

# MFT: An Internal Forward Tracker for the ALICE Muon Spectrometer

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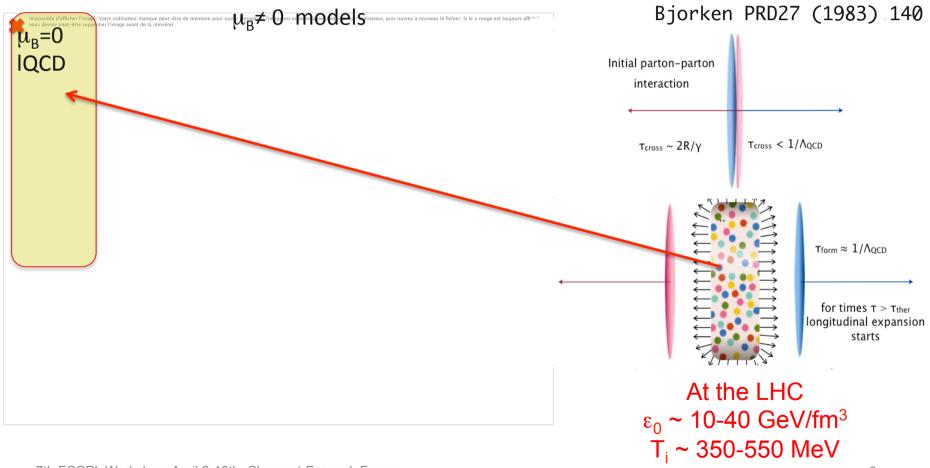






# ALICE: Study of the Quark Gluon Plasma at the LHC AL

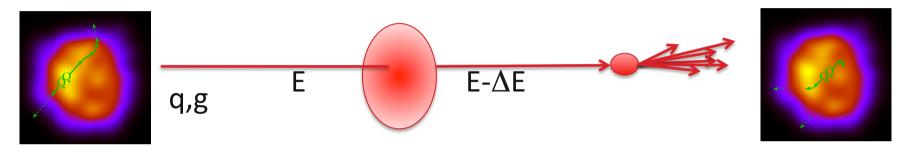
Experimental study of the hadronic-matter phase diagram by means of the heavy ion collisions at ultra relativistic energies





## **Heavy Quark Production**

One of the most promising probes to study the QGP in heavy-ion collisions

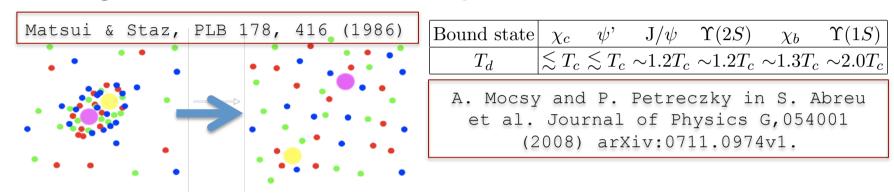


- Heavy flavours produced in initial hard scatterings & experience the full evolution of the system: sensitivity to medium properties.
  - Nuclear modification factor mass and colour charge dependence of parton energy loss:  $(\Delta E)_q > (\Delta E)_{(u,d,s)} > (\Delta E)_{(c,b)}$ .
  - Elliptic flow: transport coefficients of heavy quarks in the medium, degree of thermalization of heavy quarks in QGP (low  $p_T$ ) and path length dependence of heavy quark energy loss (high  $p_T$ ).



#### **Quarkonium Production**

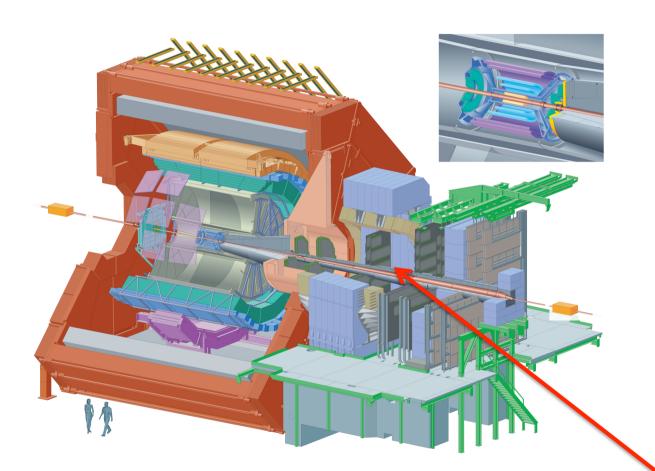
Privileged witness of the deconfined phase.



