ALICE

ALICE Upgrades

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for the ALICE Collaboration

Universiteit Utrecht

NIKHEF

Outline

- Physics Motivation and Strategy
- Core Upgrade (endorsed by LHCC)
  - ITS Upgrade
  - High Rate Capabilities (TPC, Electronics, DAQ/HLT/Offline, ...)
  - Physics Performance Examples
- Further Additions
  - MFT (internally approved, to be submitted)
  - FoCal (under internal consideration)
- Summary

Physics Motivation

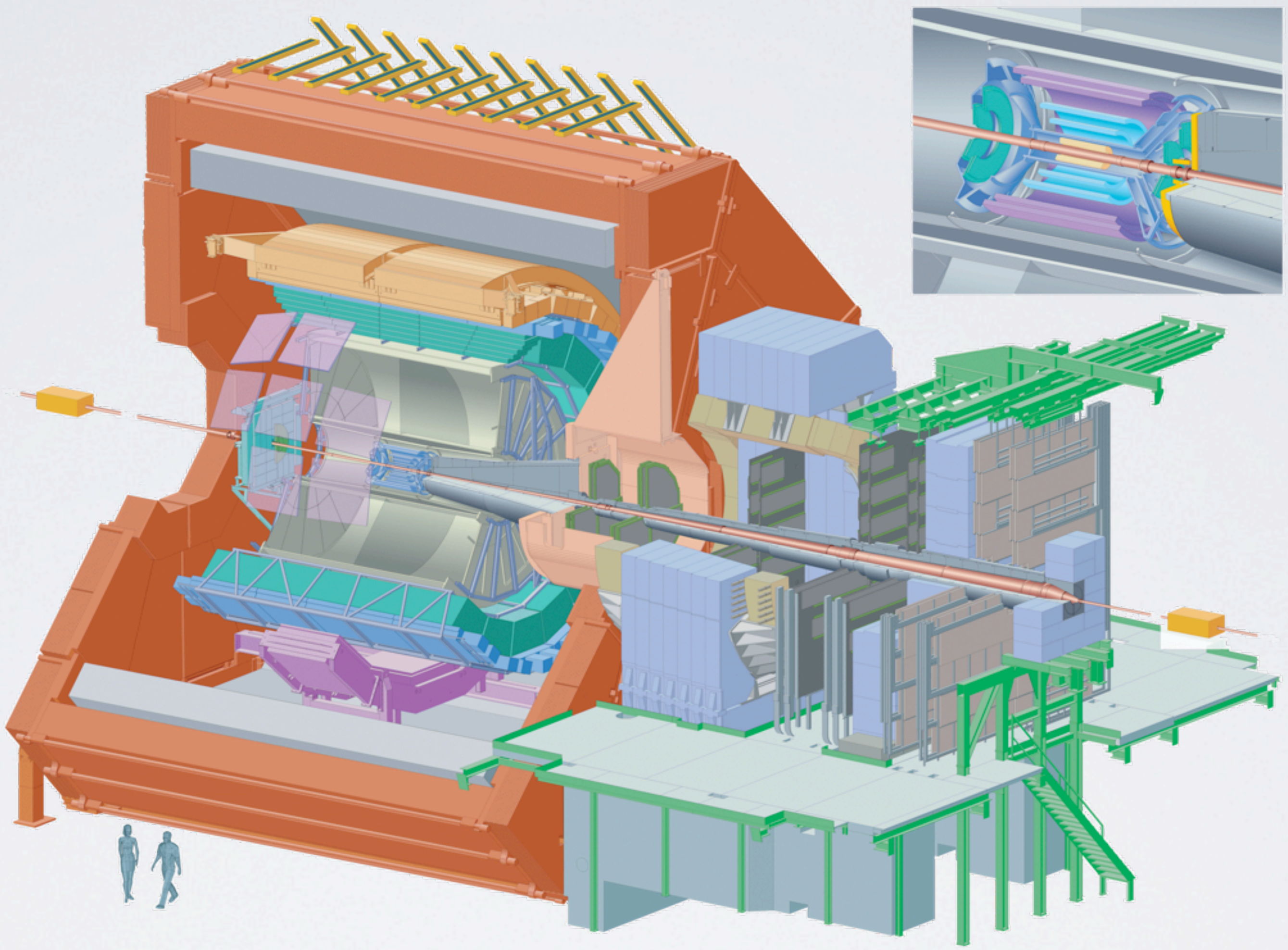
- measurement of heavy-flavour transport parameters
    - study of QGP properties via transport coefficients
- charmonium states down to $p_T=0$
    - statistical hadronization vs. dissociation/recombination
    - enhancement of forward measurement (to be endorsed)
- measurement of low-mass and low-p_T dileptons
    - chiral symmetry restoration, thermal radiation
- jet quenching and fragmentation (with PID)
- light anti- and hyper-nuclei

- *optional addition: measurement of large rapidity direct photons*
    - *low-x structure and gluon saturation*

Upgrade Strategy

- focus on low p_T, untriggerable probes requiring high statistics
    - increase rate capabilities for minimum bias heavy-ion collision
        - upgrade of TPC and ITS, all readout electronics, etc.
    - target: inspection of 50 kHz of minimum bias Pb+Pb
        - factor 100 increase in statistics (for untriggered probes)
    - collect > 10 nb^{-1} of integrated luminosity
        - upgrade in LS2, implies running few years after LS3
- ALICE is unique in low-p_T/low-mass measurements and particle identification
    - further enhance capabilities, in particular with upgraded ITS
        - closer to beam, less material, better resolution

ALICE Detector Upgrades



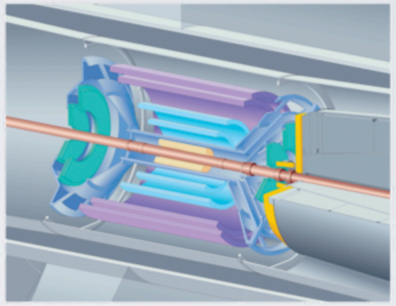
LoI endorsed by LHCC, TDRs in preparation
LoI (addendum) to be submitted to LHCC
– planned for installation in LS2

