^{-8} mbar during Run1 pp resulted in excessive radiation load on the detector through beam-gas collisions

→ even if the IP collision rate in ALICE is low, the detector is exposed to radiation load from these beam-gas collisions.

In order to ensure that the radiation load due to beam gas collisions does not exceed the radiation load from genuine IP collisions during Run3+Run4, the vacuum pressure in the LSS must be $<10^{-9}$mbar.

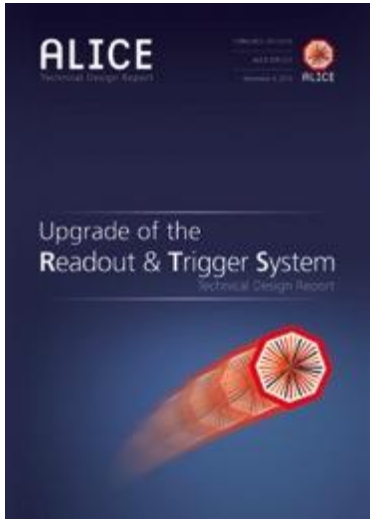
→ LS1 vacuum consolidation (ZDC vacuum Chamber, TDI) is hopefully going in the right direction

→ Replacement of TDI in LS2 might be essential

ALICE LS2 Scope

The approved ALICE LS2 upgrade is detailed in 5 Technical Design Reports

- **ITS**
- **Readout and Trigger System**
- **TPC (under review)**
- **MFT (Nov. 2014)**
- **Online Offline System (Jun. 2015)**



ALICE Upgrade

New Inner Tracking System (ITS)
- **improved pointing precision**
- **less material**

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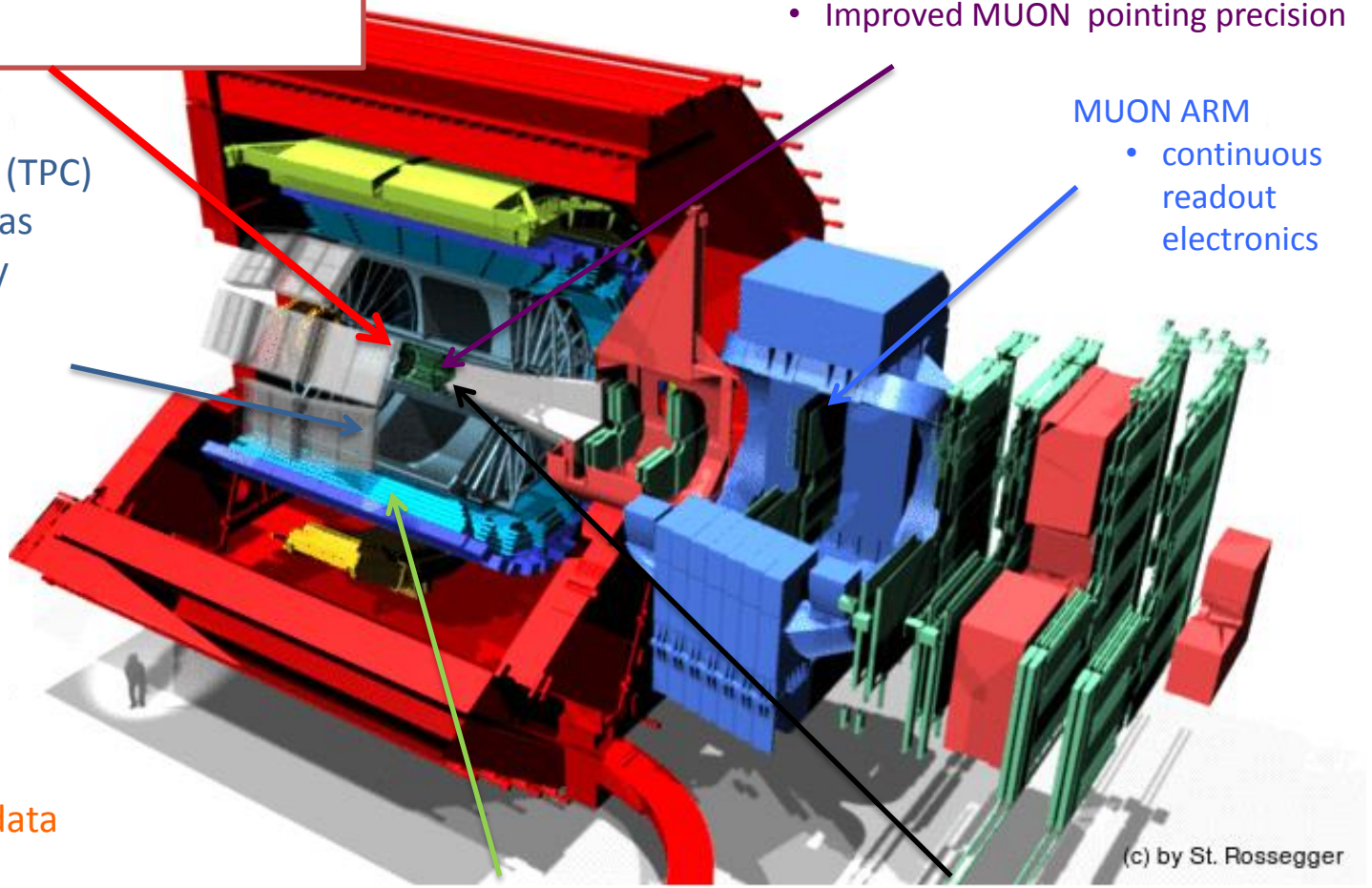
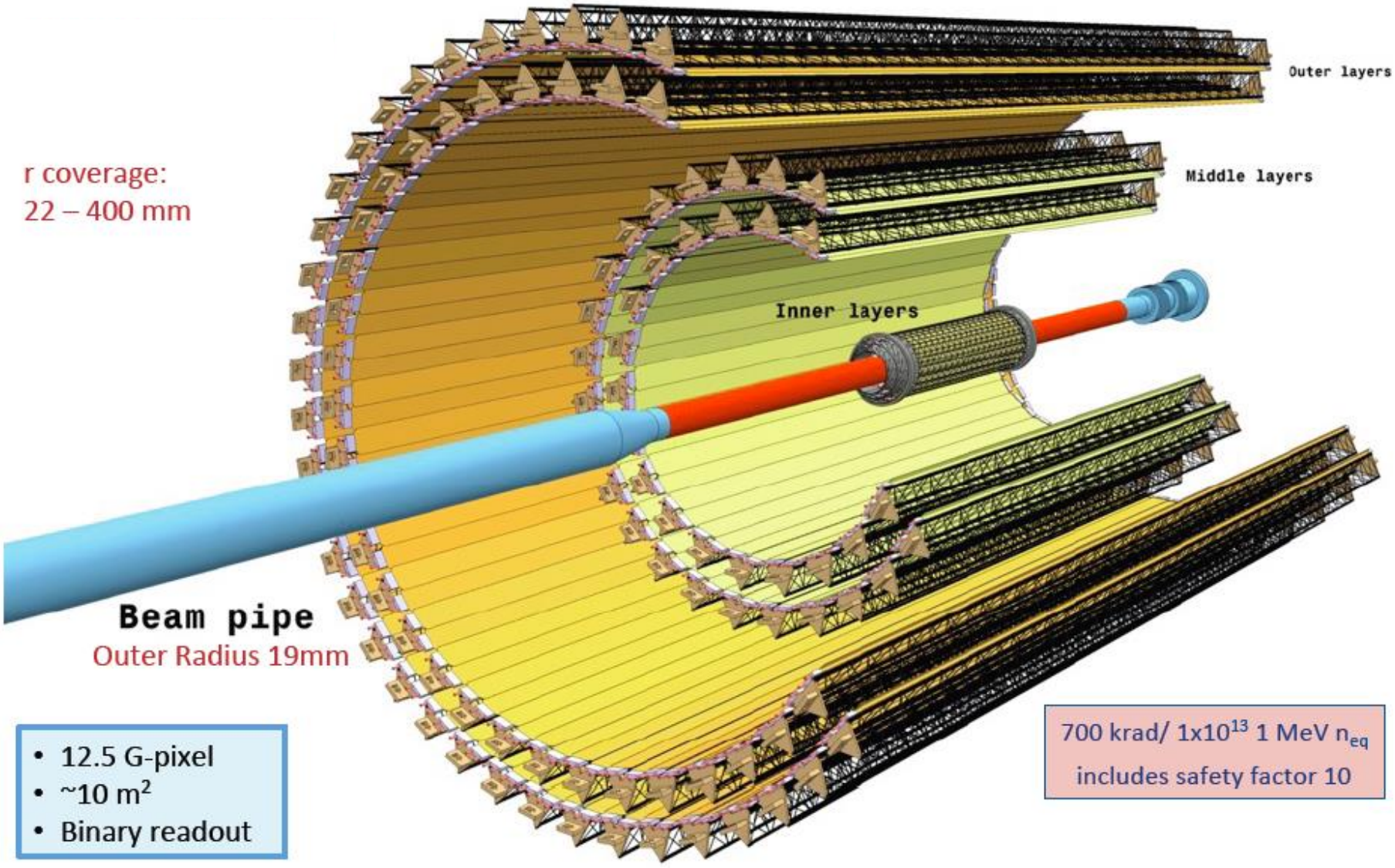


TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

7 layers of Monolithic Active Pixel Sensors

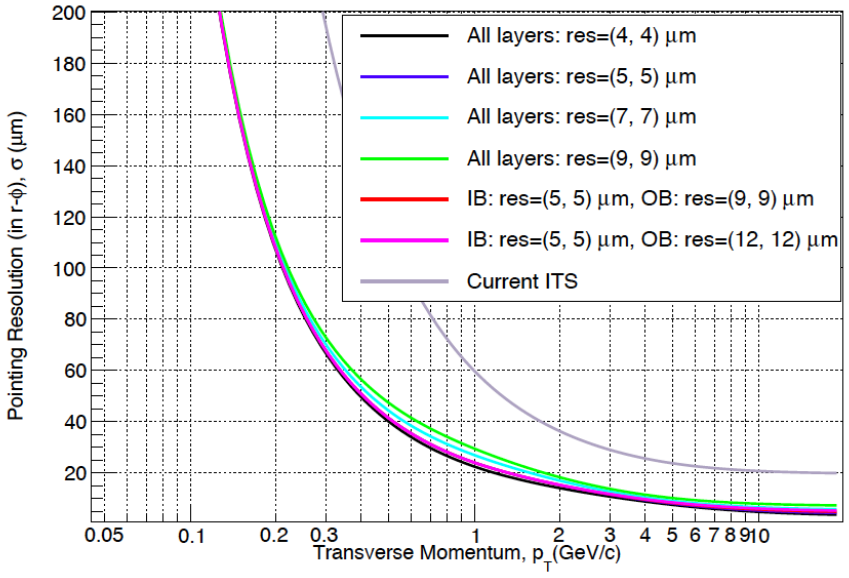
r coverage:
22 – 400 mm

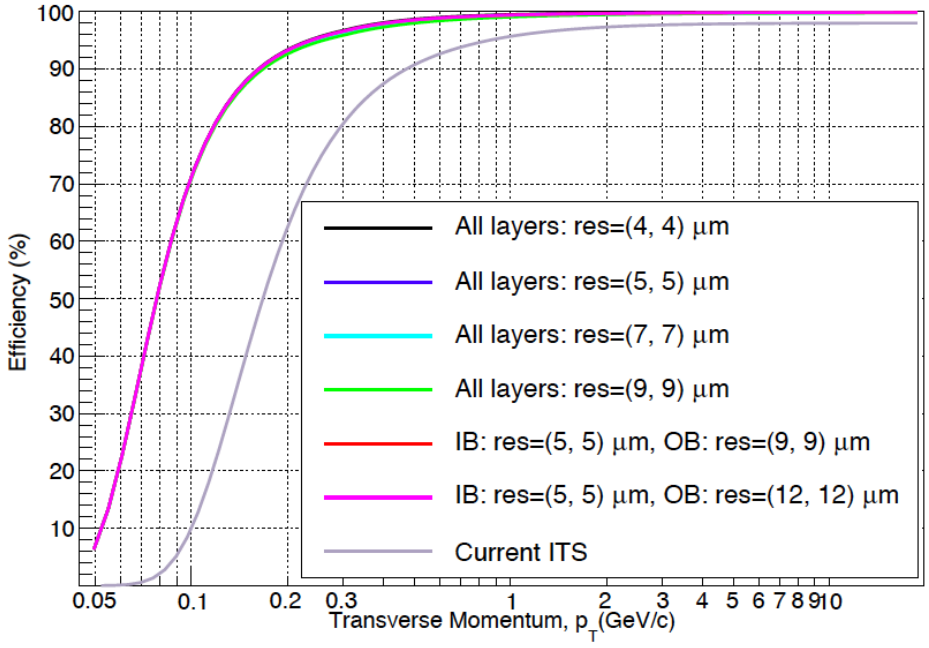


- 12.5 G-pixel
- ~10 m^2
- Binary readout

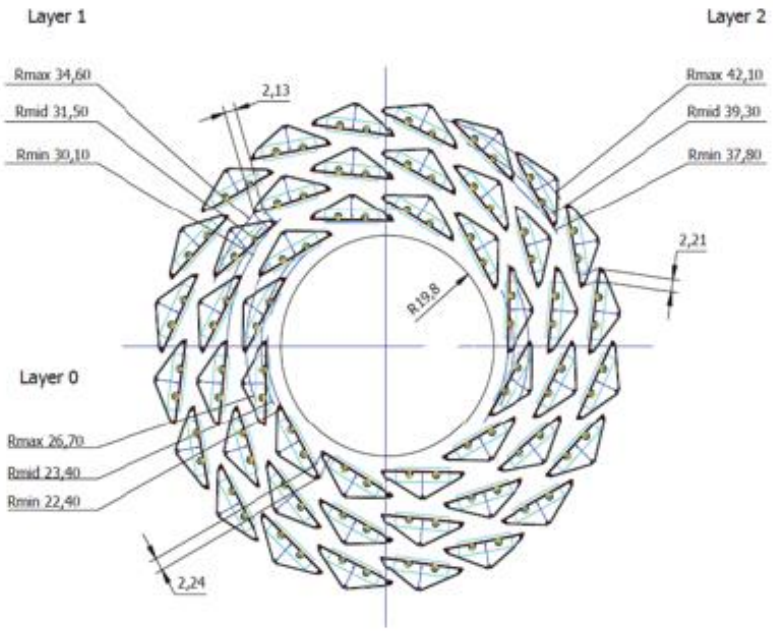
700 krad/ $1x10^{13}$ 1 MeV n_{eq}
includes safety factor 10

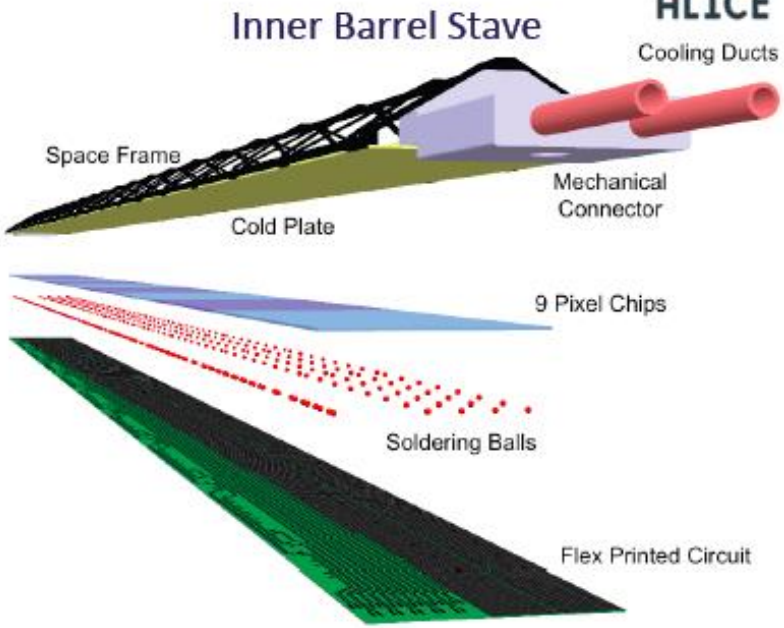
ITS performance improvement





Inner Barrel





Inner Barrel (IB): 3 Inner Layers

Radial position (mm): 23, 31, 39

Length in z (mm): 271

Nr. of staves: 12, 16, 20

Nr. of modules/stave: 1

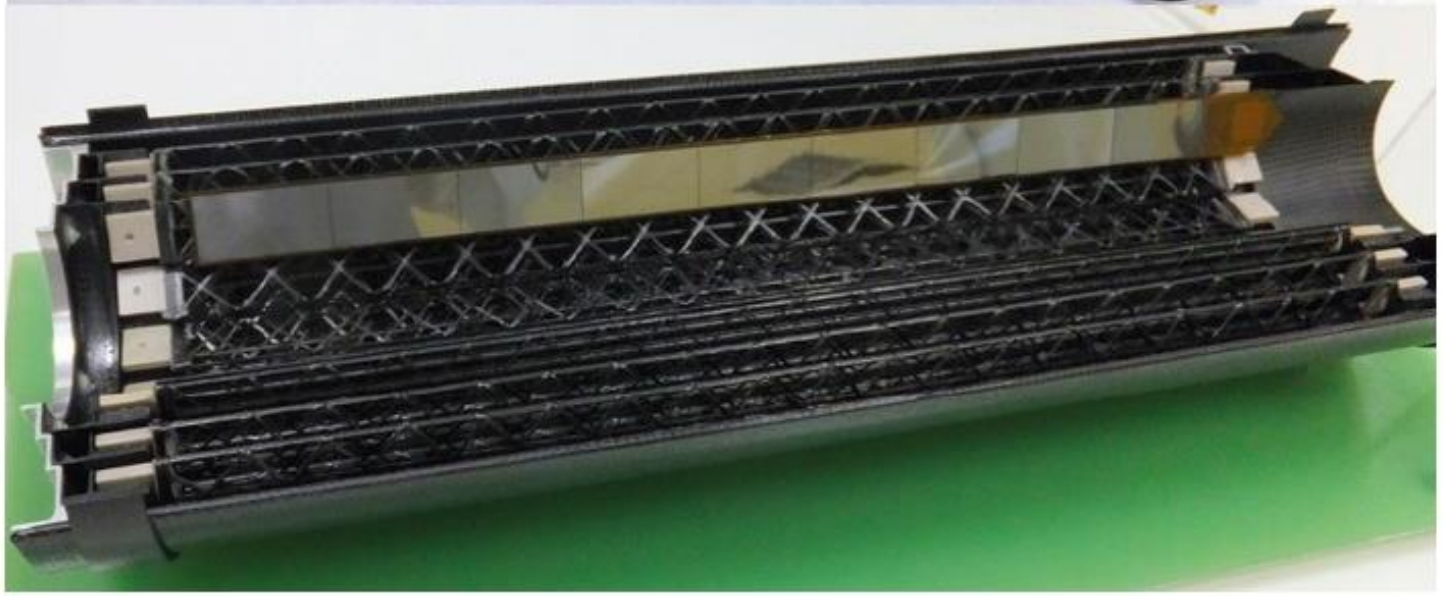
Nr. of chips/module: 9

Nr. of chips/layer: 108, 144, 180

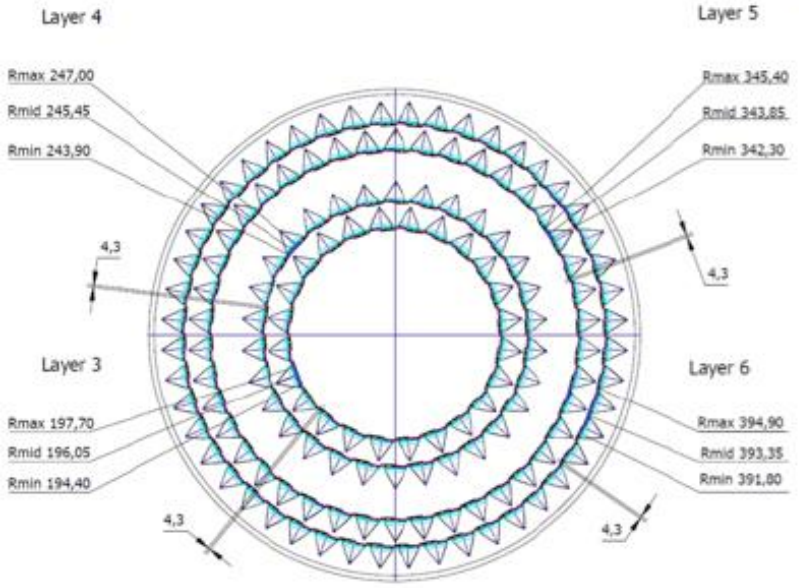
Material thickness: $\leq 0.3\%\ X_0$ per layer

Stave weight
~ 1.4 grams

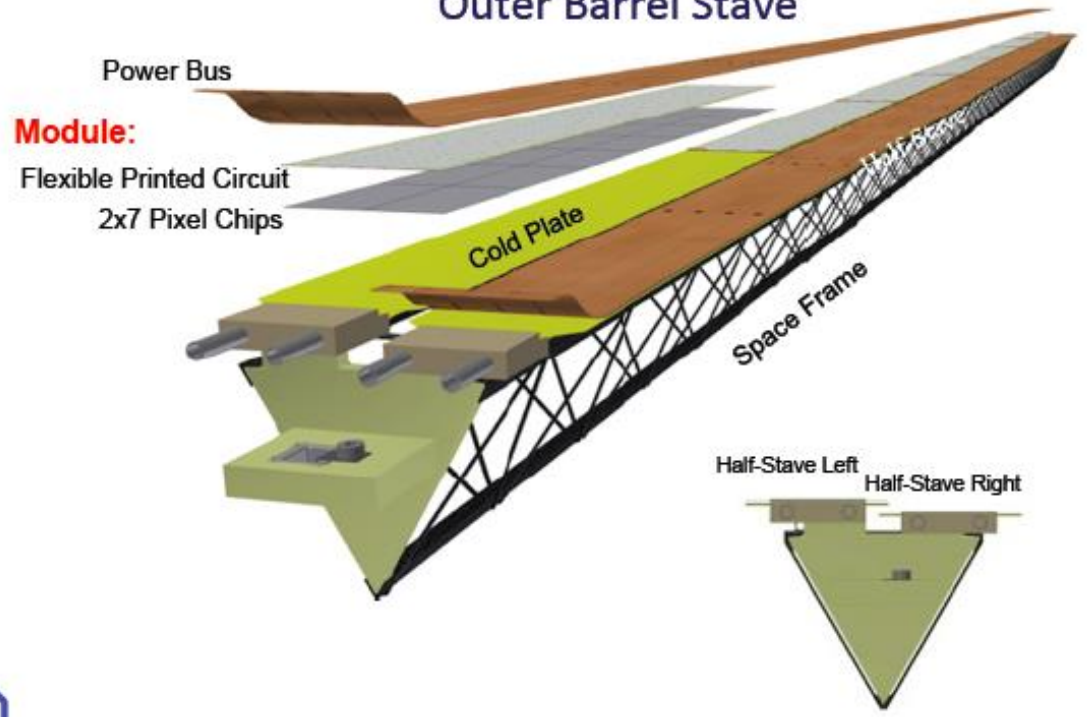
Inner Barrel: full-scale prototypes of the mechanical structures