- Bound states of heavy quarks that would melt in the QGP at different temperatures.
- Formed quickly (<1 fm/c) after the heavy quark production</li>
- But quarkonium could be formed in later stage, at lower temperatures, if  $\rho_O$  is large: Recombination.



#### **ALICE Detector**



#### **ALICE-France**

**IPHC Strasbourg** 

**IPN** Lyon

**IPN** Orsay

**IRFU Saclay** 

LPC Clermont

LPSC Grenoble

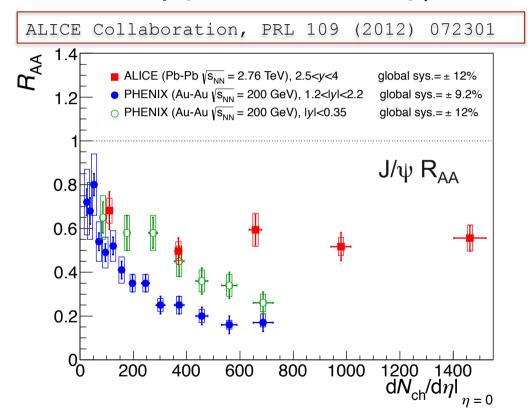
**Subatech Nantes** 

|η|<0.8 D mesons, HFE, quarkonium e<sup>+</sup>e<sup>-</sup> and 2.5<η<4.0 HFM, μ<sup>+</sup>μ<sup>-</sup>



#### ALICE is the unique experiment to measure J/ $\psi$ quarkonium down to p<sub>T</sub>=0

- J/ $\psi$  R<sub>AA</sub> larger at the LHC.
- Flat shape.
- Upsilon(2S) melt at the LHC (CMS result).

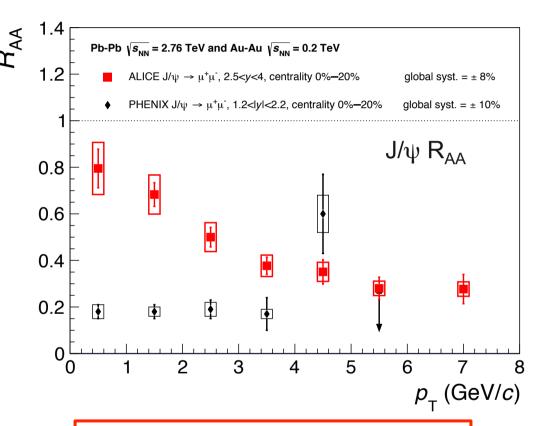


Inclusive J/ $\psi$ : ~90% prompt and ~10% from B decays.



Large  $J/\psi R_{AA}$  at low pT

- At low p<sub>T</sub> charm density is larger.
- At y=0 charm density is larger.



B decays contribution increase with p<sub>T</sub>.

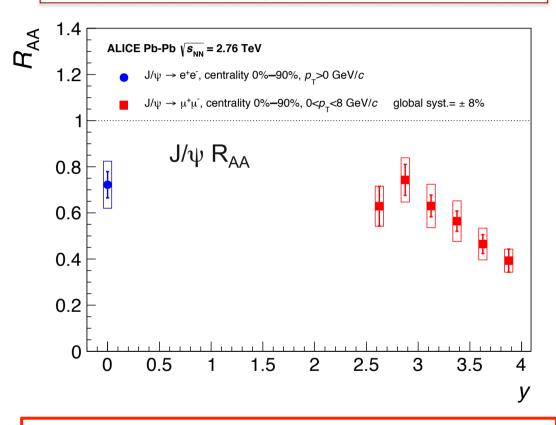
ALICE Collaboration, arXiv:1311.0214 (2013)



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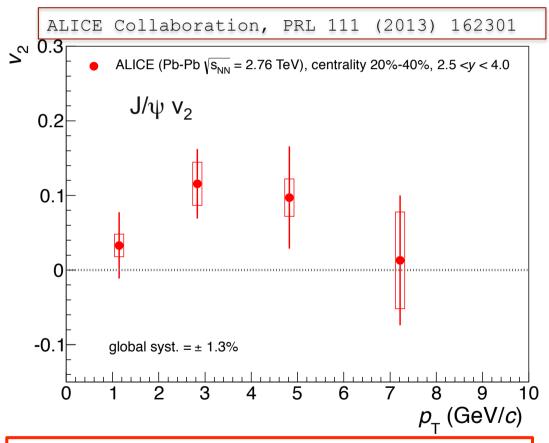


Inclusive J/ψ: ~90% prompt and ~10% from B decays.



