ALICE MUON TRIGGER PROJECT

Yongwook Baek
LPC, Clermont-Ferrand
Gangneung-Wonju Univ.

FKPPL-FJPPL_2012@Clermont-Ferrand, 28-30 May

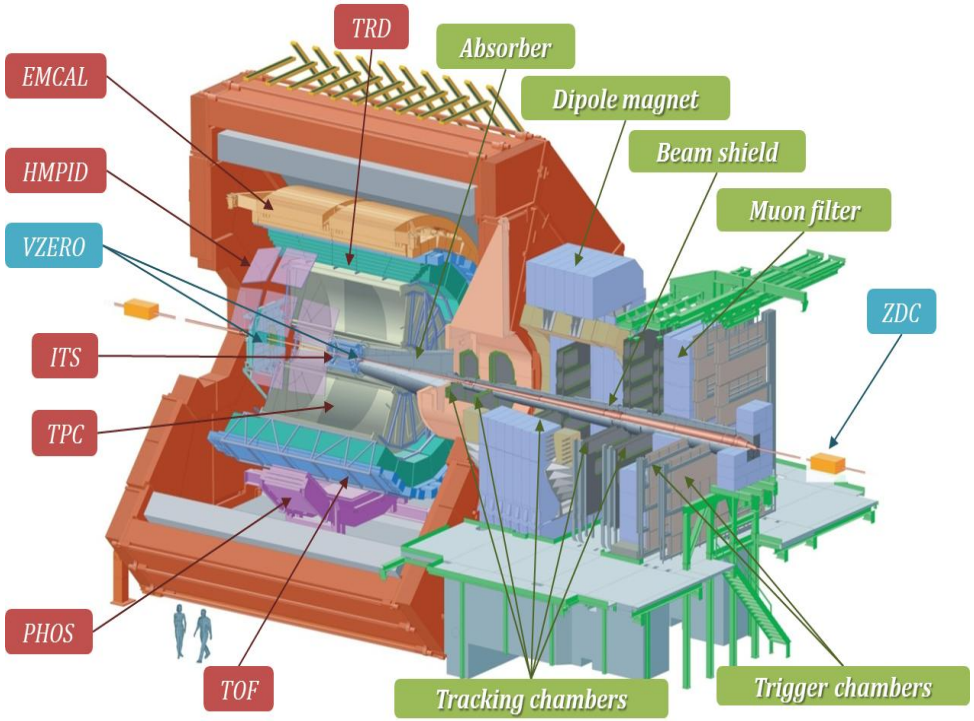
Outline

- Status of ALICE Muon Trigger project of FKPPL
- Description of ALICE & Muon Spectrometer
- Performance of Muon Trigger
- Selected Physics Results with Muon Spectrometer
- Conclusions and Perspectives

Status of ALICE Muon Trigger project

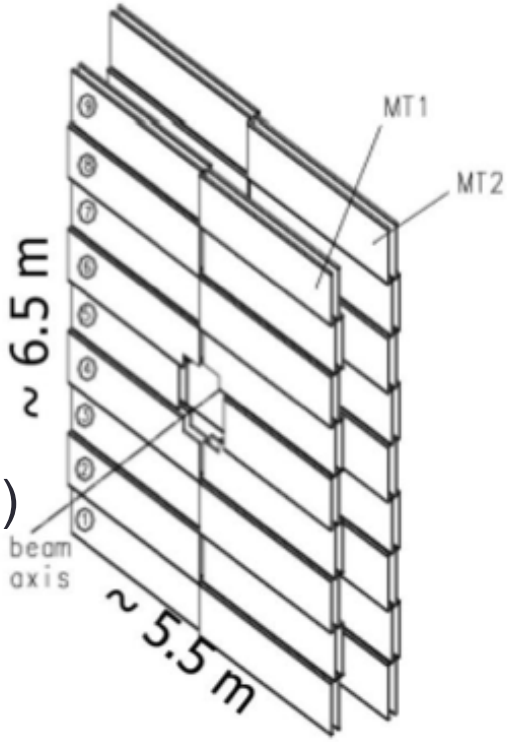
- Members & Activities in FKPPL
  - France (LPC, Clermont-Ferrand)
    - Dr. Pascal Dupieux (Leader), Pr. Philippe Rosnet, Dr. Philippe Crochet, Dr. Xavier Lopez, Dr. Sarah Portebeuf, Dr. Valerie Barret
  - Korea (Gangneung-Wonju, Konkuk)
    - GWNU: Pr. Do-won Kim, Pr. Sungchul Lee, Dr. Yongwook Baek (Leader: IN2P3 contract at LPC from 2009 to 2013), Ms. Jooho Lee
    - Konkuk: Pr. Sunkun Oh, Dr. Sang-un Ahn (PhD obtained Dec. 2011, Blaise-Pascal, and Feb. 2012, Konkuk → obtained a position in KISTI/GSDC), Ms. Hyeonjong Jeon (new member, he may join on Sep. 2012)
- Activities @CERN
  - MTR operation: Common work of run coordination & detector expertise
  - MTR maintenance: Trigger electronics & detector maintenance
  - Physics analysis: Upsilon physics
  - Shift participation: MTR on-call & ALICE General shifts

ALICE : A Large Ion Collider Experiment



- Study of the properties of strongly interacting matter
- Participates in LHC pp and heavy ion programs
- Central detectors ($|\eta| \leq 0.9$)
  - hadrons, electrons and photons detection
- Muon spectrometer ($-4 \leq |\eta| \leq -2.5$)
  - Muon Chambers + Muon Trigger + Absorbers + Dipole
  - Muons detection