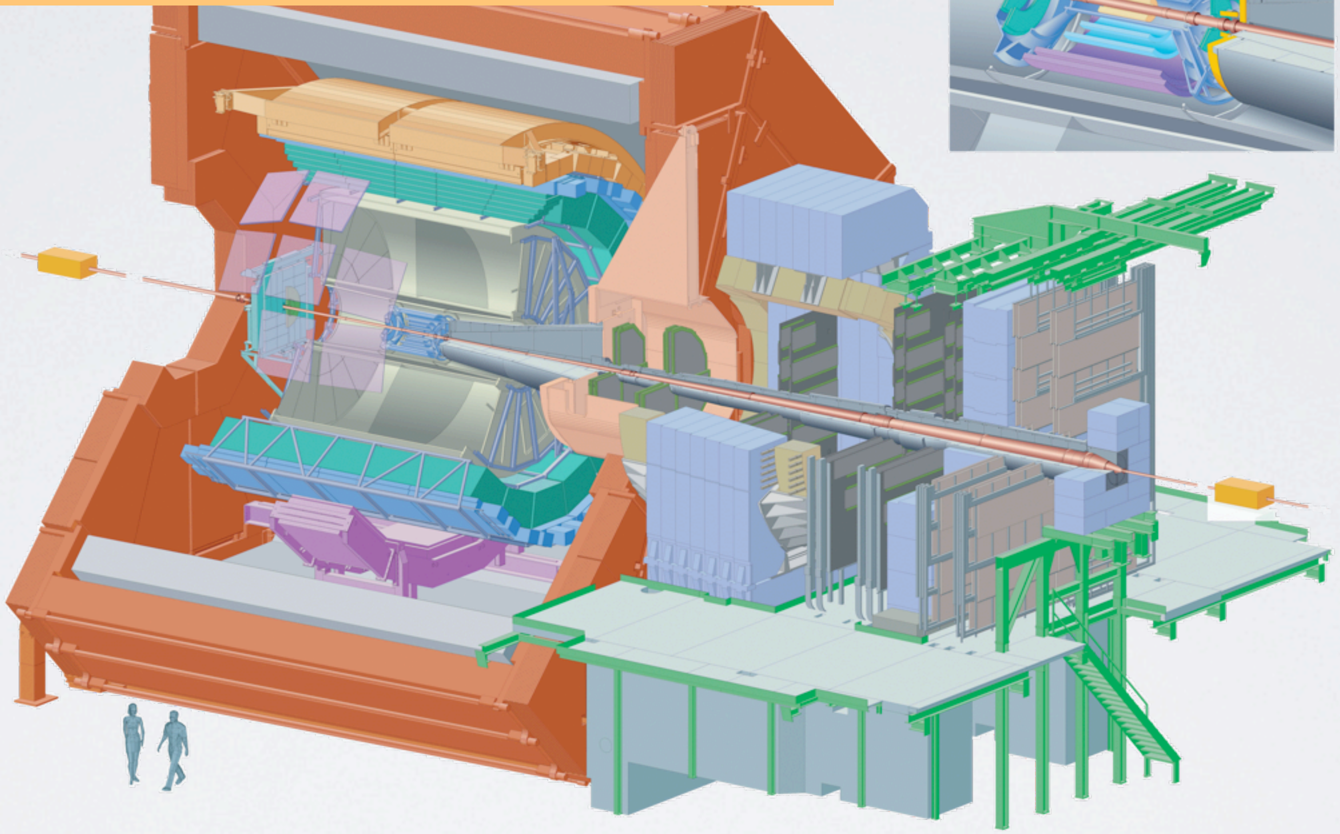
under internal review – possible installation in LS3

ALICE Detector Upgrades

new ITS: high resolution,
low material budget

TPC: new GEM readout chambers,
pipelined readout





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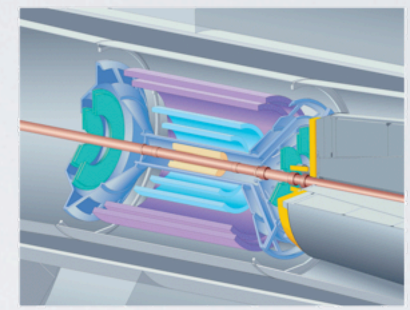
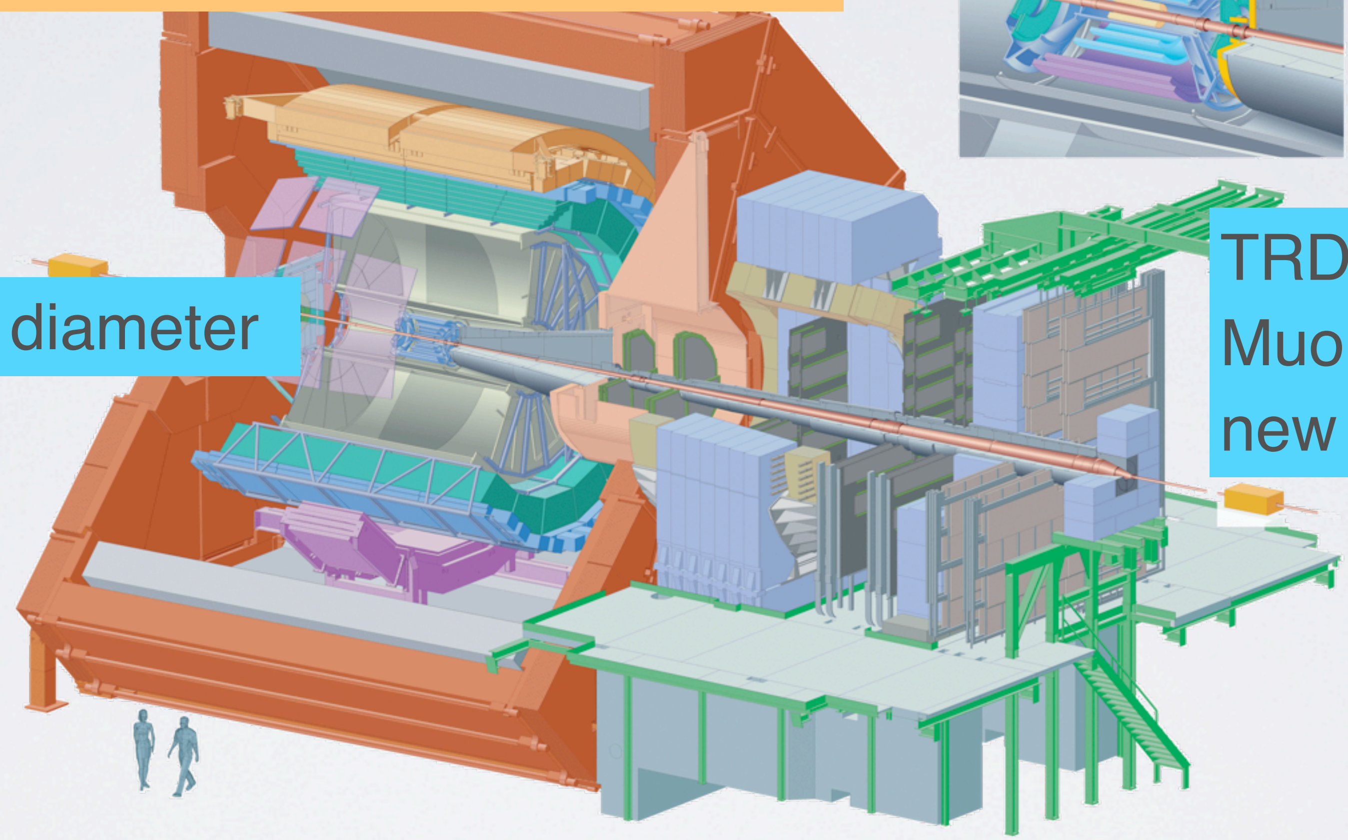