The golden measurement of the quarkonium elliptic flow.

- Difficult measurement.
- It favours non-zero
   J/ψ elliptic flow
   (2.4σ).
- B feed-down is a limitation!

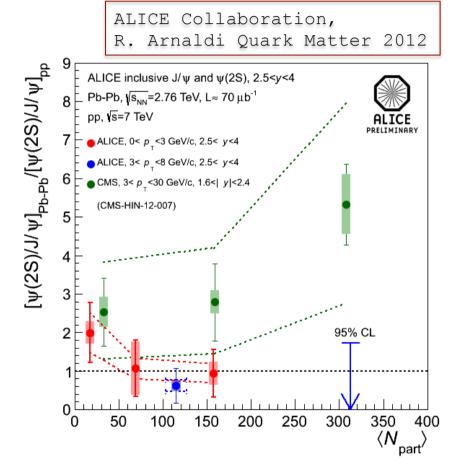


B contribution could be very high, depending on B  $v_2$ .



# Recombination at the LHC? What about $\psi(2S)$ ?

- Small S/B ratio.
- Large uncertainties.
- Difficult to conclude.

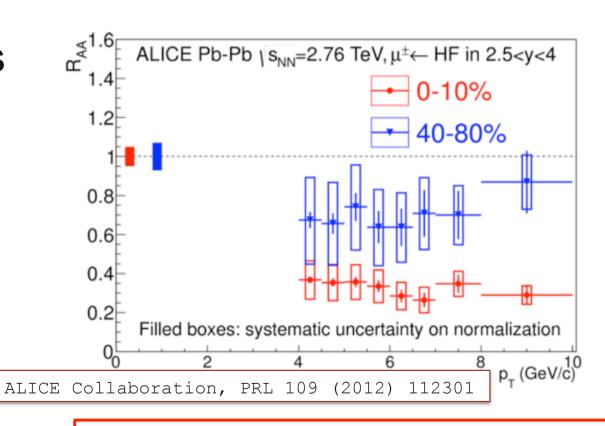




### The golden reference and quarkonium genesis

Measurement of open heavy flavours : charm and beauty, is mandatory.

- Suppression is observed for p<sub>T</sub>>4 GeV.
- Decreasing to lower p<sub>T</sub> is crucial.



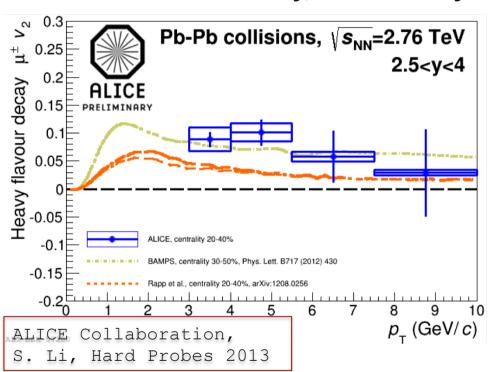
Disentangling beauty and charm contributions and reaching lower  $p_T$  reach is challenging.



## The golden reference and quarkonium genesis

Measurement of open heavy flavours : charm and beauty, is mandatory.

- Non-zero elliptic
   flow of HFM
   measured for p<sub>T</sub>>3
   GeV.
- Decreasing to lower p<sub>⊤</sub> is crucial.



Disentangling beauty and charm contributions and reaching lower  $p_T$  reach is challenging.

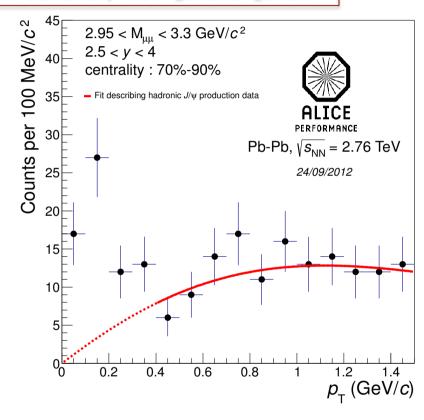


### The surprise

A new observable of the QGP?

- Excess of J/ $\psi$  yield observed at low p<sub>T</sub> (p<sub>T</sub><300 MeV).
- Observed in semiperipheral Pb-Pb collisions.
- Photo-production is the natural candidate.

ALICE Collaboration,
A. Lardeux, Hot Quarks Q2012



# ALICE

# **ALICE Detector Upgrade**

Increase luminosity (100 kHz IR) and improve vertexing and tracking capabilities of ALICE at low  $p_T$ .