Muon Trigger System



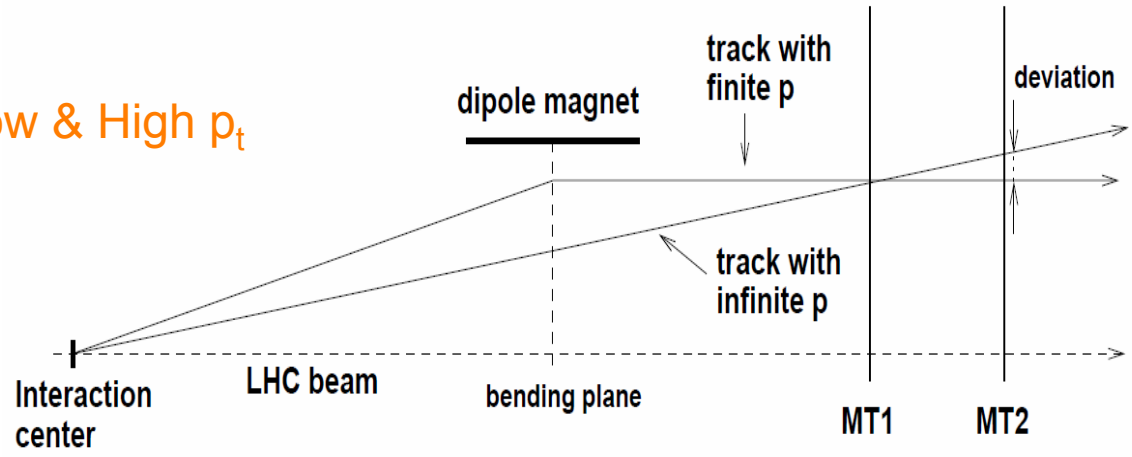
- Participate in L0 trigger decision (latency < 1.2 μs)
- p_t-based muon selection and muon identification
- 4 planes of 18 single gap RPCs (2 stations of 2 planes)
- Total surface ~ 140 m^2
- Gas mixture: 89.7% $C_2H_2F_4$ - 10% i-C_4H_{10} - 0.3% SF_6
- Saturated avalanche mode (Streamer mode with same FEE)

  → no amplification at the FE Electronics level
- ~21,000 strip and Front-End channels
- Trigger Decision and Readout Electronics

Trigger Electronics and Algorithm

- 234 Local Trigger boards:
  - Estimate of deviation wrt a straight track from IP
  - Coincidence of hits from at least 3/4 MTR planes, bending and non-bending separately
  - 2 programmable p_t cuts (LUT): Low & High p_t
- 16 Regional Trigger boards:
  - Single Muon and di-muon
- 1 Global trigger board: 6 output signals @ 40 MHz
  - single μ
  - unlike-sign di-muon
  - like-sign di-muon

} Low & High p_t



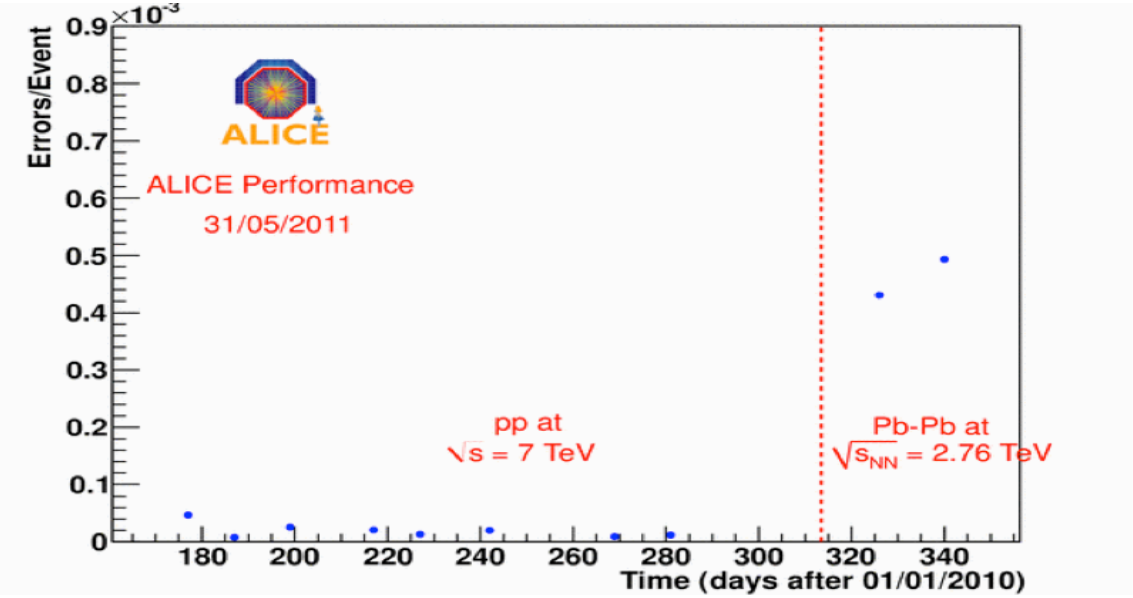
- Performance of Muon Trigger

Data taking conditions

2010	luminosity	p_t cuts (GeV/c)	rate (Hz)
pp @√s = 7 TeV	0.1 Hz/μb 1.5 Hz/μb	single = 0.5 single = 1	100 300
Pb-Pb @√s = 2.76 TeV	10 Hz/b	No dedicated muon trigger class	
2011			
pp @√s = 7 TeV	0.5 ~ 2 Hz/μb	single = 1 single = 4 Di-muon = 1	400 40 20
Pb-Pb @√s = 2.76 TeV	300 Hz/b	single = 1 single = 4 Di-muon = 1	400 70 150

- Integrated Luminosity @Pb-Pb @√s = 2.76 TeV
  - L_{int} (2011/2010) ~ 144 / 9.5 μb^{-1}