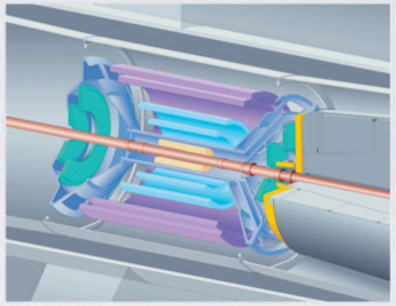
- (orange, blue) LoI endorsed by LHCC, TDRs in preparation
- (yellow) LoI (addendum) to be submitted to LHCC

  – planned for installation in LS2

- (green) under internal review – possible installation in LS3

ALICE Detector Upgrades

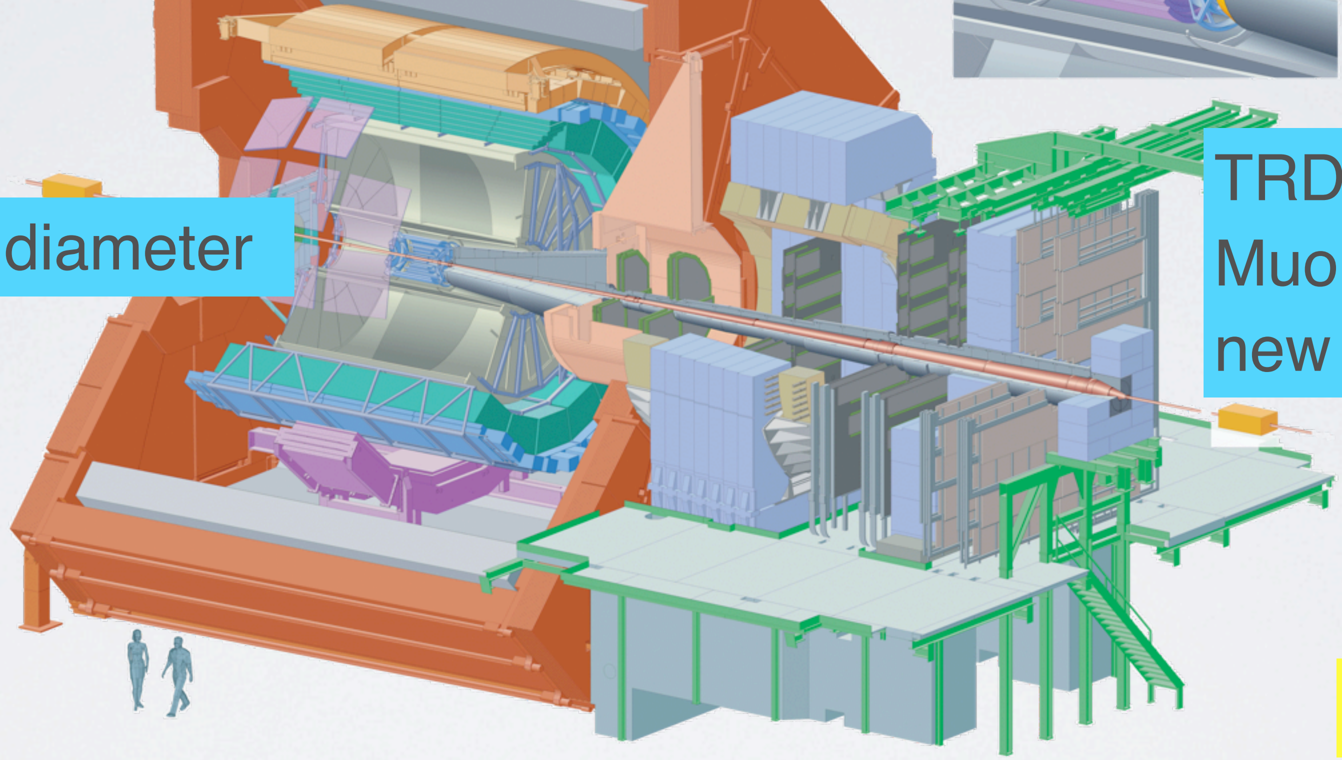
new ITS: high resolution,
low material budget