Extension of EMCAL (DCAL) LS1

TRD, TOF,
PHOS: upgrade
of the readout
electronics

New beam pipe
with smaller
radius
29mm → 18.0 mm

Upgrade of the forward detector triggers (ZDC, TO, VZERO) for high rate operations

TPC: replacement of the readout multi-wire chambers (MWC) with Gas Electron Multiplier (GEM) detectors and new pipelined readout electronics New ITS, high resolution. low-materialthickness Inner Tracking System Muon spectrometer MFT project upgrade of the readout electronics



## **ALICE Upgrade documents**

#### Letter of Intent:

- ✓ ALICE
- ✓ ITS
- ✓ MFT

#### TDR:

- √ Readout-Upgrade
- ✓ ITS
- ✓ TPC
- ✓ O2 (in progress)
- √ MFT (in progress)





#### **Strategy of the ALICE collaboration 2015-2025**

Low pT and |y|<4 coverage for heavy flavours, quarkonium, di-lepton and jet chemistry in heavy ion collision.

- ✓ Heavy flavours: measurement of the total production crosssection.
- ✓ Quarkonium: Precision measurement of the dissociation and recombination of quarkonium states.
- ✓ Low mass di-lepton: Measurement of the thermal virtual photons and the rho meson spectral function.

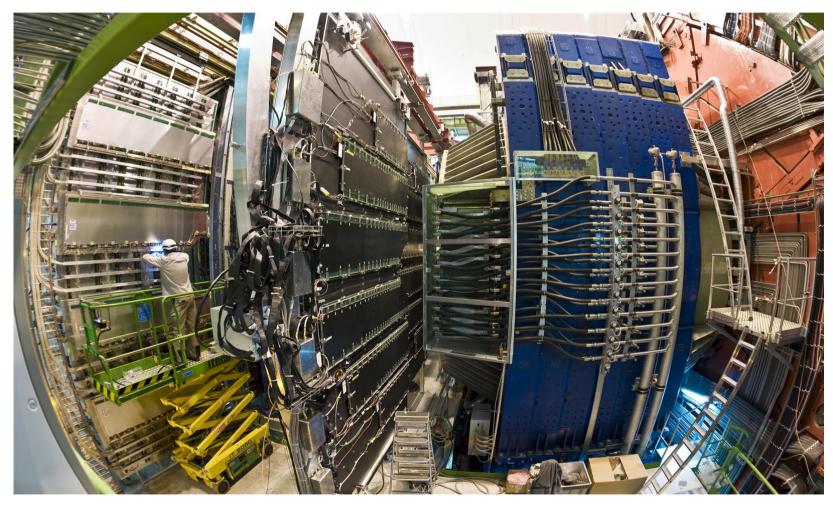
  MFT+MUON

✓ Jets: Particle identification in jets, low p<sub>T</sub> c and b jets and dissipation of the lost energy in the medium.

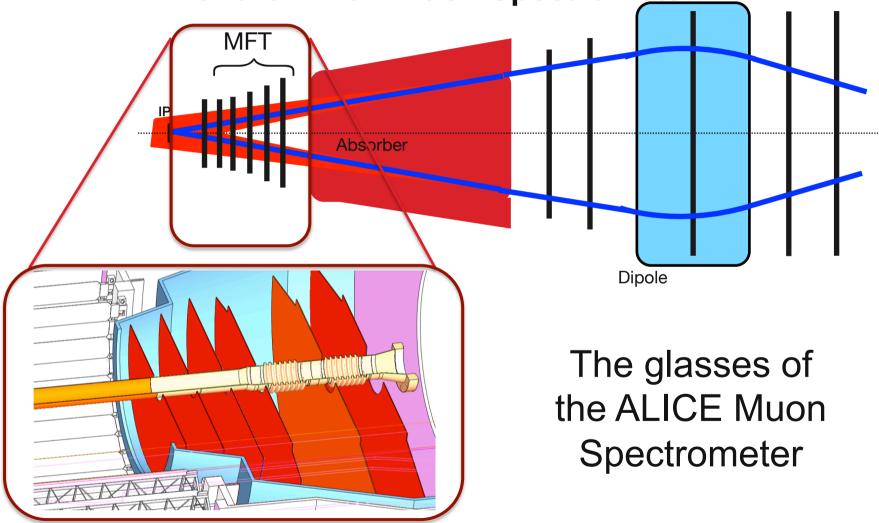


# **ALICE Muon Spectrometer**

#### New read-out electronics at 100 kHz IR. Muon trigger → Muon ID



Muon Forward Tracker: An internal Forward Tracker for the ALICE Muon Spectrometer.