Outer Barrel



Outer Barrel Stave

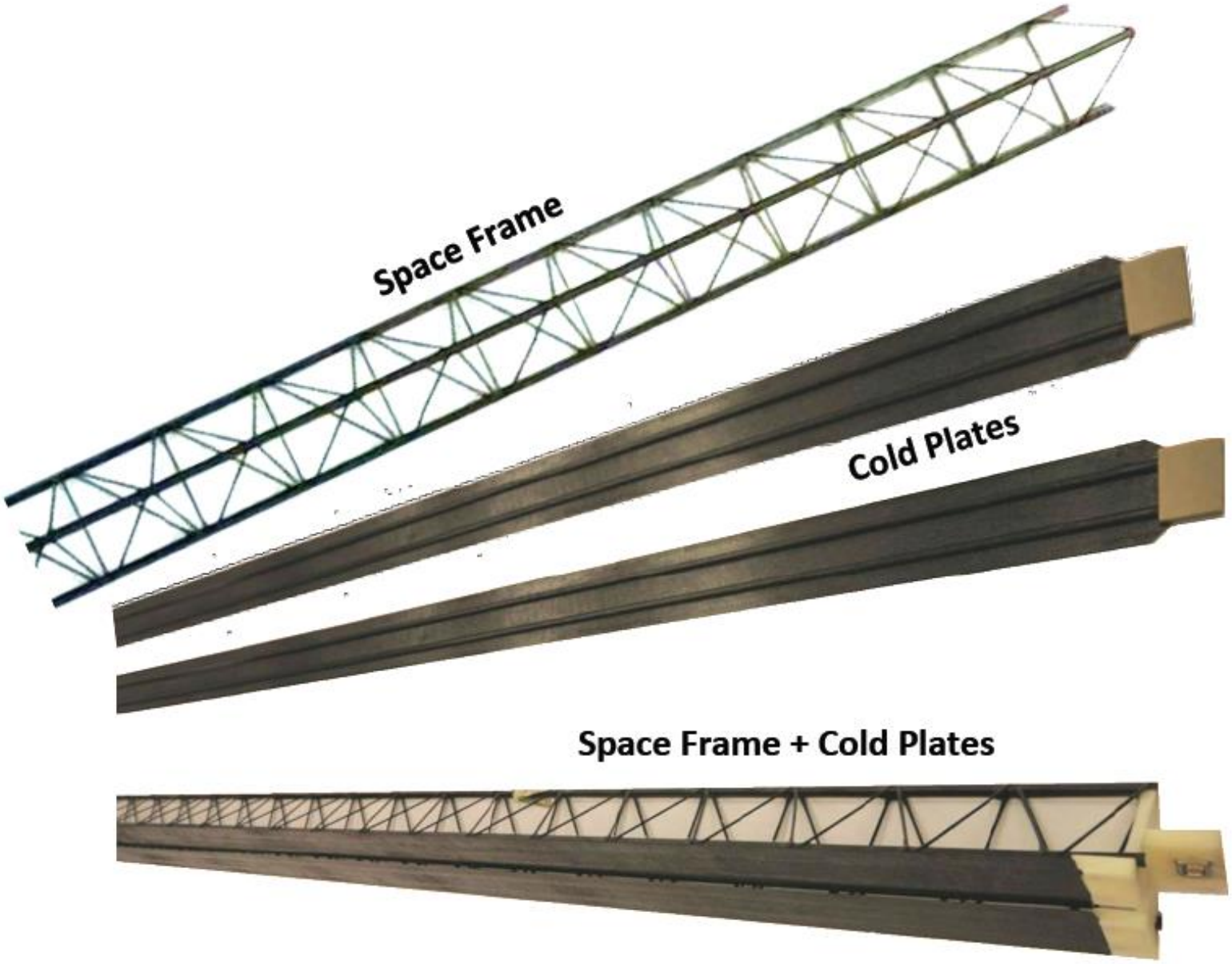


Outer Barrel (OB): 2 ML + 2 OL

Radial position (mm): 196, 245, 344, 393
Length in z (mm): 843, 1475
Nr. of staves: 24, 30, 42, 48
Nr. of half-staves/stave: 2
Nr. of modules/half-stave: 4 (ML), 7 (OL)
Nr. of chips/module: 14
Nr. of chips/layer: 2688, 3360, 8232, 9408
Material thickness: ~ 0.9% X_0 per layer

Module to Module and Power Bus connections

Outer Barrel: full-scale prototypes of the mechanical structures

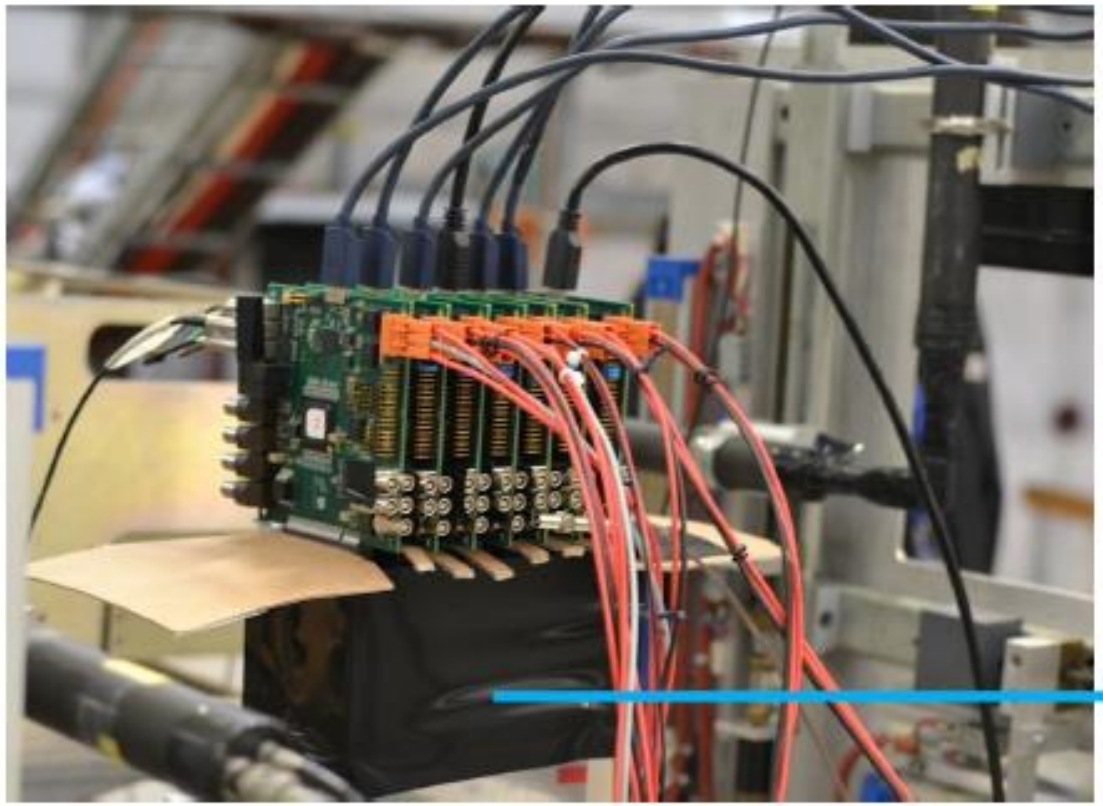


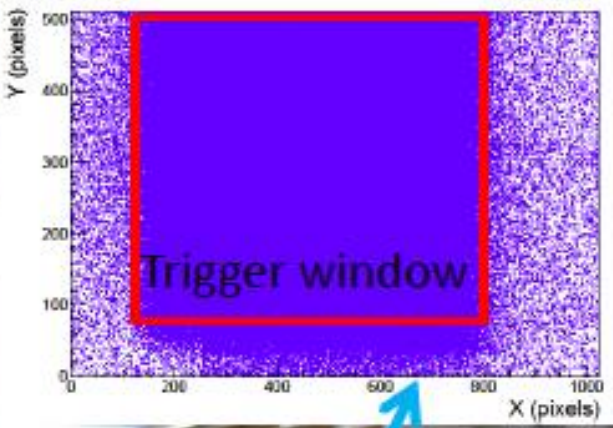
Status of ITS CMOS Pixel Sensor

Internal Architecture (two options)

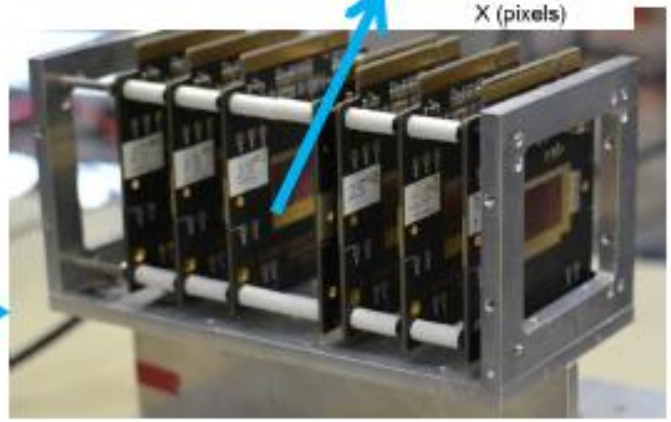
- ALPIDE
  - Specs comply with Inner Barrel and Outer Barrel
  - Pixel Size: 28μm x 28μm Integration time: ~4μs
  - Power density : 40 mW/cm^2
- MISTRAL (more conservative approach)
  - Specs optimized for OB (L3-L6)
  - Pixel Size: 36μm x 62μm Integration time: ~20 μs
  - Power density: ~ 100 mW/cm^2
- Full scale prototype of ALPIDE and MISTRAL are currently being characterized in the laboratory and test beam
- Preliminary very encouraging

pALPIDEfs – measurements at PS test beam



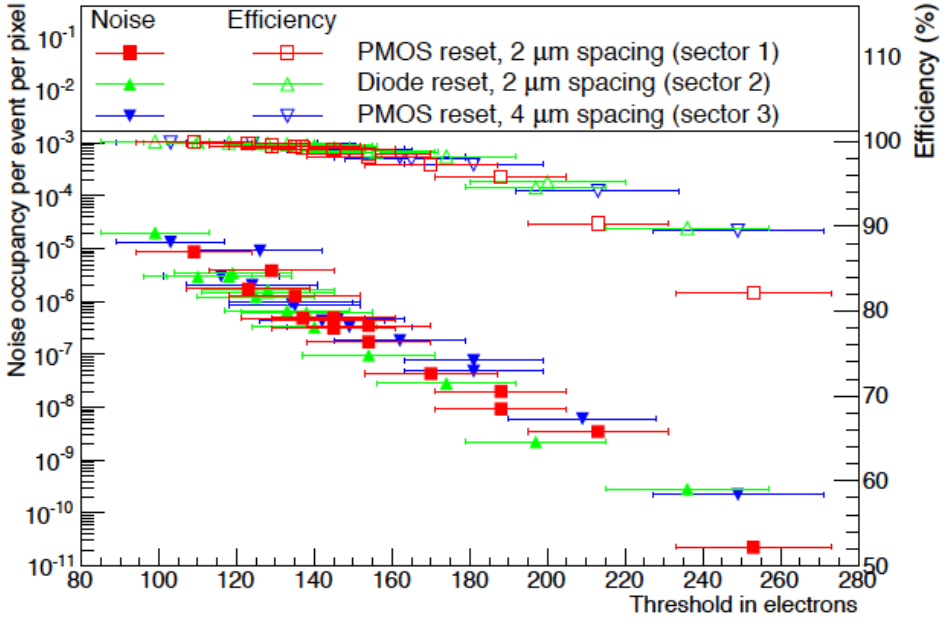


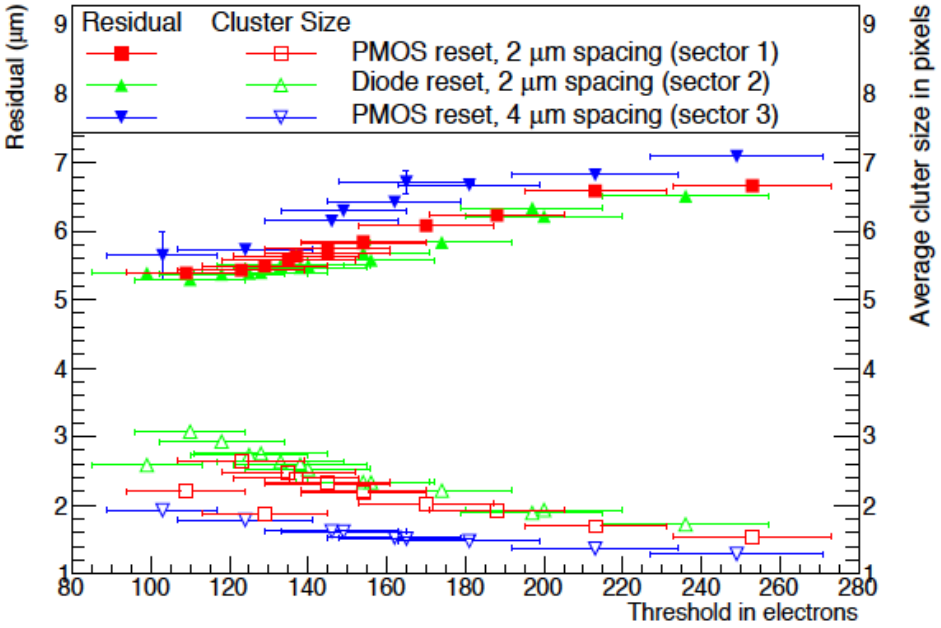
hit map

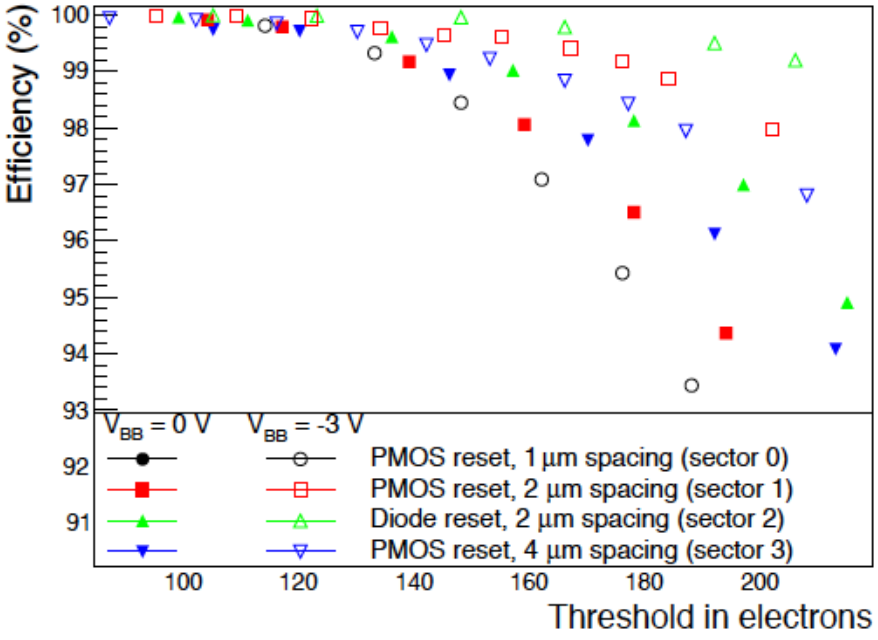


- Four weeks of test beam at the PS (5 – 7 GeV pions)
- Telescope based on a stack-up of 6 or 7 layers of pALPIDEfs
- Tested both thinned (50μm) and thick (450μm) chips
- 0V and 3V reverse substrate bias (measurem. at -6 V and after irradiation ongoing)
- Comprehensive characterization will continue at PS and in October at SPS

pALPIDEfs – measurements at PS test beam







- 99% efficiency at fake hit rate of 10^{-5} achievable (only 20 pixels masked) at 0V
- Reverse substrate bias (V_{BB}) provides additional margin
- Telescope based on a Stack-up of 6 or 7 layers of pALPIDEfs
- Spatial resolution (including tracking error of ~3µm): 5.5 µm