Muon Trigger Electronics Performance

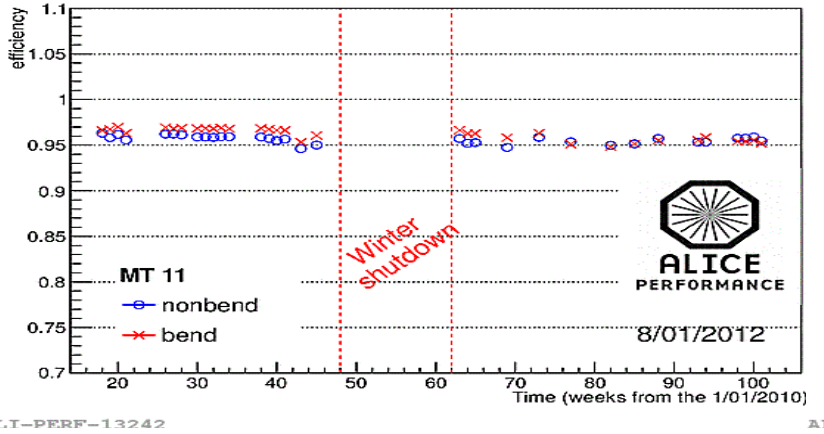


- Front-End electronics status:
  - < 0.5% of dead or noisy channels ~ 100 channels

  → 0.05% (10 channels) after maintenance during shutdown in 2012
- Trigger electronics: Fully operational
- Algorithm error/event:
  - < 10^{-4} in pp
  - < 10^{-3} in Pb-Pb

RPC performance - Efficiency

- HV scans performed periodically
- Efficiency obtained using redundancy wrt trigger condition (ratio of 44/34 coincidences)
- Efficiency in time (2 years): stable > 95%(±0.5%)



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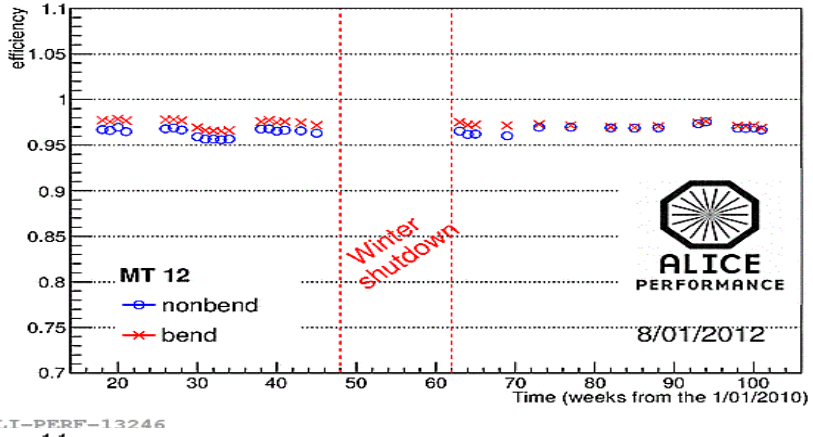

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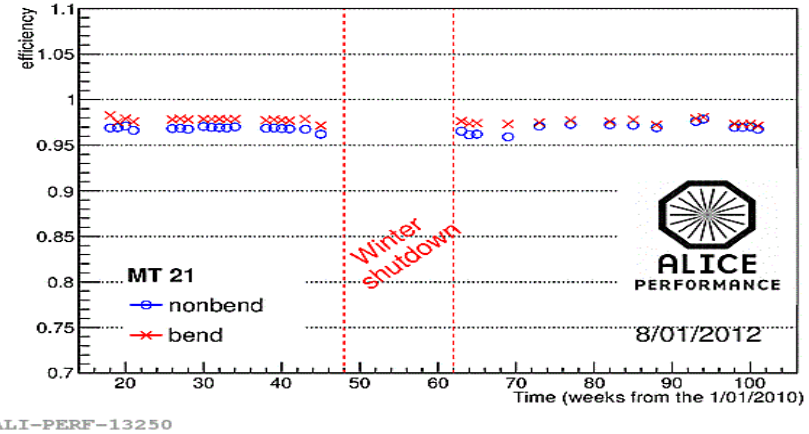

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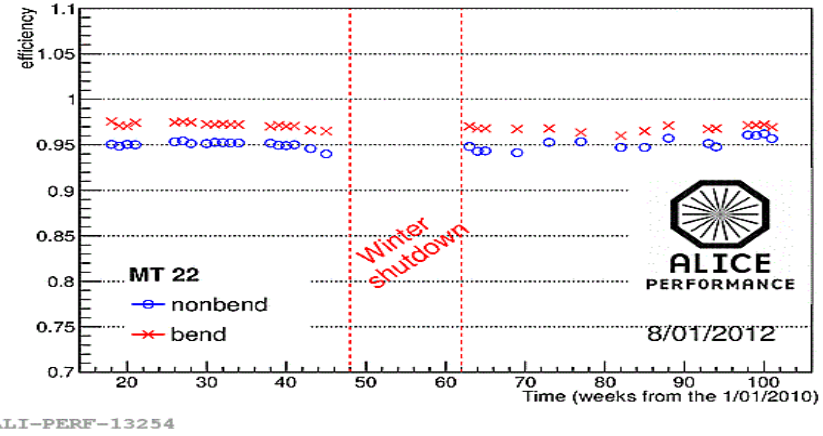