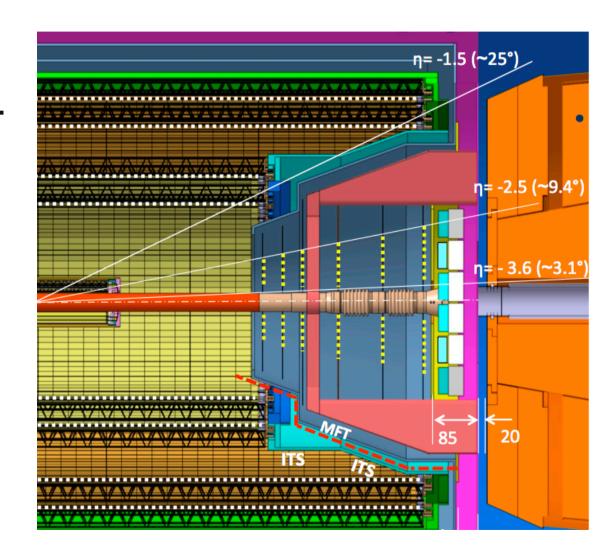
# Many new physics cases become accessible.

Topic	Observable	MUON upgrade	MUON + <b>MFT</b> upgrade
Heavy flavour	<b>R<sub>AA</sub></b> (J/ψ from B)	Unmeasurable	p⊤>0 ; 10% (to be improved "à la LHCb")
	<b>v</b> <sub>2</sub> (J/ψ from B)	Unmeasurable	Not evaluated yet
	μ decays from <b>c</b> -hadrons	Unmeasurable	p⊤>1;7%
	μ decays from <b>b</b> -hadrons	Unmeasurable	p⊤>2 ; 10%
Charmonia	<b>R<sub>AA</sub></b> (prompt J/ψ)	Unmeasurable	рт>0 ; 10%
	<b>v</b> <sub>2</sub> (prompt J/ψ)	Unmeasurable	Not evaluated yet
	ψ'	рт>0 ; 30%	рт>0; 10%
Low Mass	Low Mass spectral func. and QGP radiation	Unmeasurable	рт>1;20%



#### MFT detector in a few words.

- Precision of the tracking: tens of μm.
- 2000 charged particles per unit of rapidity.
- Challenging integration and matching between muon and the MFT tracks.