FSBB-M0 – Full Scale Building Block of MISTRAL

FSBB-M0 (Full Scale Building Block Mistral 0)

- About 1/3 of a complete sensor (approx. 9mm x 17mm)
- 416 x 416 pixels of 22µm x 33µm (final chip 36µm x 62µm)
- 40µs integration time
- Full chain working (front-end, discr., zero suppression)
- 25 sensors characterized showing similar noise perfor.
- Test beam measurements at SPS in October

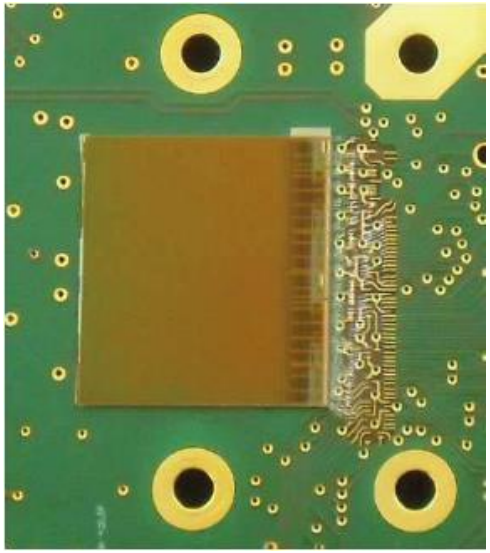
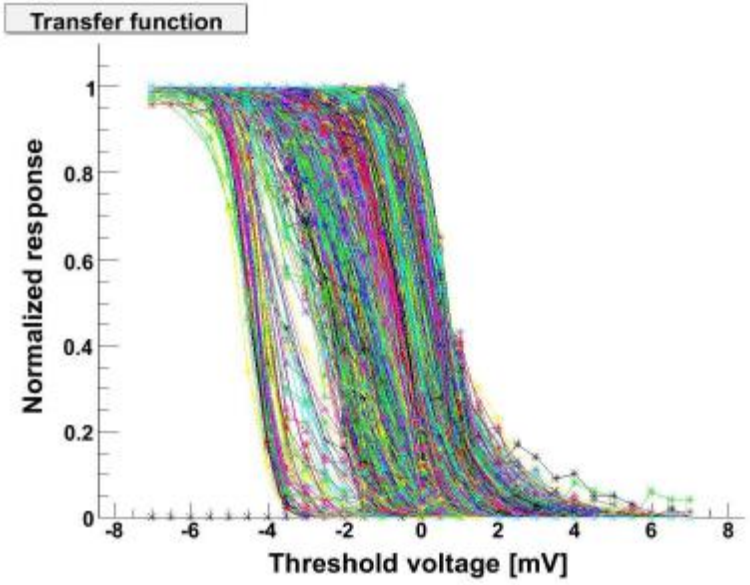
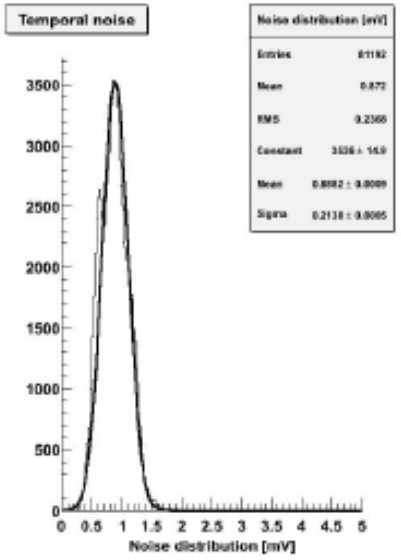


Figure: Two FSBB M0

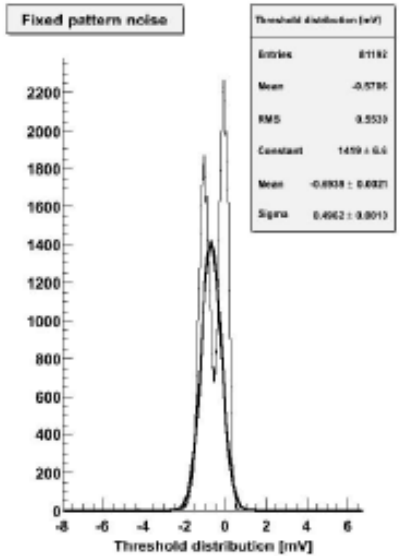
TN = 0.87mV

FPN = 0.55mV





Temporal Noise



Fixed Pattern Noise

ALICE Upgrade

Muon Forward Tracker (MFT)
- **new Si tracker**
- **Improved MUON pointing precision**

New Inner Tracking System (ITS)
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- less material -> thinnest tracker at the LHC

Time Projection Chamber (TPC)
- New Micropattern gas detector technology
- continuous readout

MUON ARM
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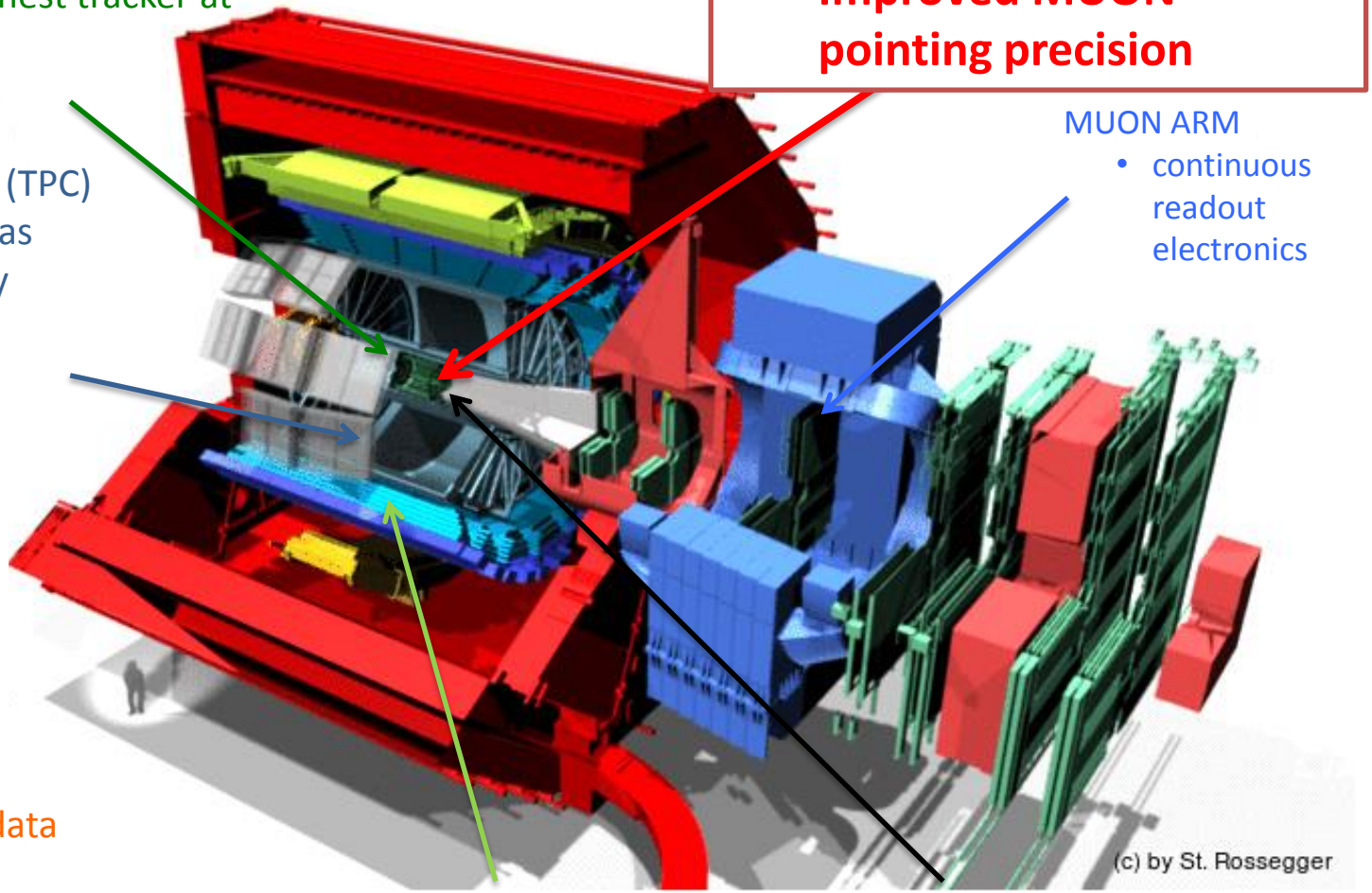
New Central Trigger Processor (CTP)

Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate



TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

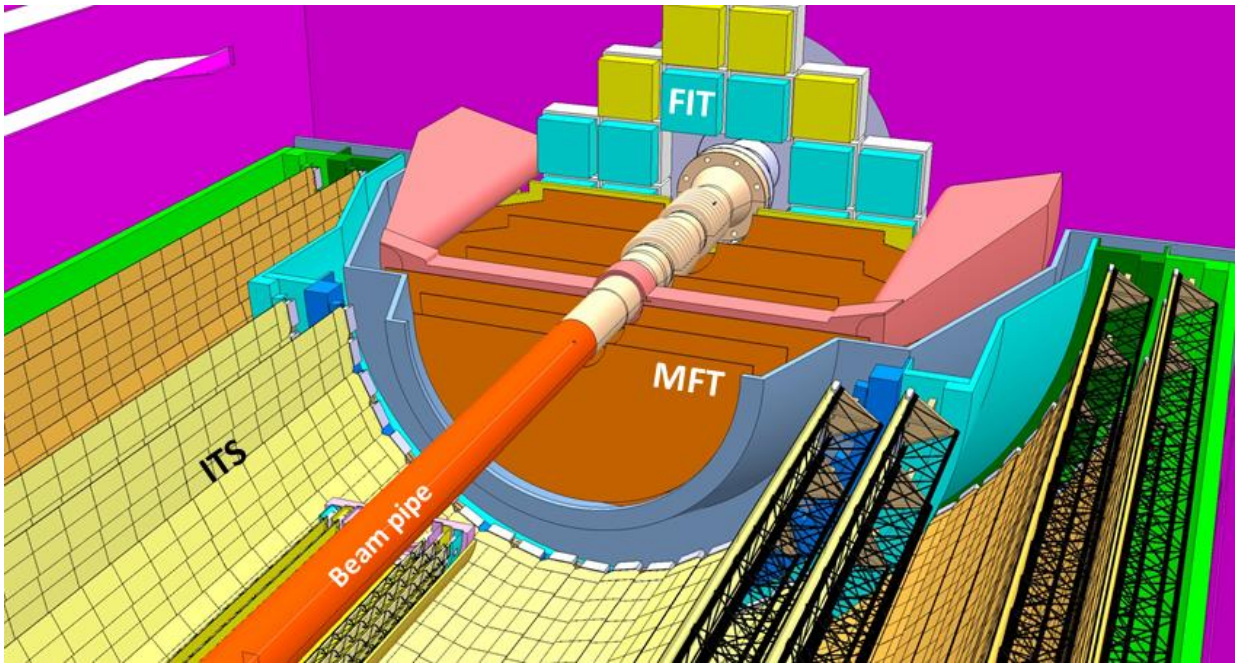
Muon Forward Tracker (MFT)

The primary goal of the Muon Forward Tracker (MFT) is to measure muon tracks in the ALICE muon spectrometer acceptance with high precision vertexing before the large absorber.