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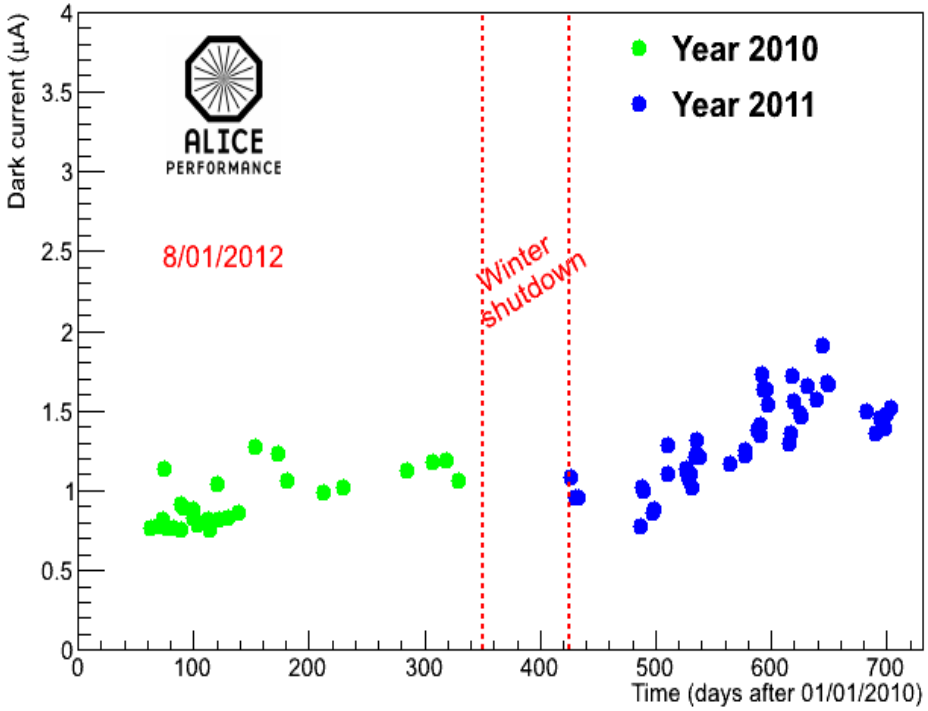
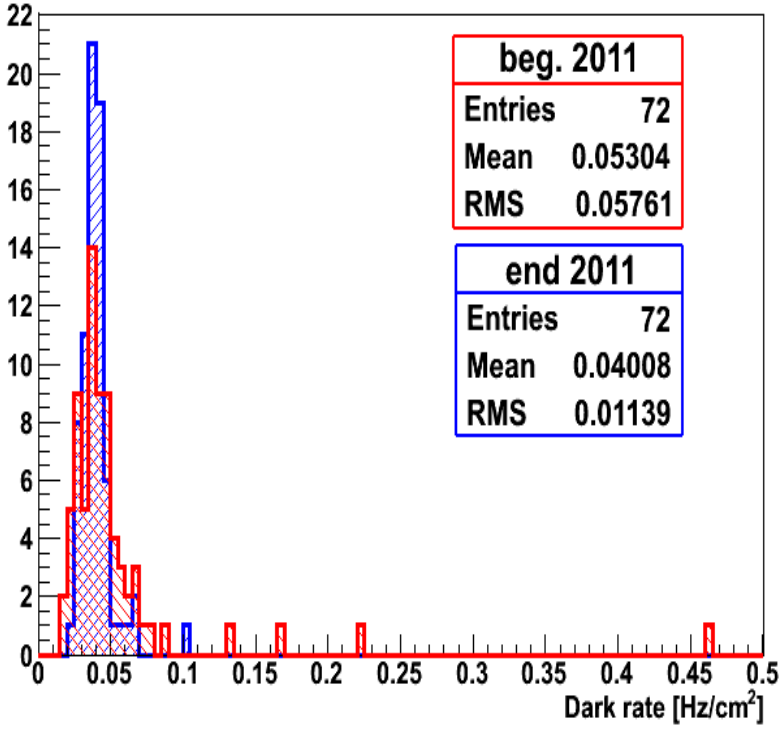
RPC performance – Aging

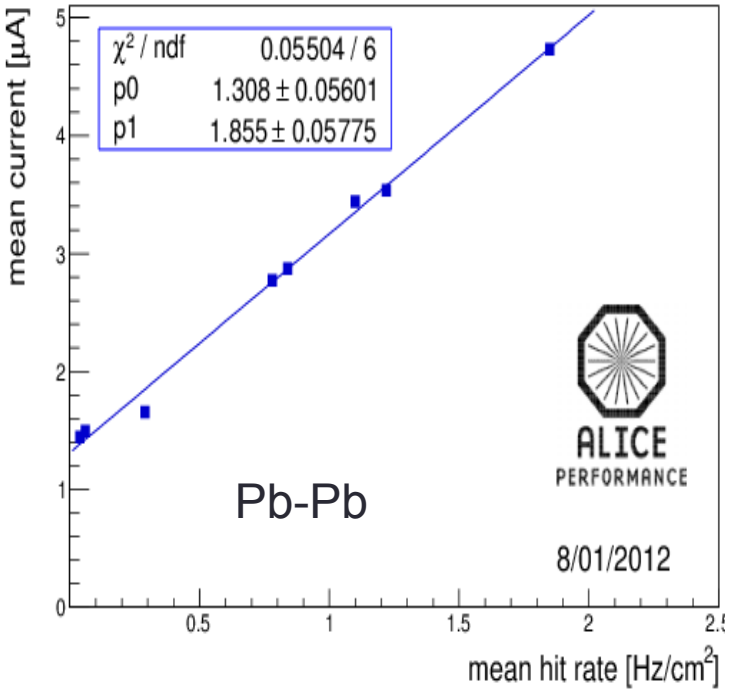
- Dark current and Dark rate measured right after physics data taking between fills
- Dark current: very slow increase in time and very low (< 2 μA / RPC)
- Dark rate ~ 0.05 Hz/cm^2 → Stable in time