TPC: new GEM readout chambers,
pipelined readout

FoCal project

new beam pipe: smaller diameter



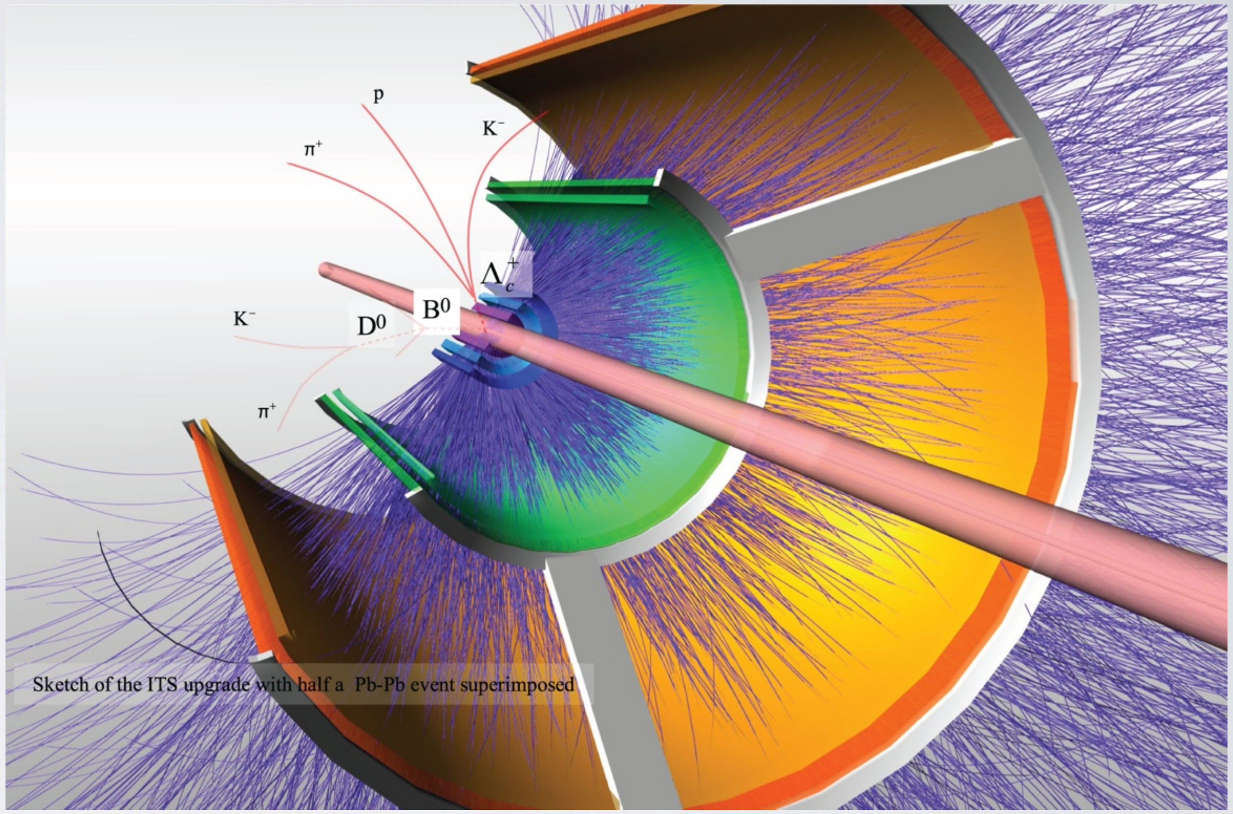
TRD, TOF, PHOS, EMCal,
Muon spectrometer:
new readout electronics

Upgrade of forward/
trigger detectors
(ZDC, VZERO, T0)

MFT project

Orange/blue	LoI endorsed by LHCC, TDRs in preparation	– planned for installation in LS2
Yellow	LoI (addendum) to be submitted to LHCC	
Green	under internal review	– possible installation in LS3

ITS Upgrade



improve secondary vertex resolution by factor ≈3 (5) in rϕ (z):

- inner layer as close as possible (R = 2.2 cm)
  - smaller beam pipe (R = 1.9cm)
- less material budget
  - thin sensors (goal: 0.3% X_0/layer)
  - thinner beam pipe (ΔR = 800μm)
- smaller pixel size (2 options)
  - baseline: monolithic pixels (20μm x 20μm)
  - fallback: hybrid pixels (50μm x 50μm)