The MFT is a silicon pixel tracker complementing the acceptance of the ALICE upgraded Internal tracking system (ITS) and covering most of the acceptance of the muon spectrometer $2.5<\eta<3.6$.

The MFT detector is placed inside the ITS outer barrel, between the ITS inner barrel and the absorber and surrounding the ALICE vacuum beam-pipe.

Common Silicon Sensor with ITS (15 mm x 30 mm)



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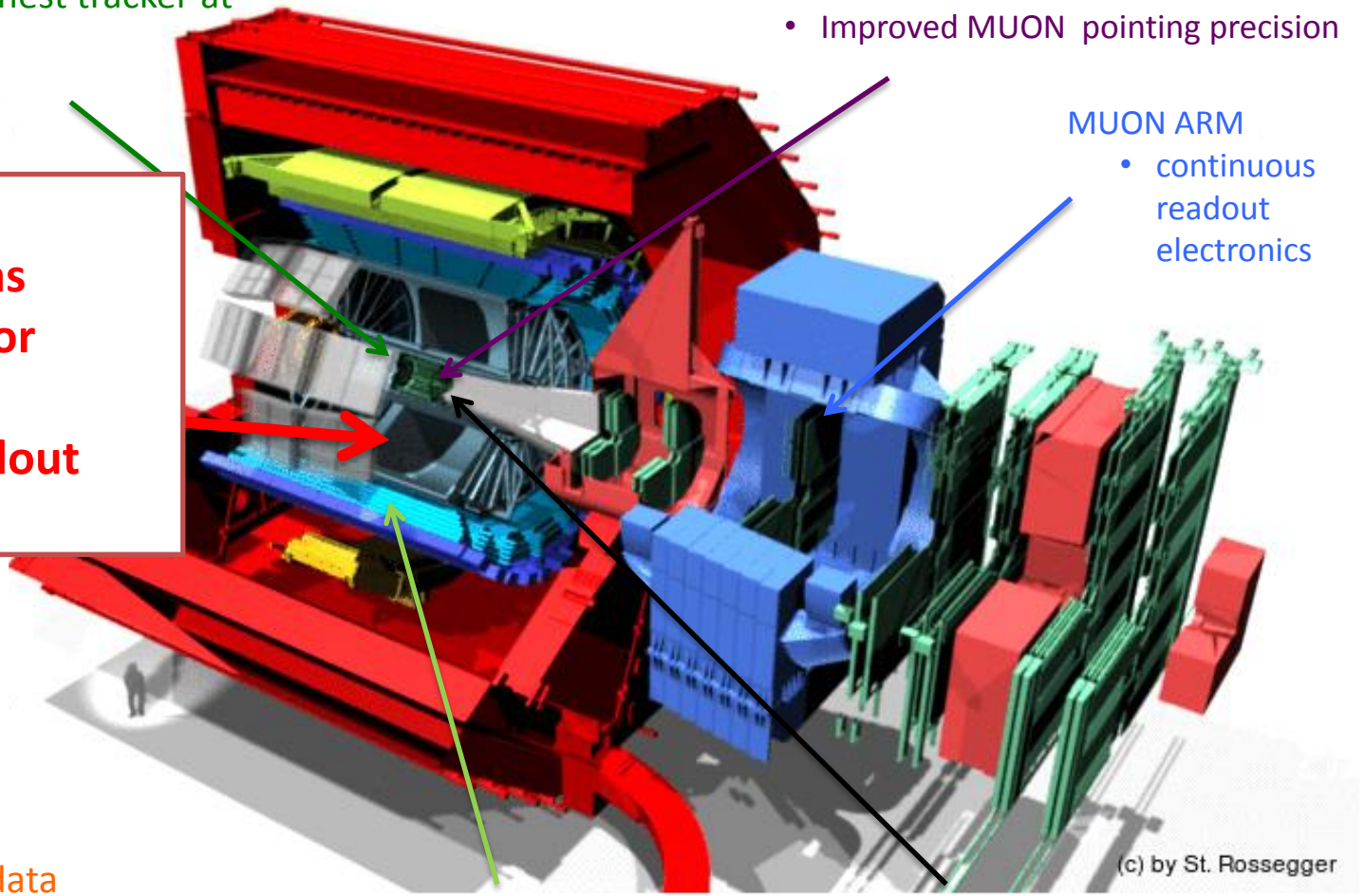
TPC
- **Micropattern gas detector detector technology**
- **continuous readout**



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- new architecture
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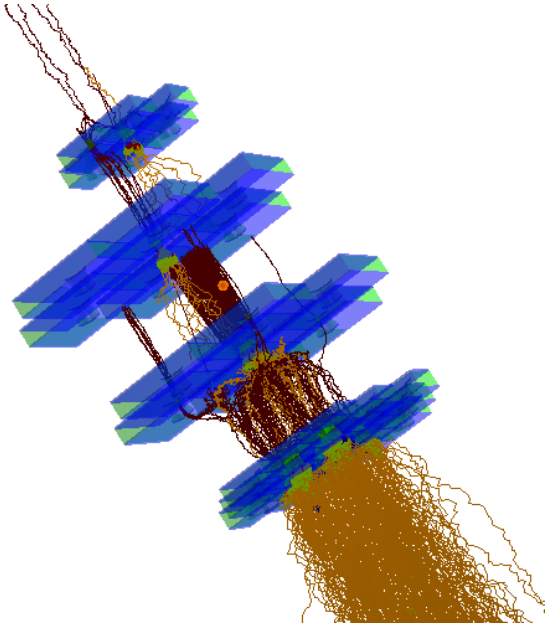
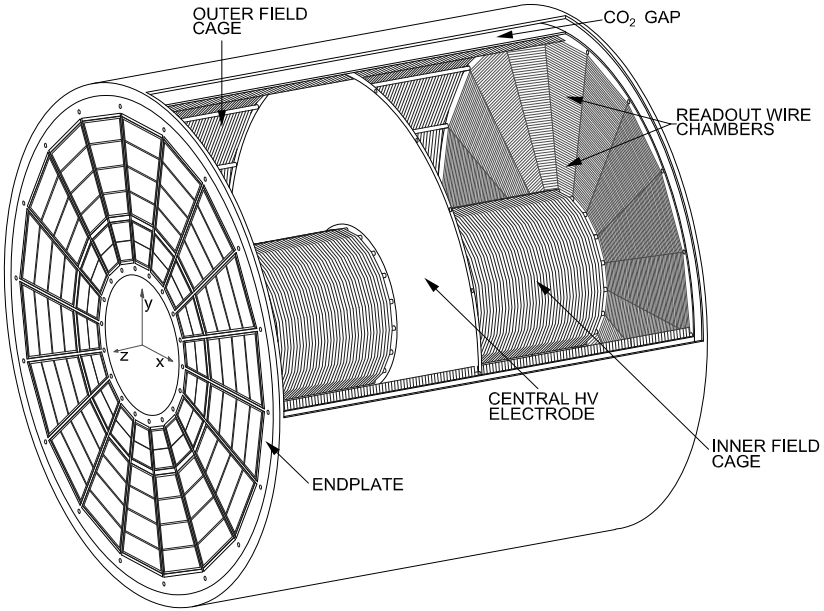
TPC Upgrade

With an average of 5 PbPb collisions inside the drift time of 100us, the classic gating of TPC wire chambers does not work.

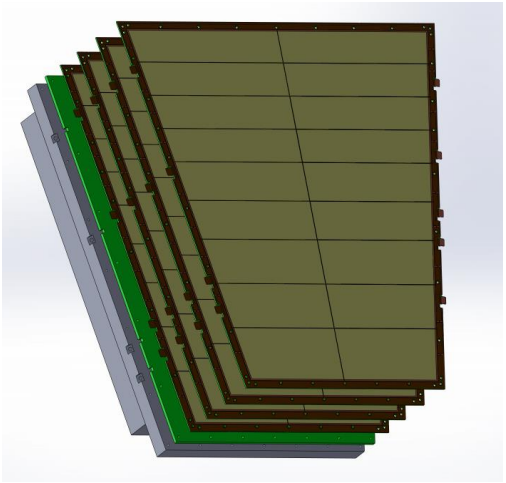
Replace wire chambers
with 4-GEM or Micromega+2 GEM

Specified to have <20 Ions flowing back into the TPC volume for every primary electron being amplified, i.e. ion back flow (IBF) of <1% for a gas gain of 2000