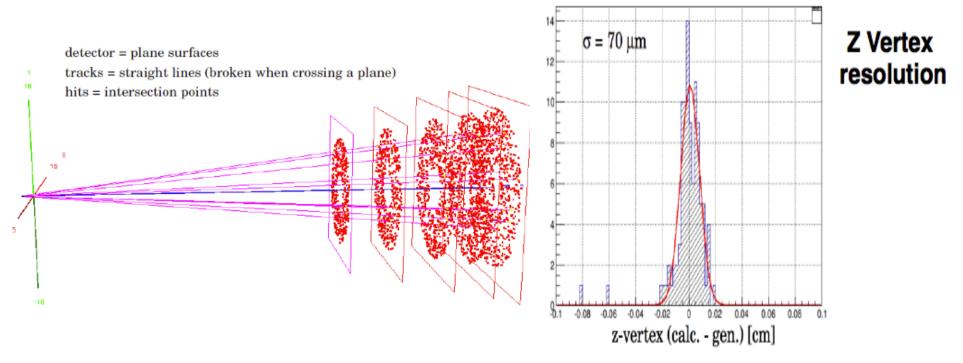




## MFT Standalone tracking

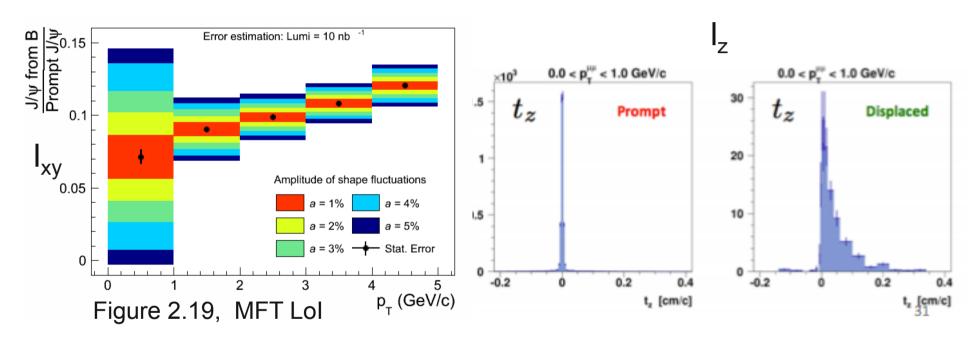
#### In progress

# Implementation of the algorithm "cellular automaton" in AliRoot. NIM A489 (2002) 389





# The displacement of the J/ $\psi$ vertex: A measurement of the open beauty down to p<sub>T</sub>=0.

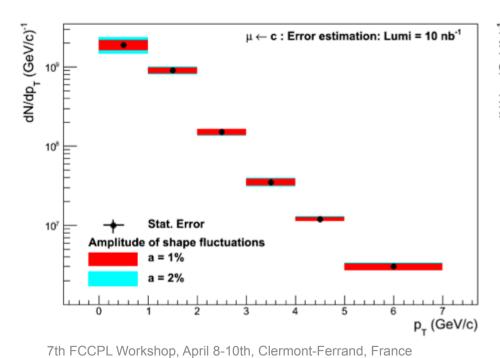


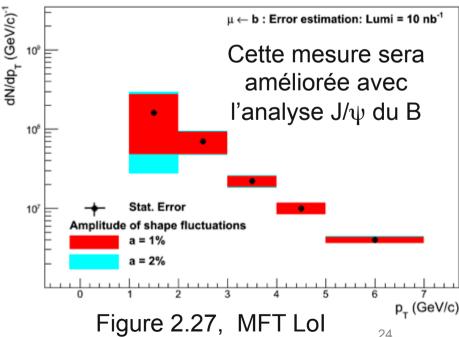
Lorentz Boost facilitates the measurement at low  $p_T$ . Longitudinal displacement analysis in progress. Unique at the LHC for  $p_T$ =0.



# HFM: Separation between beauty and charm.

- Rejection of secondary interactions in the absorber.
- Rejection of muons from  $\pi$  and K weak decays.
- Separation of the beauty and charm.
- Charm measurement down to p<sub>T</sub>=1 GeV of the HFM.



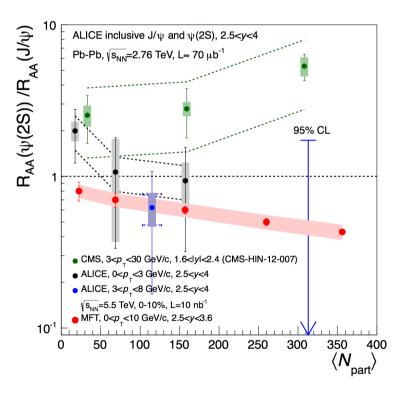


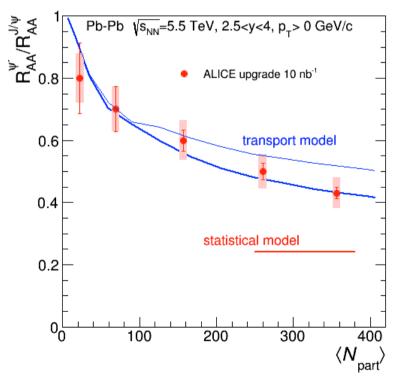


# The measurement of the $\psi(2S)$ .

Improvement of the precision on  $\psi(2S)$ .

S/B ratio increases by a factor 3-5.