high standalone efficiency and p_T resolution

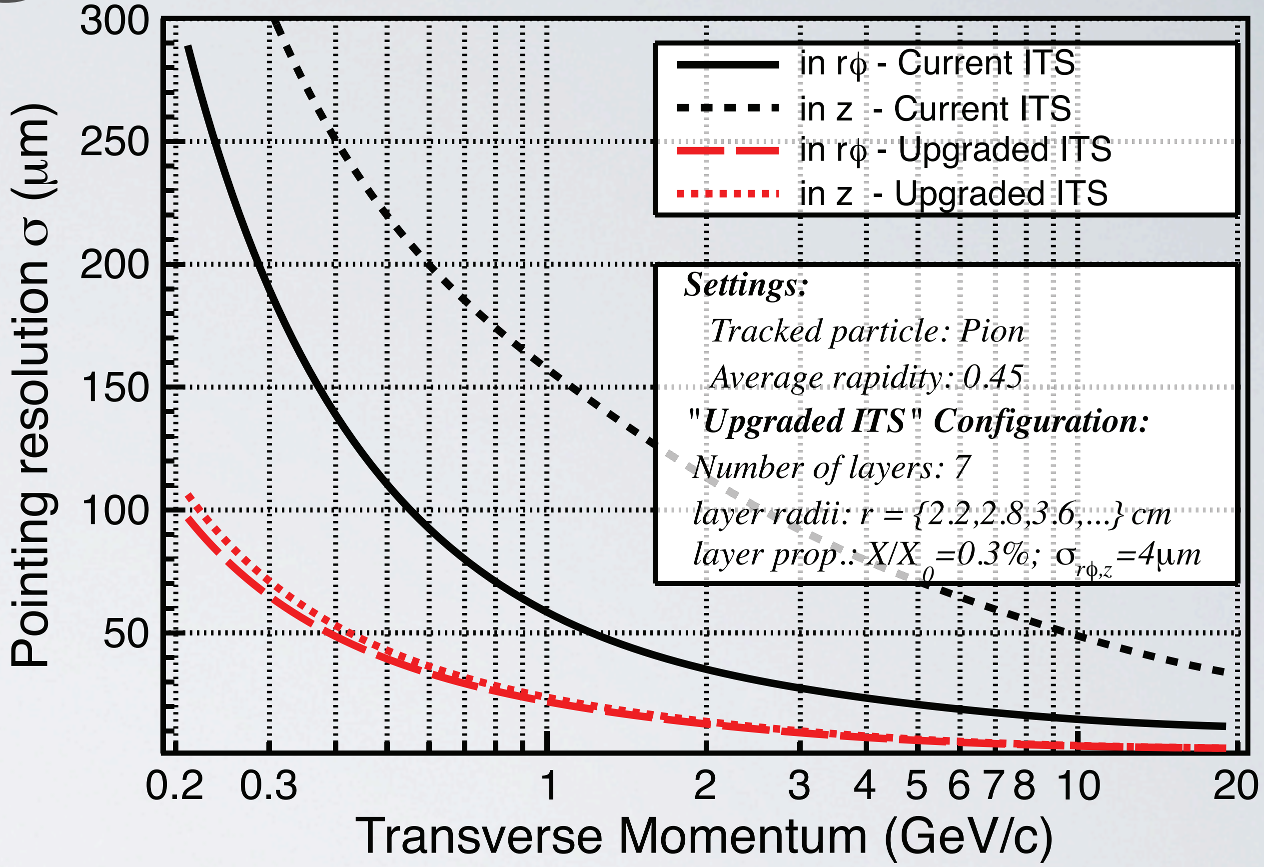
fast readout

fast removal/insertion for easy possible yearly maintenance

ITS Upgrade

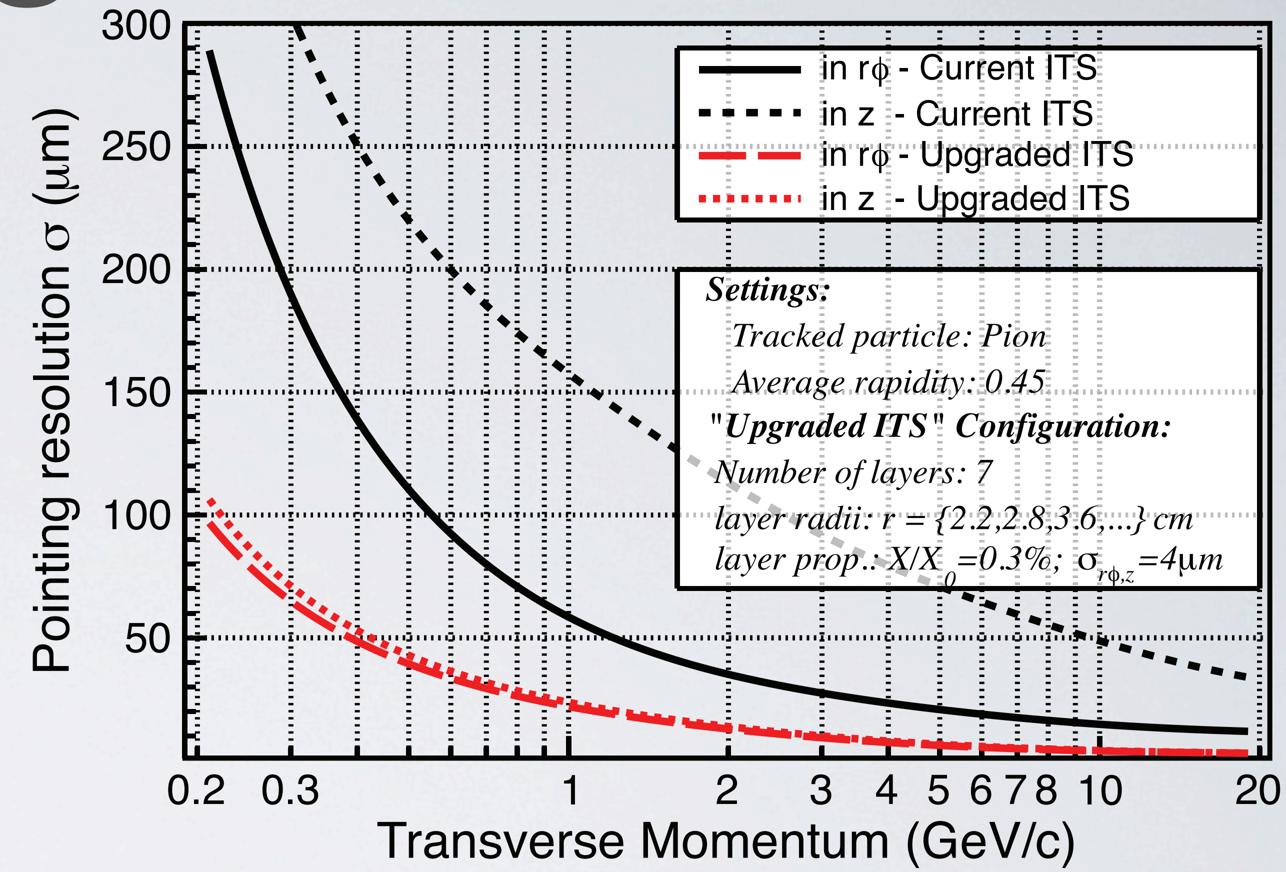
improved performances:

- pointing resolution



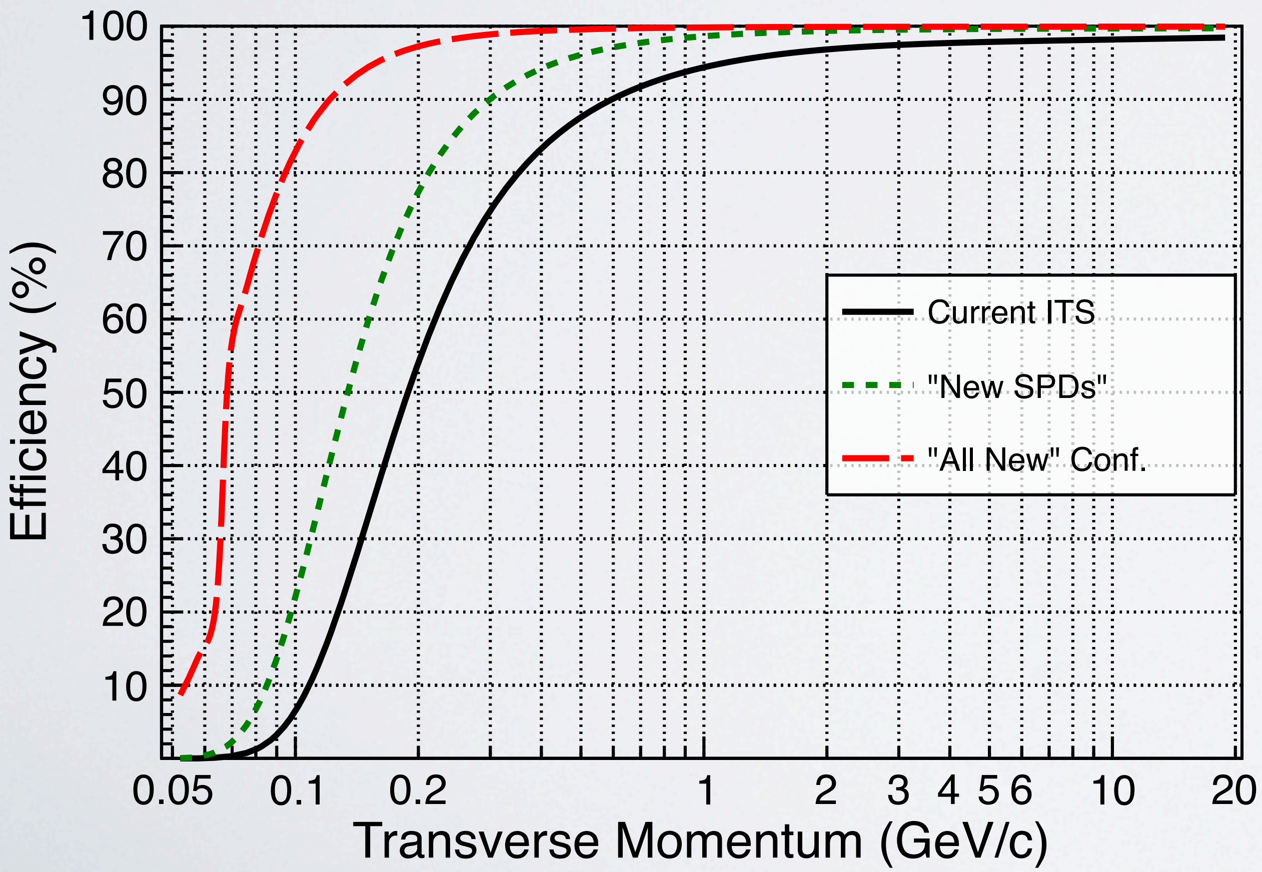
T. Peitzmann, ALICE upgrades, LHCP 2013

ITS Upgrade



improved performances:

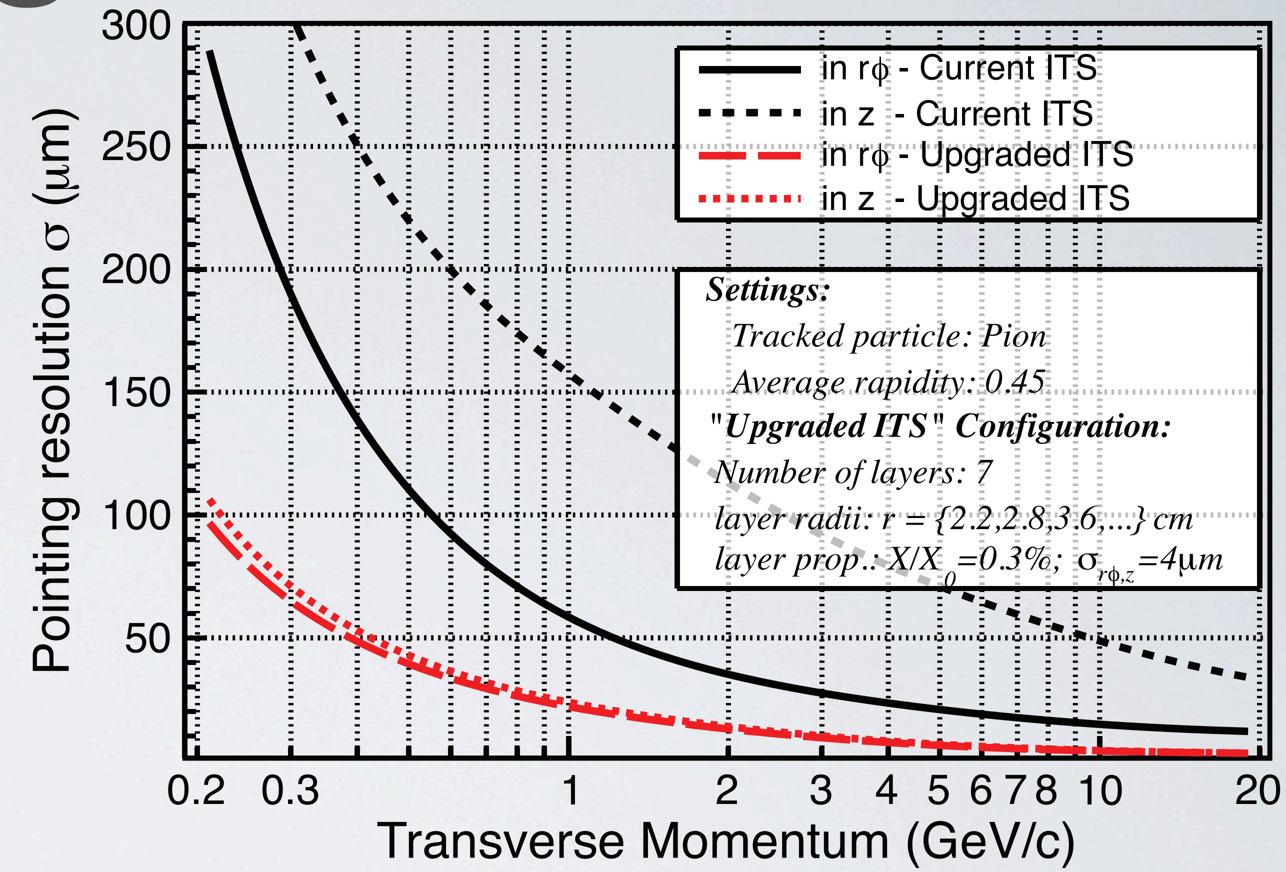
- pointing resolution
- standalone tracking efficiency at low p_T