Exploded view of a GEM IROC

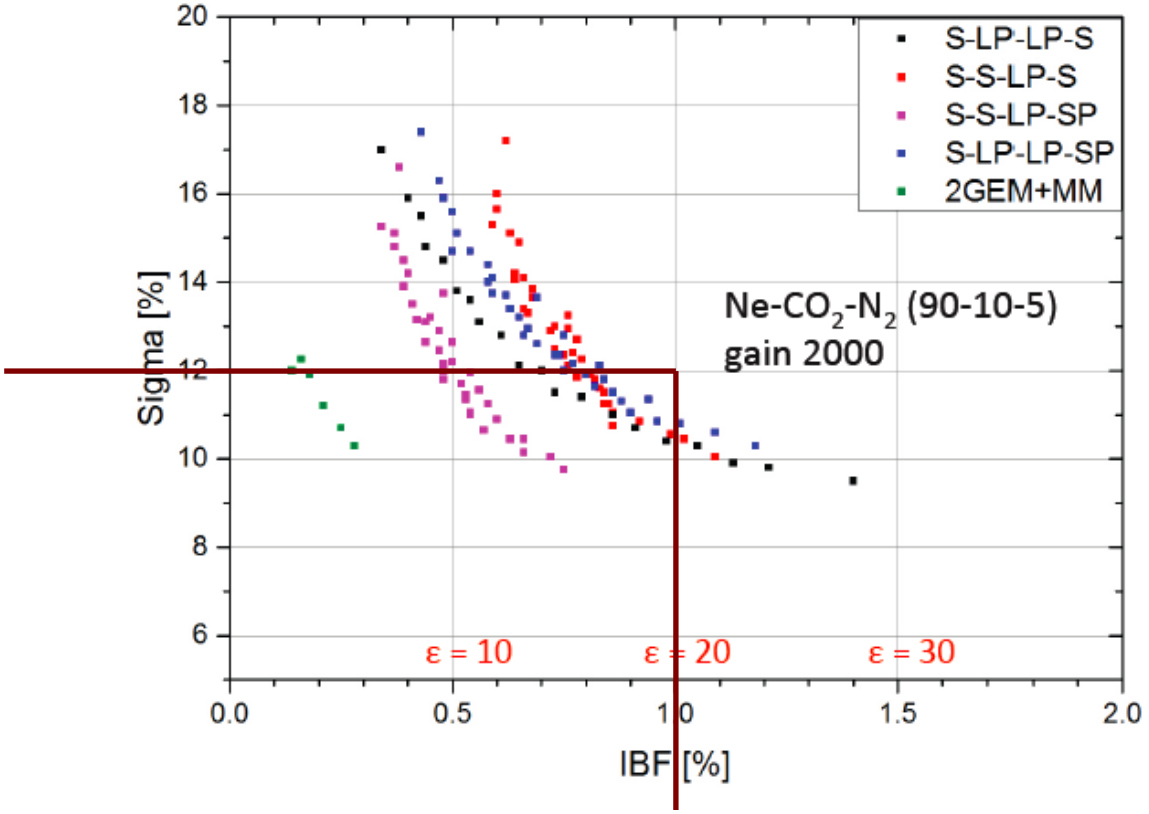


TPC Upgrade

ALICE

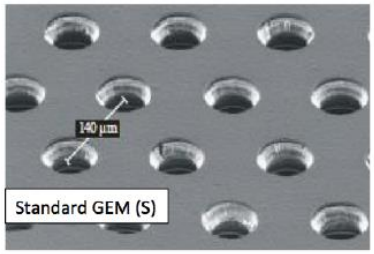
4GEM small prototypes

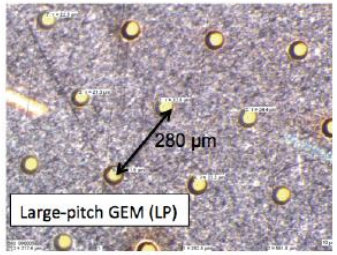
present status

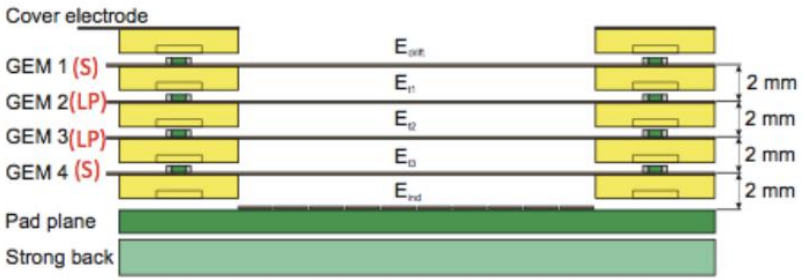


GEM holes:
Diam: 70um

Distance:
SP: 90um
S: 140um
LP: 280um







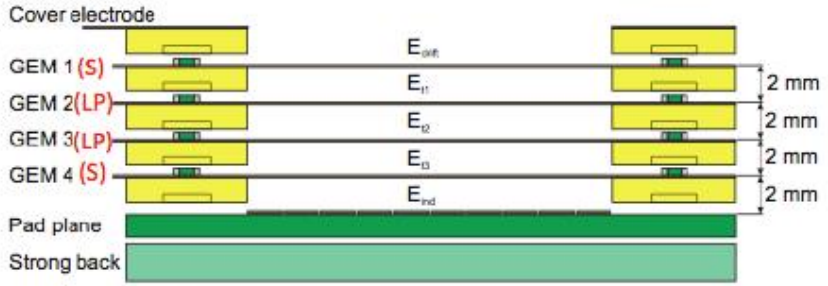
TPC Upgrade

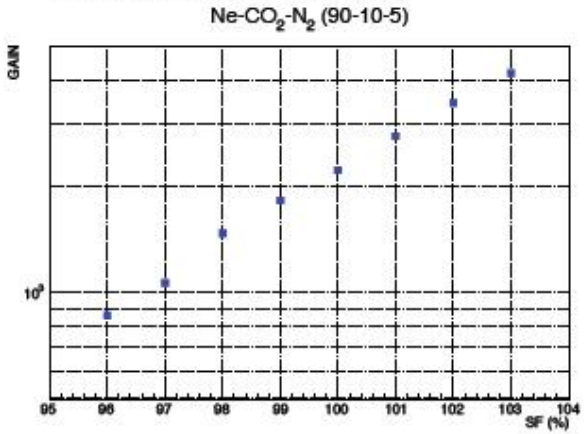
A Large Ion Collider Experiment

ALICE

4GEM IROC prototype

- 4 single-mask GEMs: S-LP-LP-S configuration
- Prototype ready in August 2014
- Commissioning with ^{55}Fe source
  - Baseline HV settings
  - Gain curve
  - Energy resolution ($\sigma_E/E \approx 12\%$ at G=2000 w/o corrections)
- To do:
  - Gain scan with multi-channel readout
  - Stability studies with ^{220}Rn source
  - Install FEE for test beam
  - Readout commissioning





Testbeam: PS Nov. 2014, SPS Dec. 2014

TPC Upgrade

A Large Ion Collider Experiment

ALICE

2GEM+MM IROC prototype

detector concept:

- pre-stretched Micromegas (400 LPI) with pillars and a spacer frame (128 µm) glued on top of a spare IROC alubody+padplane (same as for 4GEM IROC)
- 2 standard (pitch = 140 µm) IROC GEMs mounted (screwed/glued) on top

planned for the test-beam campaign for a direct comparison with 4GEM IROC

status:

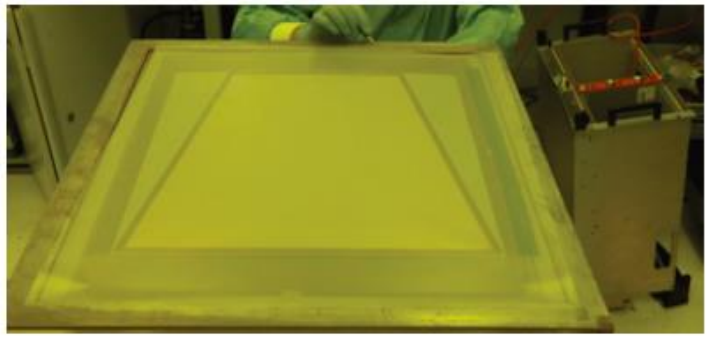
alu-body + pad plane:

- wires and frames removed, feed-throughs drilled
- pad plane polished and cleaned

GEMs

- framed

mesh gluing



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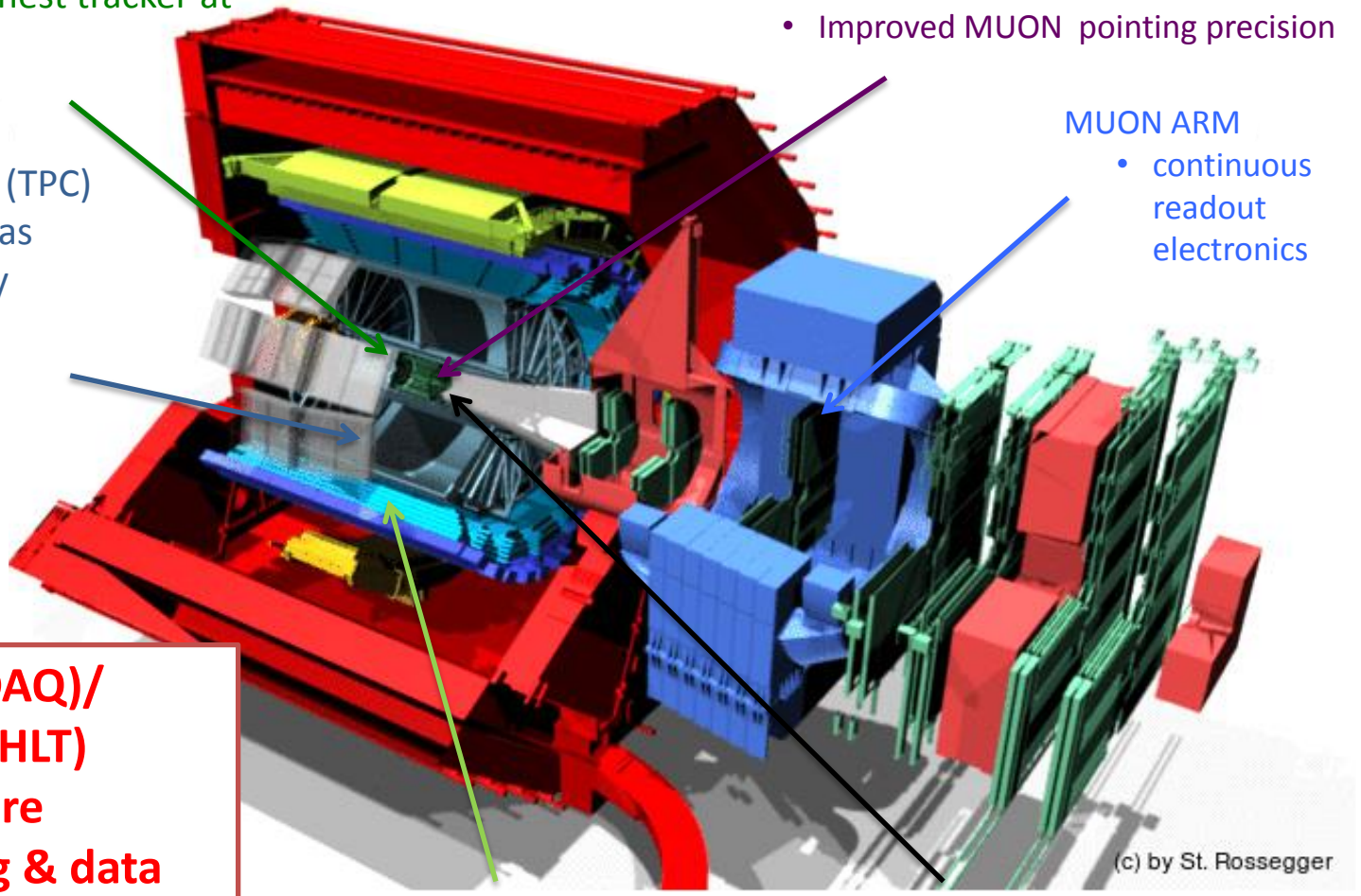

Data Acquisition (DAQ)/ High Level Trigger (HLT)
- **new architecture**
- **on line tracking & data compression**
- **50kHz PbPb event rate**

TOF, TRD
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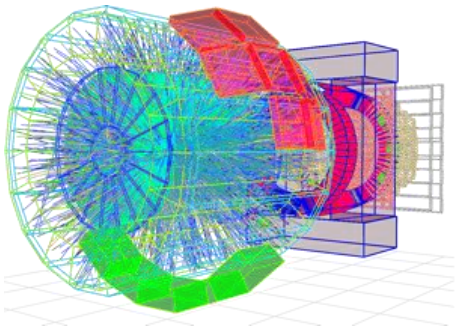
New Trigger Detectors (FIT)

ALICE & LHCb in 2018



50 kHz

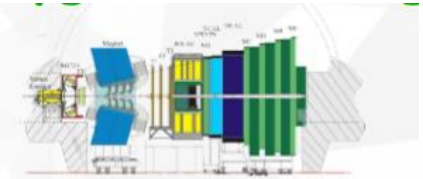
Reconstruction + Compression

Storage

75 GB/s

1 TByte/s into PC farm

O^2 (Online Offline) System



40 MHz

DAQ

40 MHz

LLT: μ,e/γ, hadrons

5-40 MHz

HLT: event recon.

50 kHz (1.5 MB/event)

Storage

2 GB/s

4 TByte/s into PC farm

← PEAK OUTPUT →

ALICE Upgrade

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

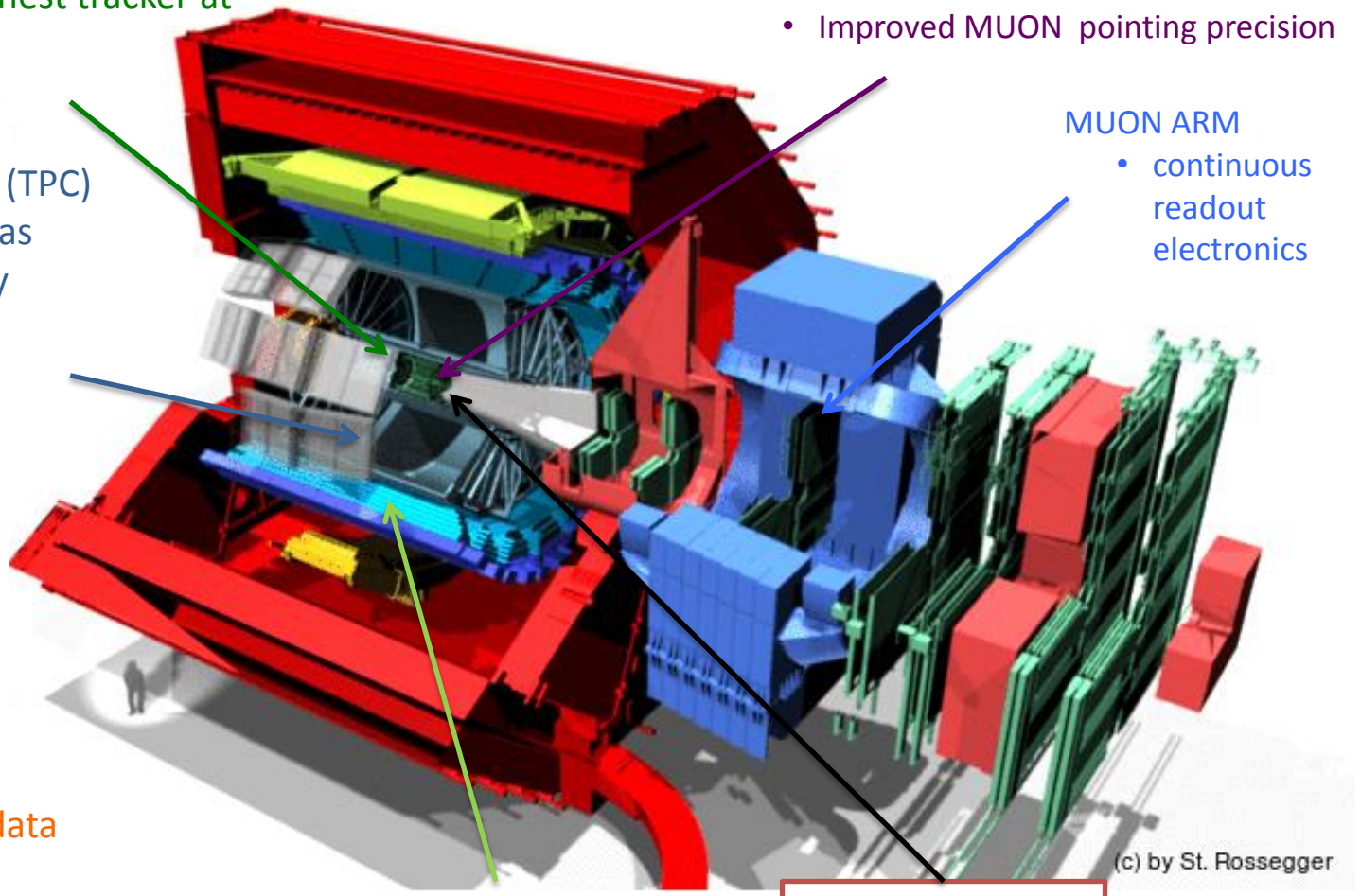
Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