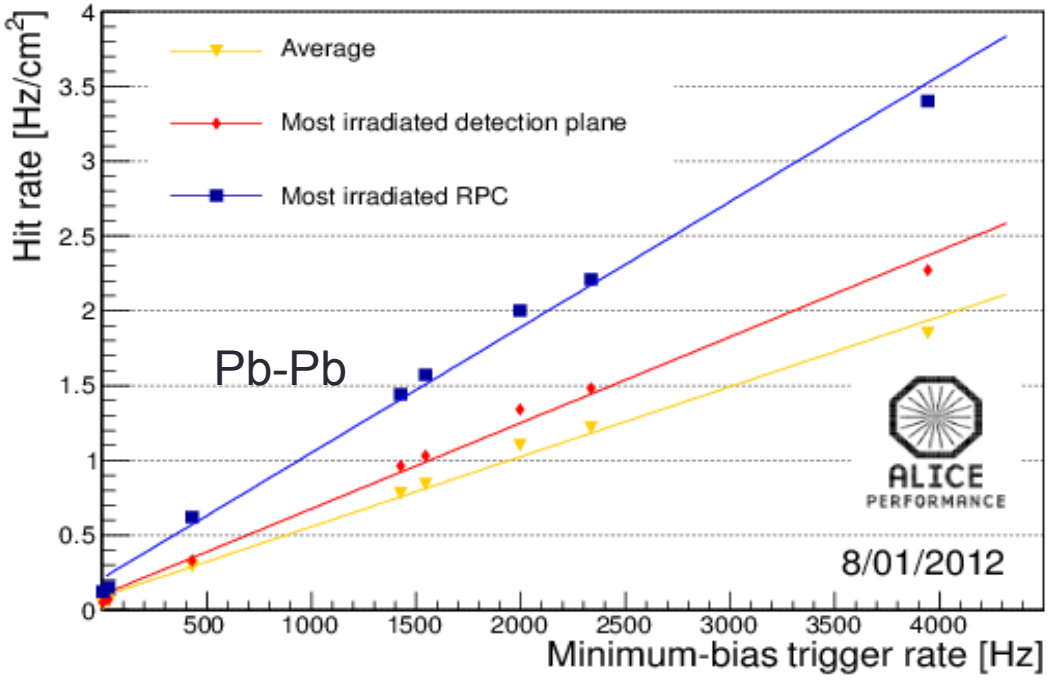




Hit rate vs. RPC current & Interaction rate

- Linear correlation
  - RPC mean current vs. Hit rate: ~2μA/(Hz/cm^2) per RPC
  - Hit rate vs. Interaction rate : < 1 (Hz/cm^2) / 1kHz MB Pb-Pb rate

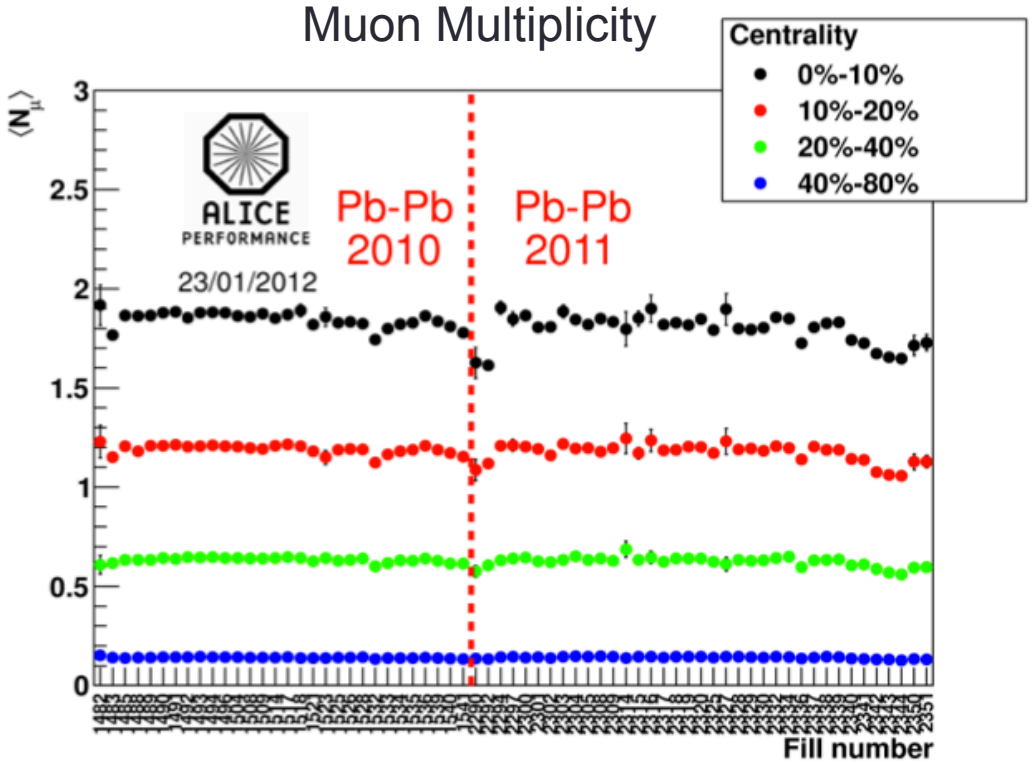




Pb-Pb performance - Multiplicity

- Average value of Muon multiplicity/event
- Muon Transverse momentum > 0.5 GeV/c

→ Stable operation in Pb-Pb data taking



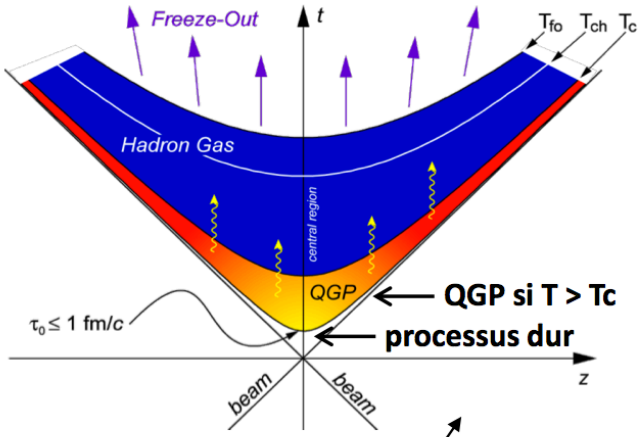
- Selected Physics Results with Muon Spectrometer