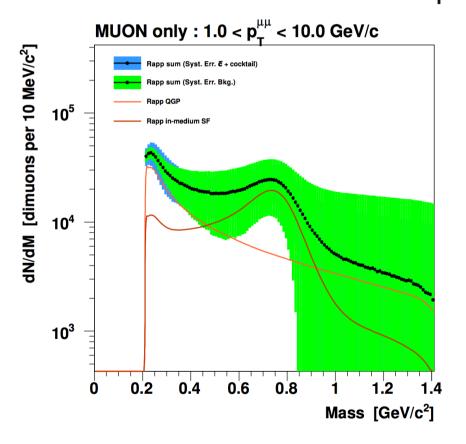


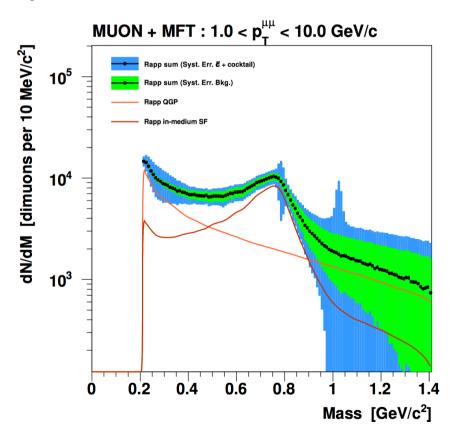




#### **Vector mesons and low masses**

# Only ALICE can address this physics case at forward rapidity.



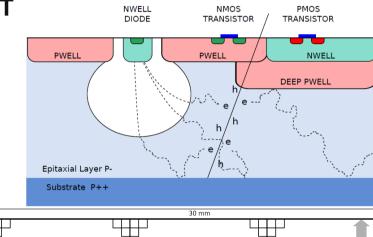


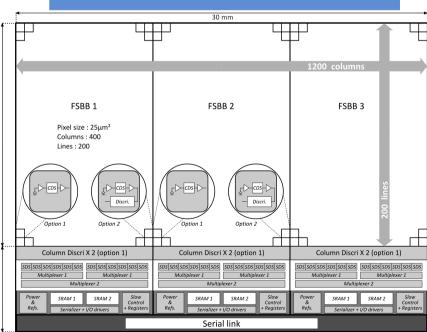


#### Silicon Pixel Sensor

#### R&D in progress. Joint effort ITS and MFT

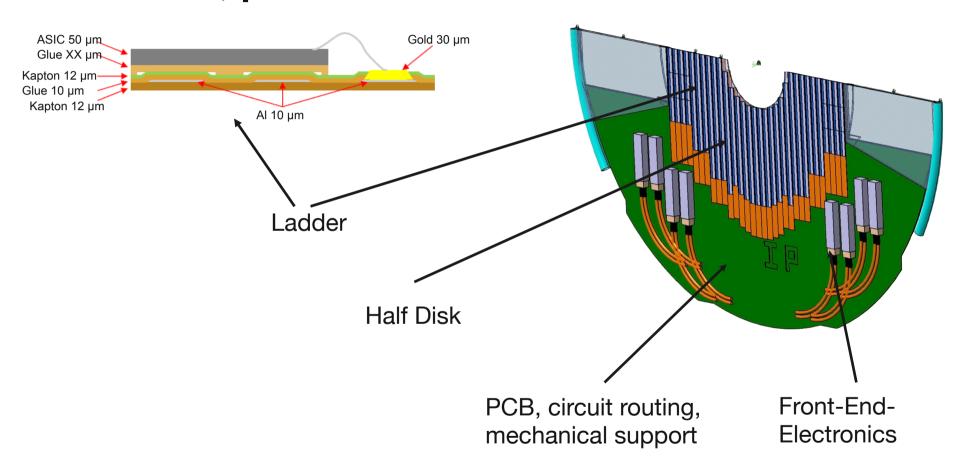
- ✓ MAPS (Monolithic Active Pixel Sensors) CMOS 0.18 µm from TowerJazz technology.
- ✓ 50  $\mu m$  thickness
- ✓ Radiation hard: 700 kRad (dose)
   et 10<sup>13</sup> neq/cm<sup>2</sup> (neutron
   equivalent).
- ✓ Final architecture to be chosen at the end of the year.







# Ladders, planes and half disks

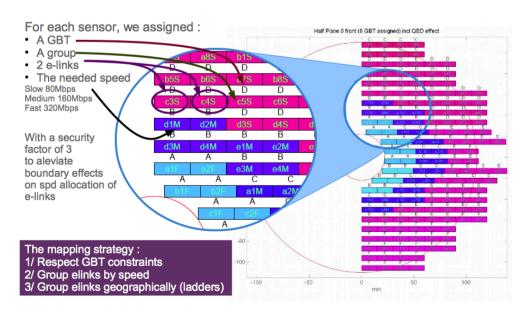




### **MFT** readout system

#### Standard ALICE readout architecture.

- ✓ Sensor-FEE-DAQ.
- ✓ Design for Pb-Pb-MB 100kHz with a 3 fold security factor.
- ✓ Mapping has been optimised: 166 optical links ~3 GB/s (6 detection planes).