MUON ARM
- continuous readout electronics

Time Projection Chamber (TPC)
- New Micropattern gas detector technology
- continuous readout

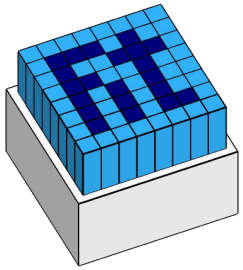
New Central Trigger Processor (CTP)

Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate



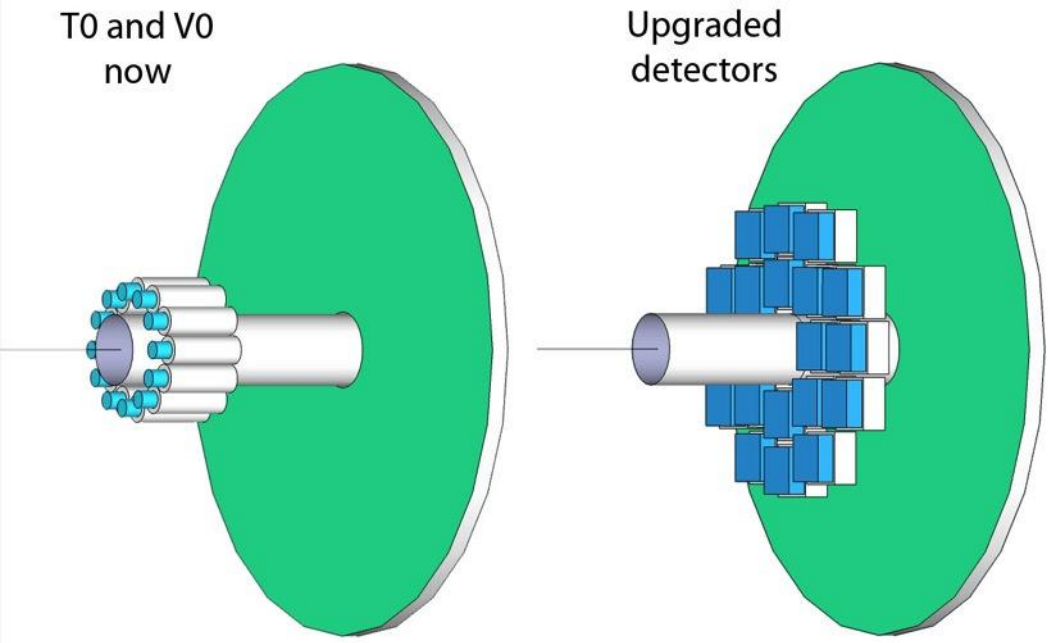
TOF, TRD
- Faster readout

New Trigger Detectors (FIT)



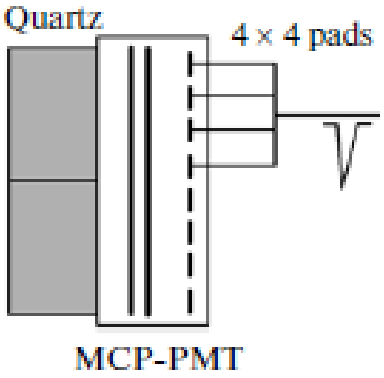
Fast Interaction Trigger (FIT)

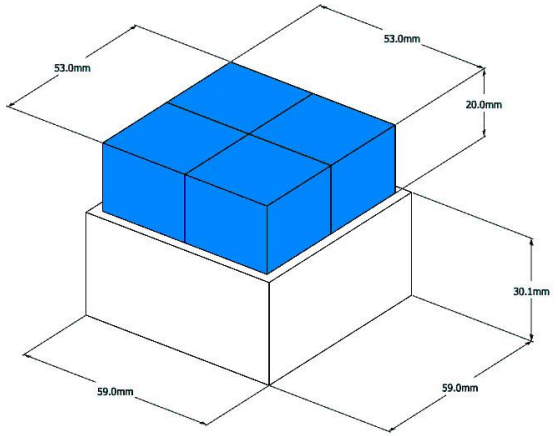
Upgraded Quartz Cherenkov (T0+) and Plastic Scintillator (V0+)



1 pixel per T0 module

4 pixels per T0+ module

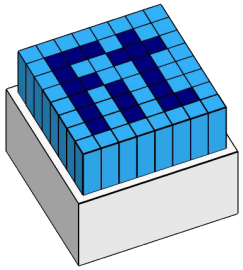




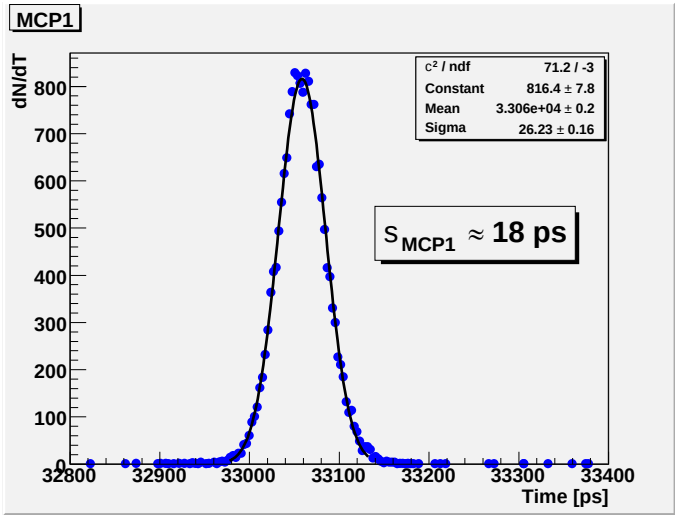
FIT: T0+ Prototypes

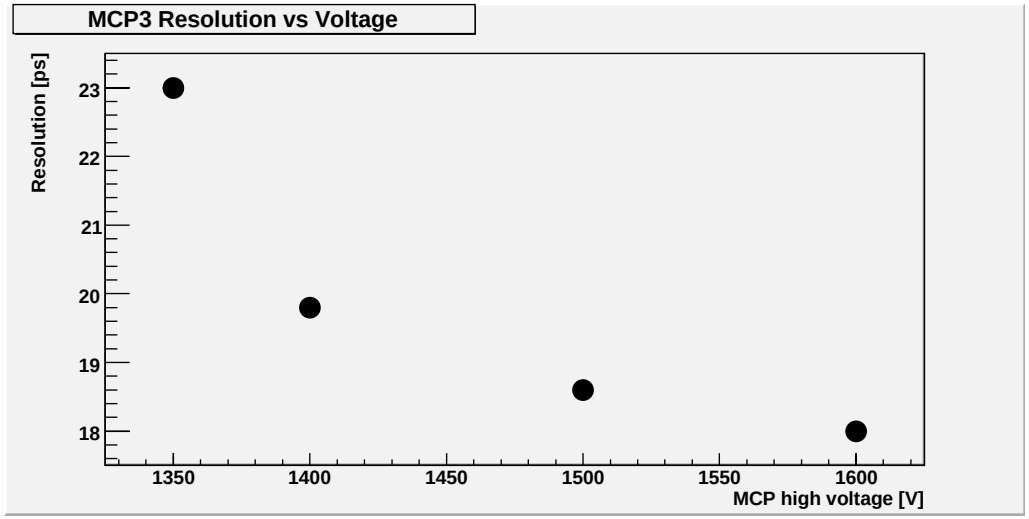
1st prototype with amplifier on the detector

2nd prototype with amplifier after 8m of cable.



FIT: T0+ Time Resolution





Excellent time resolution !

For Minimum Bias Trigger, TOF Time Zero and Vertex Selection.

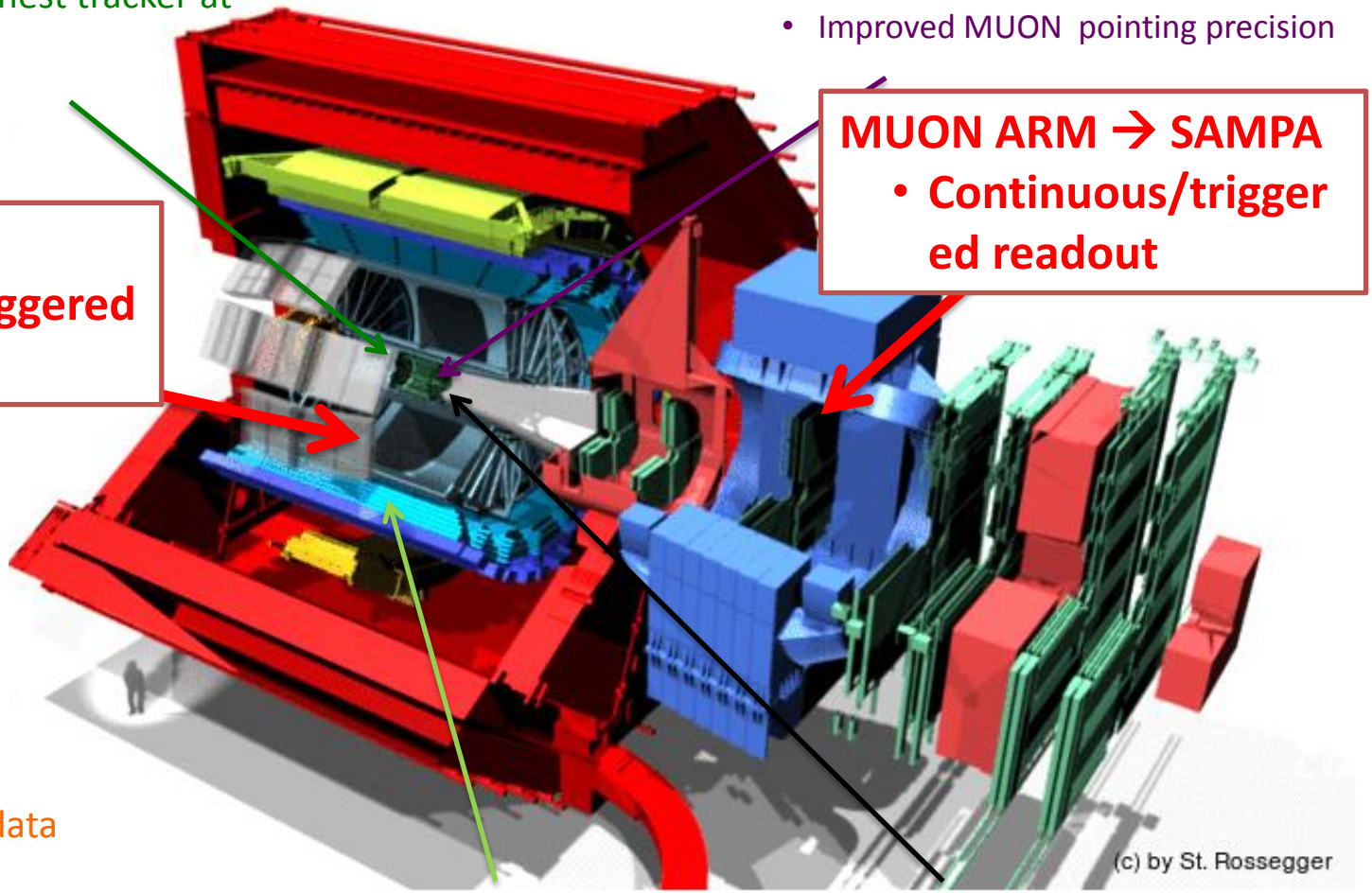
ALICE Upgrade

New Inner Tracking System (ITS)
- improved pointing precision
- less material -> thinnest tracker at the LHC