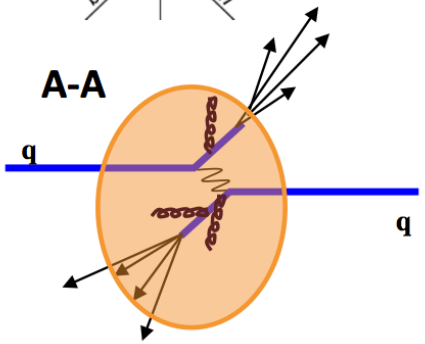
Motivation: Heavy Flavor Physics

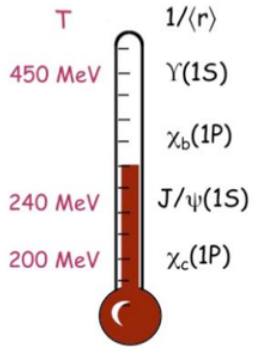
- Open heavy Flavors: hadrons (D, B) containing c or b quarks
- Resonances:
  - J/ψ ($c\bar{c}$) and Υ($b\bar{b}$) family

→(di-)muon decay

- Information about QGP
  - Energy losses of open heavy flavors provides information on the density of the medium
  - Dissociation rate of resonances provides information on the temperature of the medium
  - Collective flow study of heavy flavors provides information on the thermalisation of QGP phase

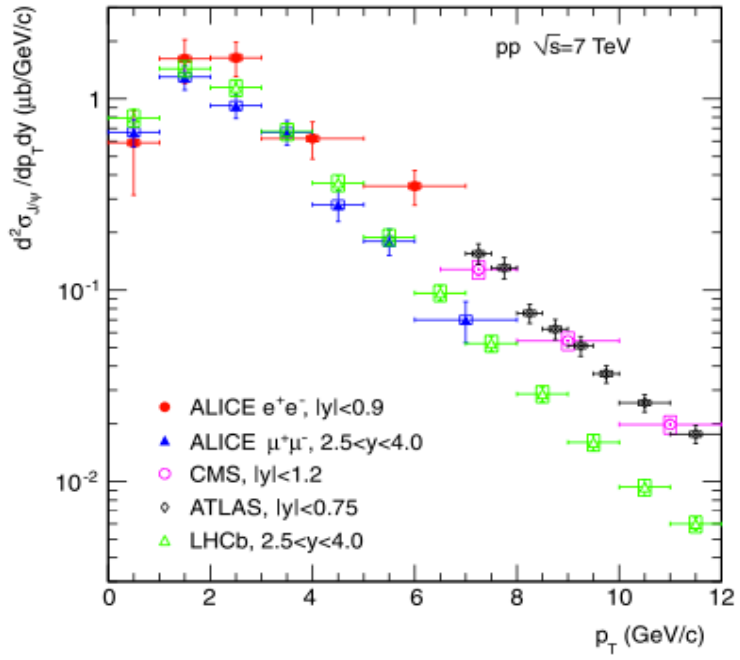


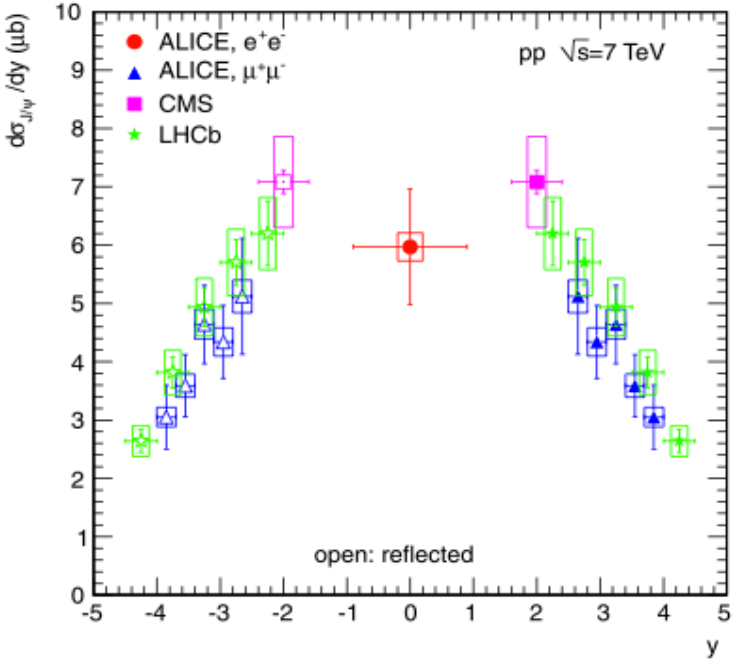




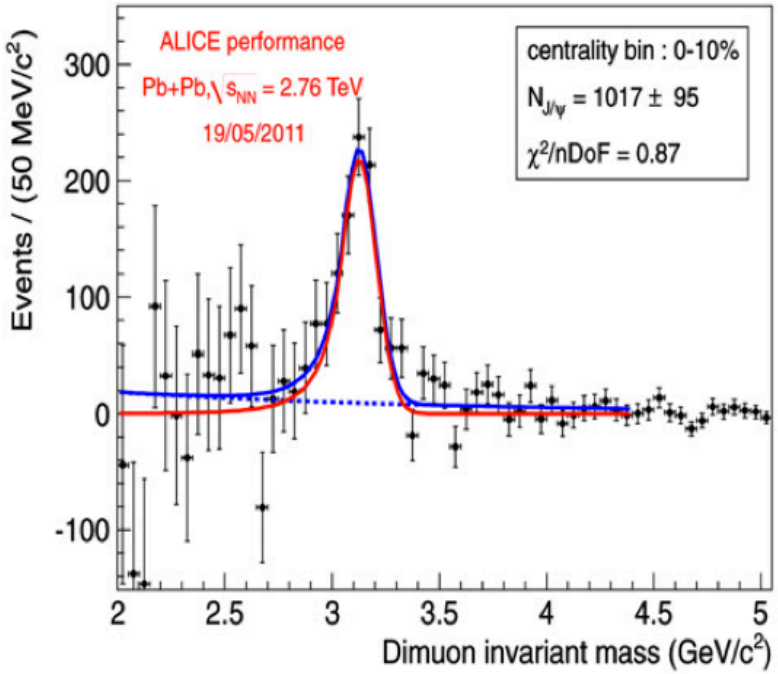
Rapidity and transverse momentum dependence of inclusive J/ψ production in pp collisions at √s = 7 TeV (Phys.Lett.B 704 (2011) 442-455)