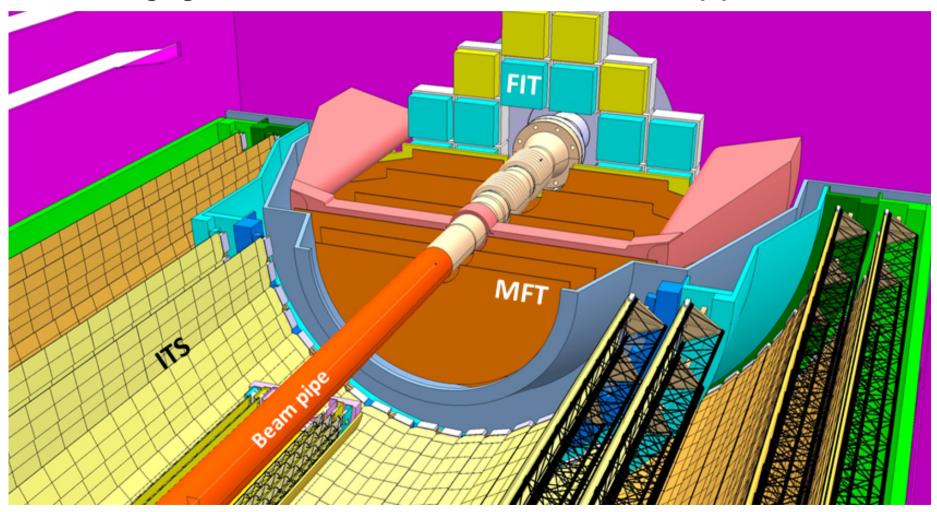


mm				
	Front	Back		
Half Plane 0b	6 GBT's	6 GBT's		
Half Plane 0	6 GBT's	6 GBT's		
Half Plane 1	8 GBT's	7 GBT's		
Half Plane 2	7 GBT's	7 GBT's		
Half Plane 3	7 GBT's	7 GBT's		
Half Plane 4	8 GBT's	8 GBT's		
TOTAL whole MFT	166 GBT's			
<u> </u>				



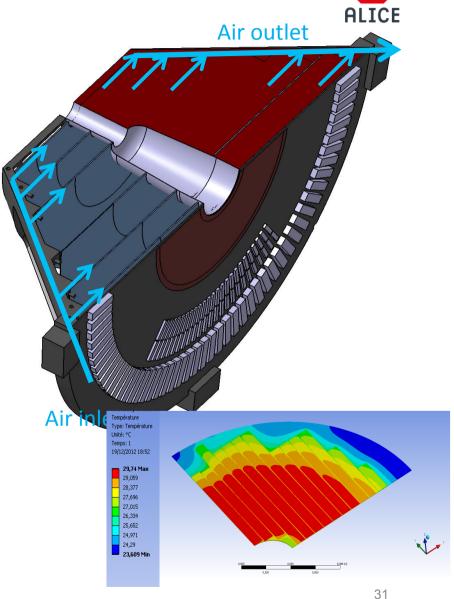
# **MFT Mechanics and integration**

Challenging: between FIT and ITS and around the beam-pipe.



## **MFT** cooling

- ✓ MFT Power ~1.5 kW.
- ✓ Cooling with air seems possible (Lol studies).
- ✓ New thermal studies on going with new hypothesis, detailed MFT description, DC-DC converters.
- ✓ Vibration studies to be done.



# ALICE

#### Addendum of the ALICE Lol

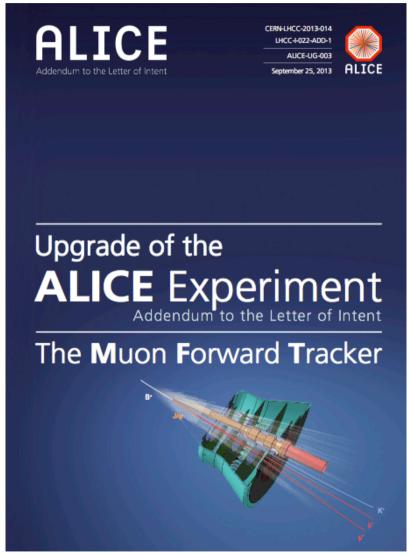
Approved by the LHCC on Sep 26th

http://cds.cern.ch/record/1592659?ln=fr
Next:

MFT TDR for the end of the year.

MFT collaboration: Clermont-Lyon- Kolkata-Nantes-Saclay-St.Petersbourg

Synergy with ITS: Strasbourg, CERN, Korea? Thailand? China?



# ALT CE

#### **Conclusions**

- ✓ ALICE experiment will perform unique studies of QGP at the LHC. Upgrade program is planned for run3.
- ✓ Heavy flavour and quarkonium probes are measured by the ALICE muon spectrometer.
- ✓ A new internal tracking system: MFT will open new physics studies: Beauty / Charm separation and prompt J/ψ and ψ(2S).
- ✓ MFT is a challenging project. Same technology as the new ALICE ITS upgrade.
- ✓ Our Chinese colleagues are welcome to join the MFT detector project.