Muon Forward Tracker (MFT)
- new Si tracker
- Improved MUON pointing precision

TPC → SAMPA
- **Continuous/(triggered) readout**

MUON ARM → SAMPA
- **Continuous/triggered readout**

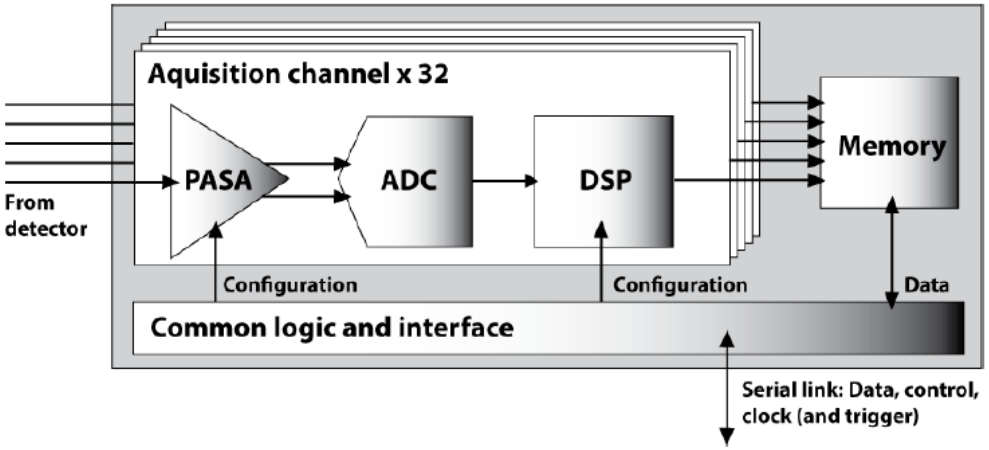


Data Acquisition (DAQ)/ High Level Trigger (HLT)
- new architecture
- on line tracking & data compression
- 50kHz Pbb event rate

TOF, TRD
- Faster readout

New Trigger Detectors (FIT)

SAMPA Chip



PASA: Low Noise Shaping Amplifier

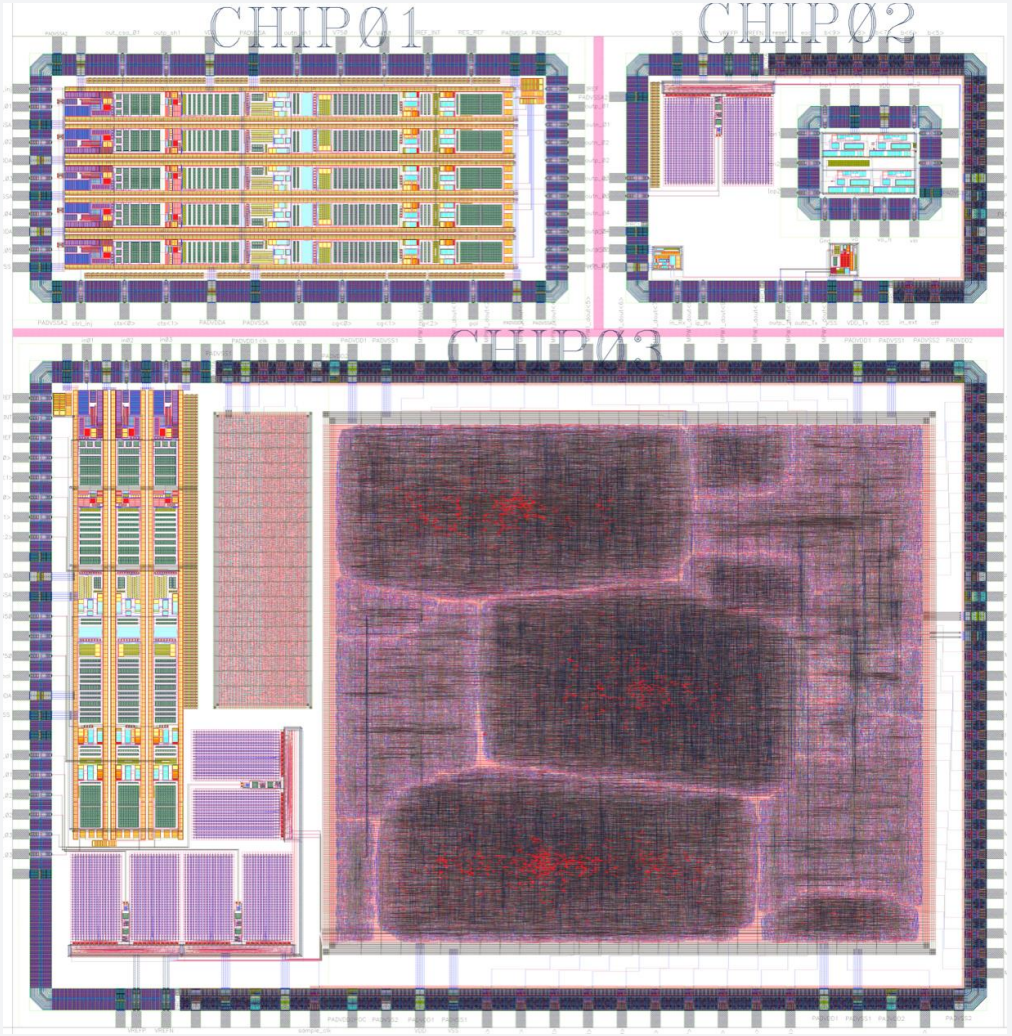
ADC: 10MHz, 10bit low power SAR ADC

DSP: Digital Signal Processing i.e. signal shaping, zero suppression …

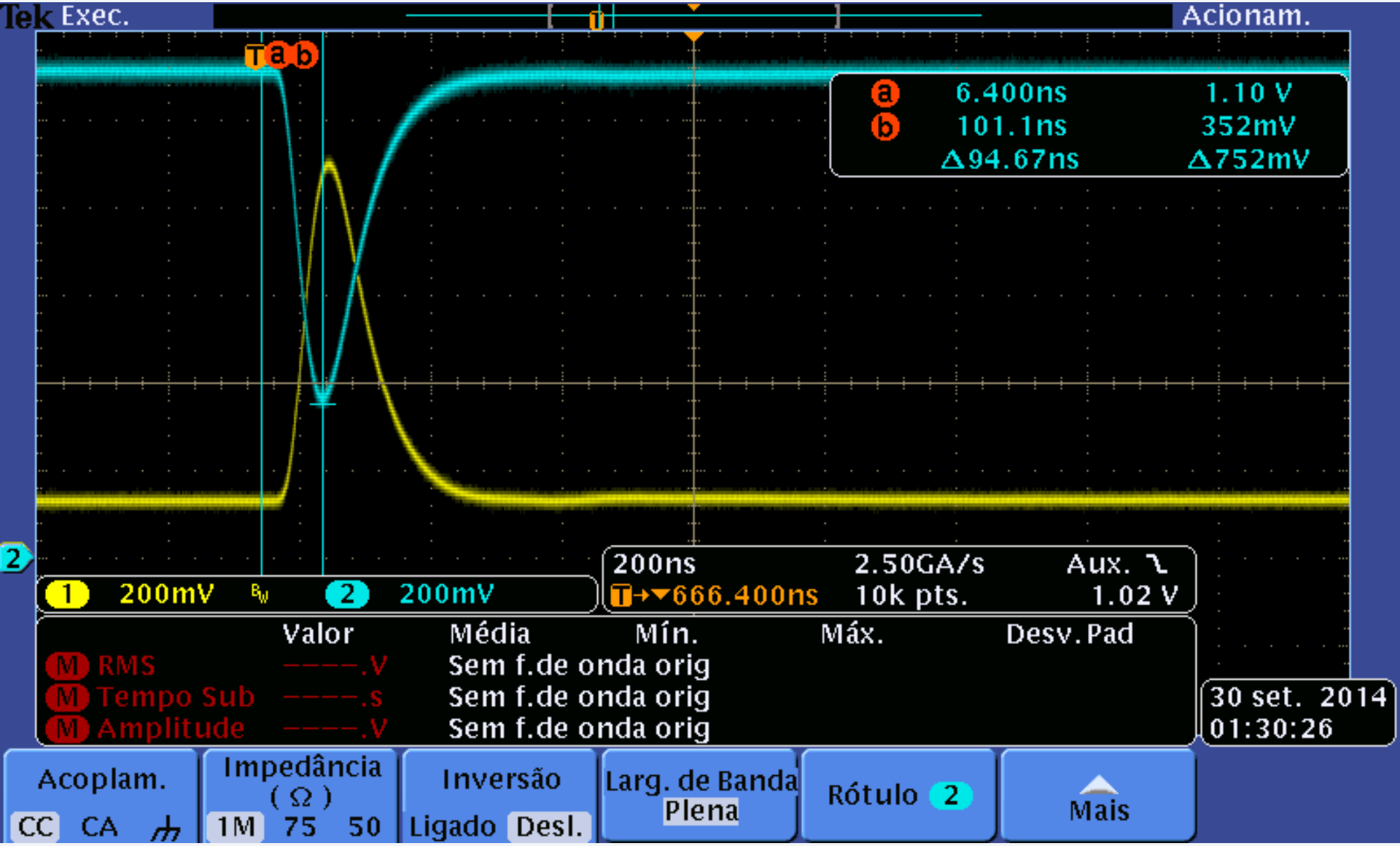
Memory, Serial link: High Speed links to Data Acquisition

SAMPA

- **SAMPA MPW1**
  - **3 ASICs**
    - ASIC 1, 5 front-end channels
    - ASIC 2, ADC and SLVS driver
    - ASIC 3, 3 channels including DSP and read-out
  - **Submission June 2014**
  - **Delivery Sept 2014**
    - Cut and packaged

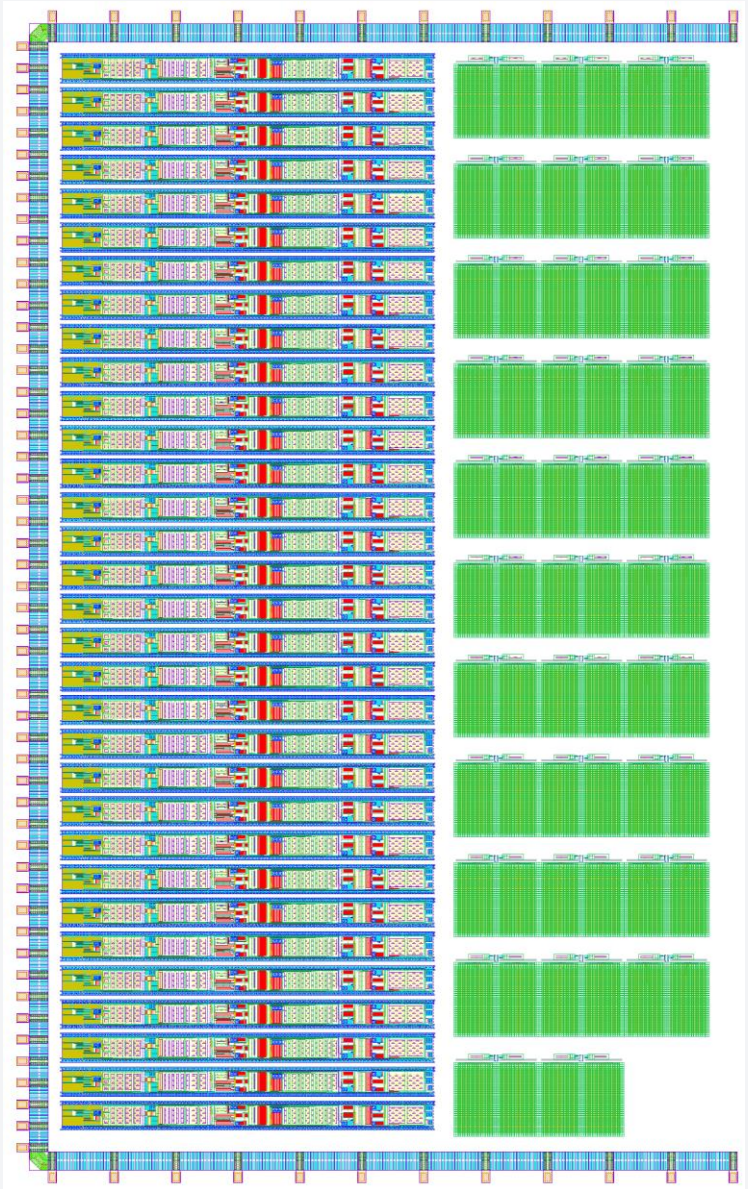


SAMPA-MPW1 (80ns 30mV/fC)



SAMPA

- **SAMPA MPW2**
  - **32 – channel full scale ASIC**
  - **full layout presently under design**
    - changes/adaptations after the of MPW1 possibly needed
    - building blocks can be changed in the lower hierarchy without changing top level



Conclusions

ALICE is preparing a major upgrade for LS2

R&D on ITS MAPs, TPC Micropattern Detectors, Online-Offline System etc. is in full swing with conclusion during 2015

Construction starting in 2015/2016