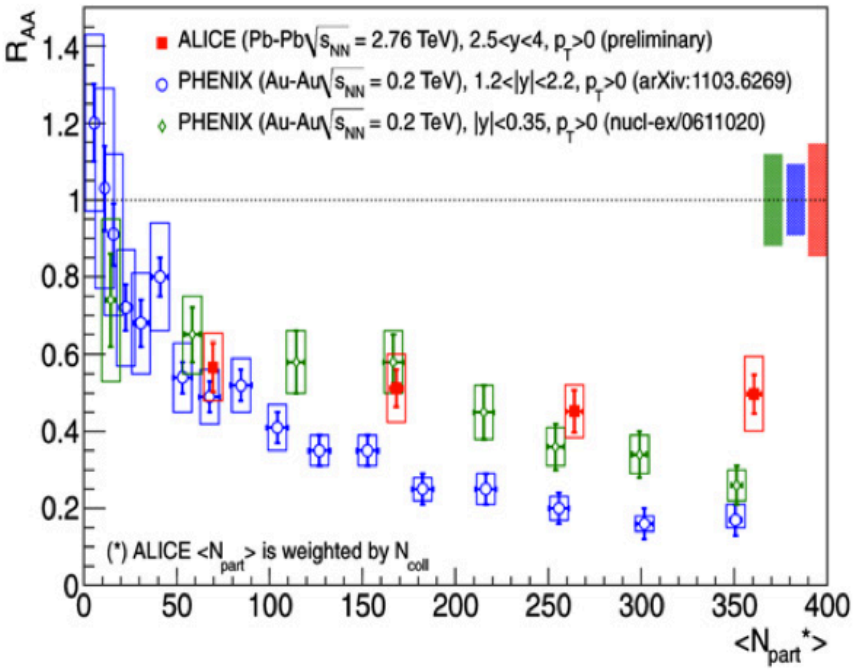
- Unlike-sign Dimuon invariant mass distribution
- $N_{J/\psi}$ = 957 ± 56, corresponding to L_{int} = 7.9 nb^{-1}
- J/ψ differential cross section
  - vs. y for 2.5 < *y* < 4
  - vs. J/ψ p_T, down to p_T = 0
  - Consistent with other experiments





Quarkonium production measurements with the ALICE detector at the LHC (arXiv:1106.5889v1 submitted for publication on journal J. Phys. G)



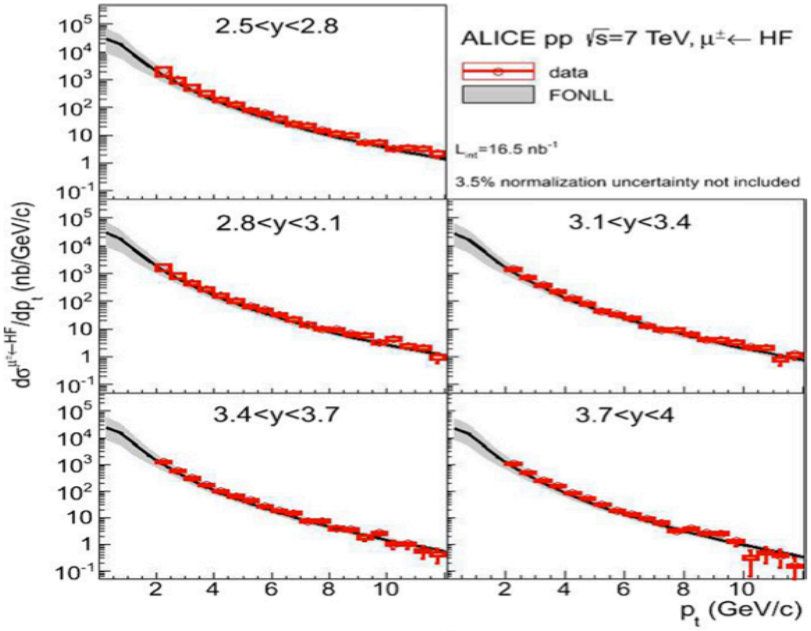


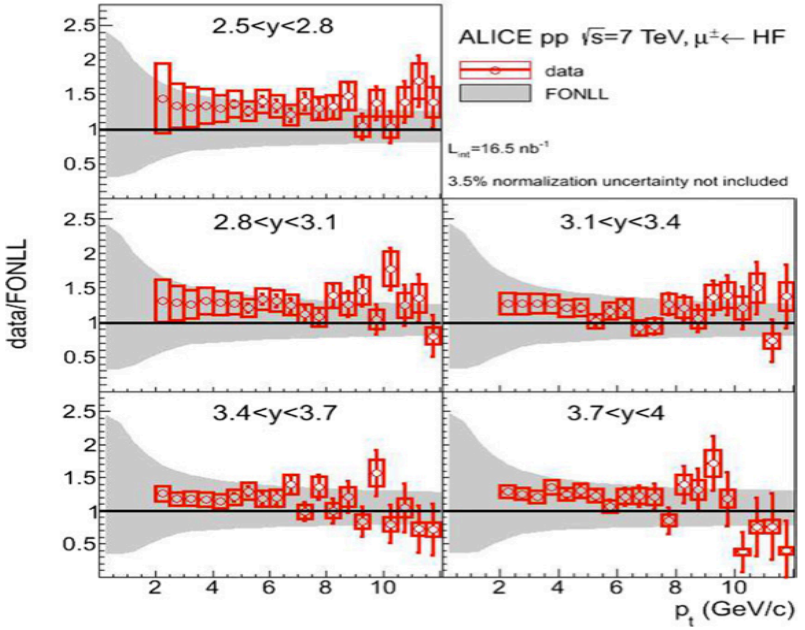
- Invariant mass distribution for unlike-sign dimuon in the centrality of 0-10%.
- J/ψ R_{AA} as a function of <N_{part}> in Pb-Pb collisions @ $\sqrt{S_{NN}}$ = 2.76 TeV
- Nuclear Modification Factor R_{AA}:

$$R_{AA}(p_t) = \frac{1}{< N_{coll} >} \times \frac{dN_{AA} / dp_t}{dN_{pp} / dp_t}$$

Heavy flavour decay muon production at forward rapidity in proton-proton collisions at √s = 7 TeV, (Phys. Lett. B 708 (2012) 265-275)

- Left panel: p_t differential production cross section of muons from heavy flavour decays in five rapidity regions mentioned in the figures. The solid curves are FONLL calculations and the bands display the theoretical systematic uncertainty.
- Right panel: ratio between data and FONLL calculations.
- Good agreement btw model and data within experimental and theoretical uncertainties



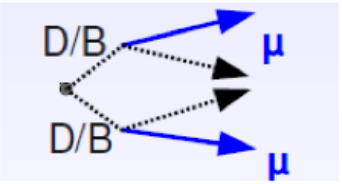


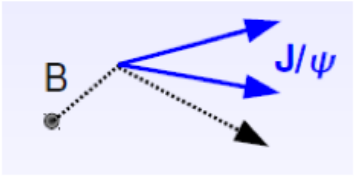
Conclusions

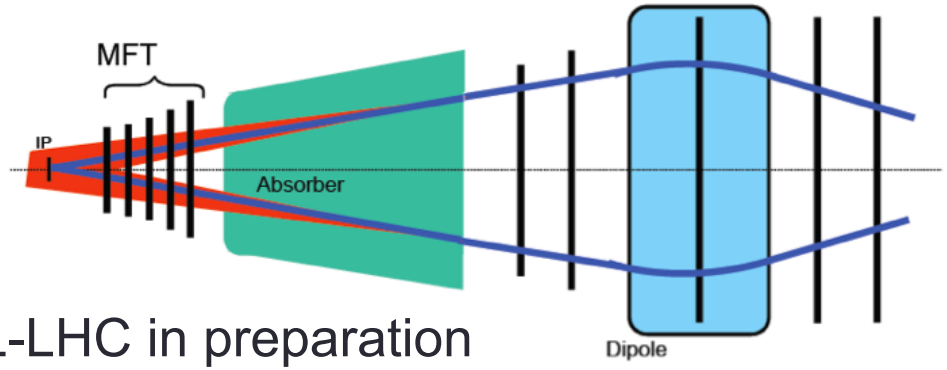
- ALICE Muon Trigger system fully operational since start of LHC program
  - Electronics robust and stable
  - RPC Efficiency > 95%
  - Stable dark current and dark rate
  - No significant aging effect
  - Successful data taking campaigns in pp and Pb-Pb, 2010 and 2011
- 2012 data taking conditions
  - pp: $\sqrt{s}$ = 8 TeV, since April
  - Main–Satellite collisions in ALICE
  - Bad Vacuum conditions : high flux of beam induced background particles

    → limited data taking periods
  - pA (Ap) expected end 2012
- 27 published papers by ALICE
- 3 papers published + 4 draft on muon physics
  - **Published**
    - **Heavy flavour decay muon production at forward rapidity in proton-proton collisions at $\sqrt{s}$ = 7 TeV**
    - **Rapidity and transverse momentum dependence of inclusive J/ψ production in pp collisions at $\sqrt{s}$=7 TeV**
    - **J/ψ polarization in pp collisions at $\sqrt{s}$=7 TeV**
  - **Draft**
    - **J/ψ Production as a Function of Charged Particle Multiplicity in pp Collisions at $\sqrt{s}$ = 7 TeV**
    - **Inclusive J/ψ production in pp collisions at $\sqrt{s}$=2.76 TeV**
    - **J/ψ production at low transverse momentum in Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV**
    - **Production of muons from heavy flavour decays at forward rapidity in pp and Pb-Pb collisions at $\sqrt{s_{NN}}$ = 2.76 TeV**

Muon Upgrade Project for HL-LHC (>2018)







- Upgrade project of ALICE for HL-LHC in preparation
- Muon Spectrometer proposed upgrade:
  - Muon Forward Tracker (MFT):
    - Combined tracking with the (present) Muon Spectrometer
    - Reconstruction of secondary vertices
      → reduce muon background from K, π
      → distinguish prompt J/ψs from secondary ones
      → Improve resolution for J/ψ, ψ', Υ(1s, 2s, 3s) and low masse resonances (ρ, ω, Φ)
    - Detector type: Silicon Pixel ~ 20 μm of vertex resolution, 5 planes
  - Main upgrade of the (present) Muon Spectrometer also needed
- New Collaborators welcome !

- Backup

Beam-induced background in pp 2011

- Since Sep. 2011 beam-induced background is the main source of hits on the RPCs. Single hit rate reaches ~ 35 Hz/cm^2 at low luminosity → Bad vacuum condition.
- Upper part of SAA3 shielding (at the beam tunnel entrance in the cavern, close to the Muon Trigger) upgraded end 2011; right part will be upgraded during the long 2013-2014 shutdown period.

- Integrated Hits (since early 2010) on the RPCs:
  - average ~13 Mhits/cm^2, maximum ~ 35 Mhits/cm^2
- RPCs could resist up to 550 Mhits/cm^2 without significant ageing effect → ageing R&D