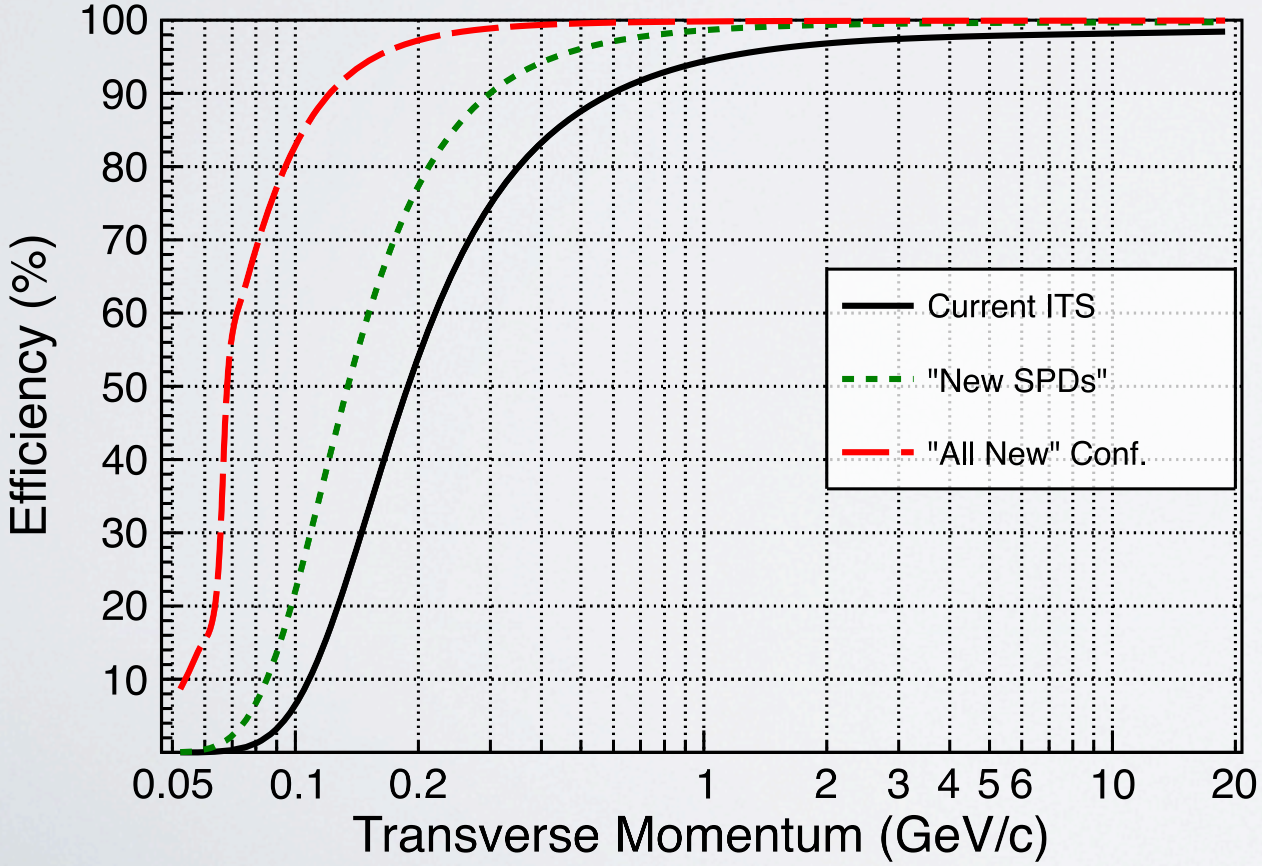


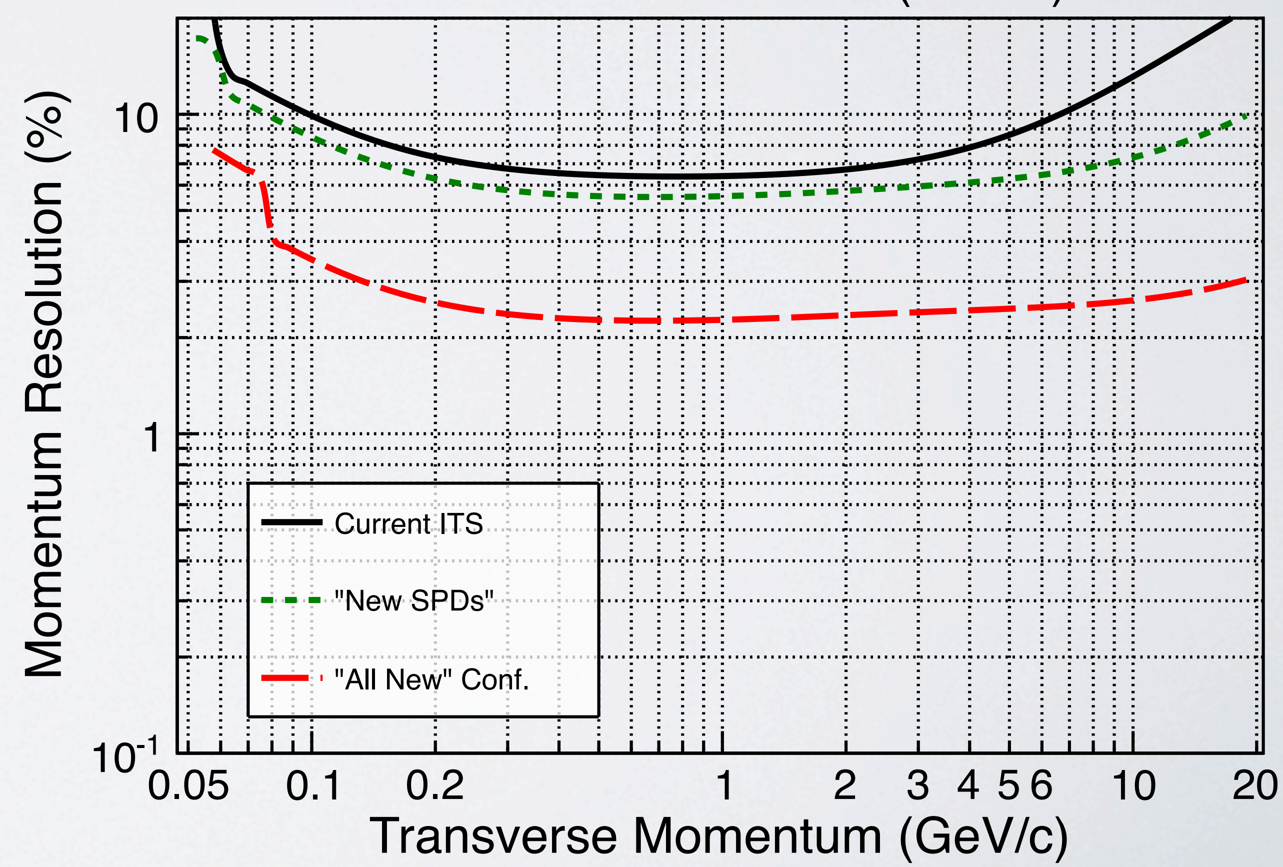
ITS Upgrade

improved performances:

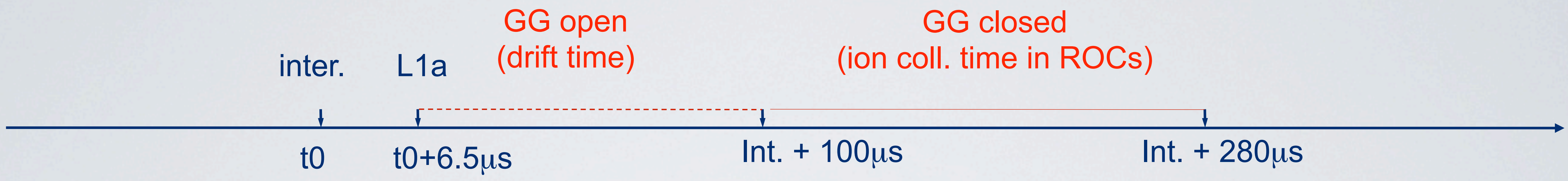
- pointing resolution
- standalone tracking efficiency at low p_T
- standalone momentum resolution







Limits of Current TPC



- gating grid (GG) of readout chambers closed to avoid ion feedback
    - limit space charge to tolerable level
    - effective dead time ≈280 μs, maximum readout rate: ≈3.5 kHz

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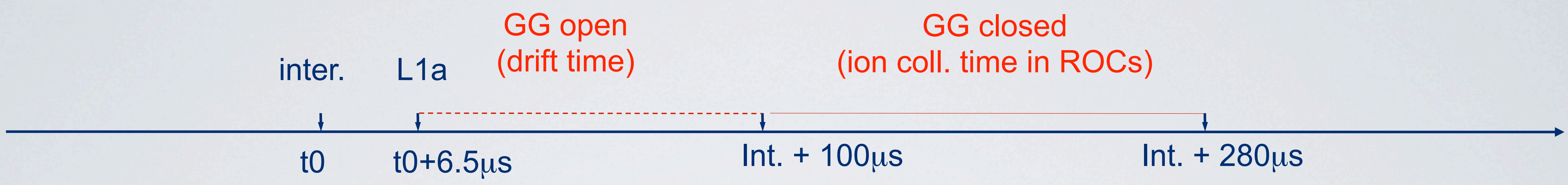
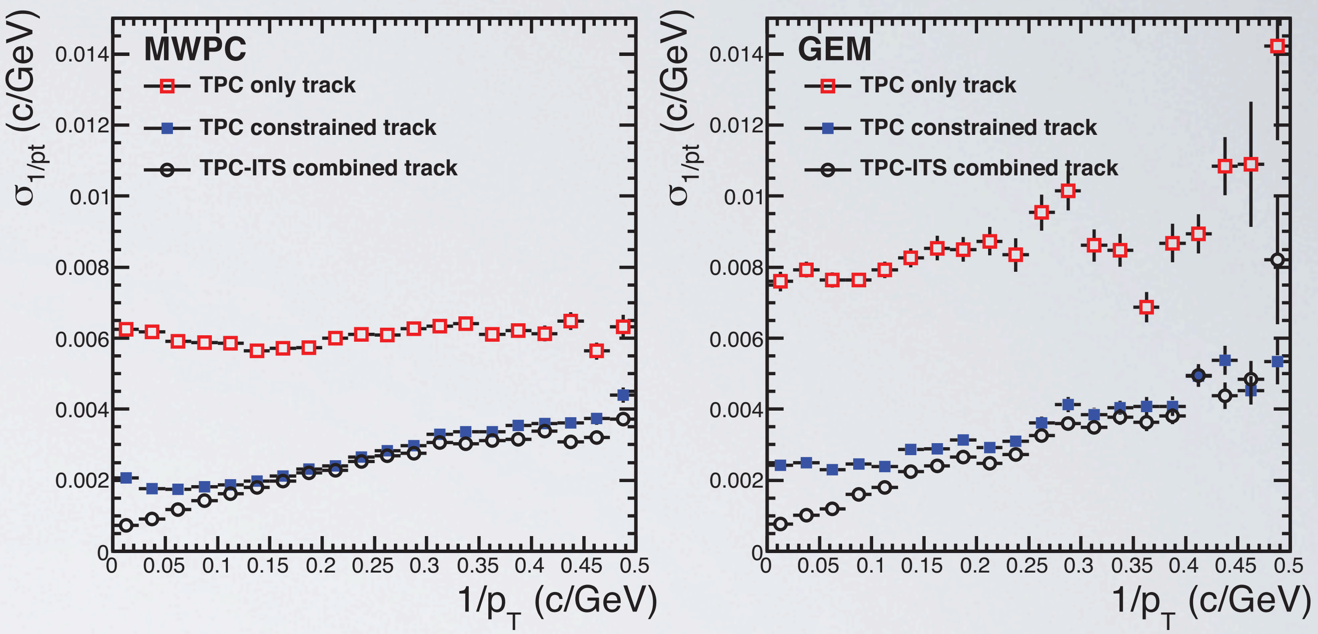


- gating grid (GG) of readout chambers closed to avoid ion feedback
  - limit space charge to tolerable level
  - effective dead time ≈280 μs, maximum readout rate: ≈3.5 kHz
- opening gating grid permanently is not possible
  - ion feedback ≈ 10^3 x number of primary charges
  - large space charge effects (of the order of electrical field)
    - space point distortions of order of 1 m - not tolerable!

TPC Upgrade

new readout chambers

- replace MWPC with GEMs
- no gating, small ion feedback
- usage of existing pad-planes possible
  - momentum resolution for constrained tracks not affected



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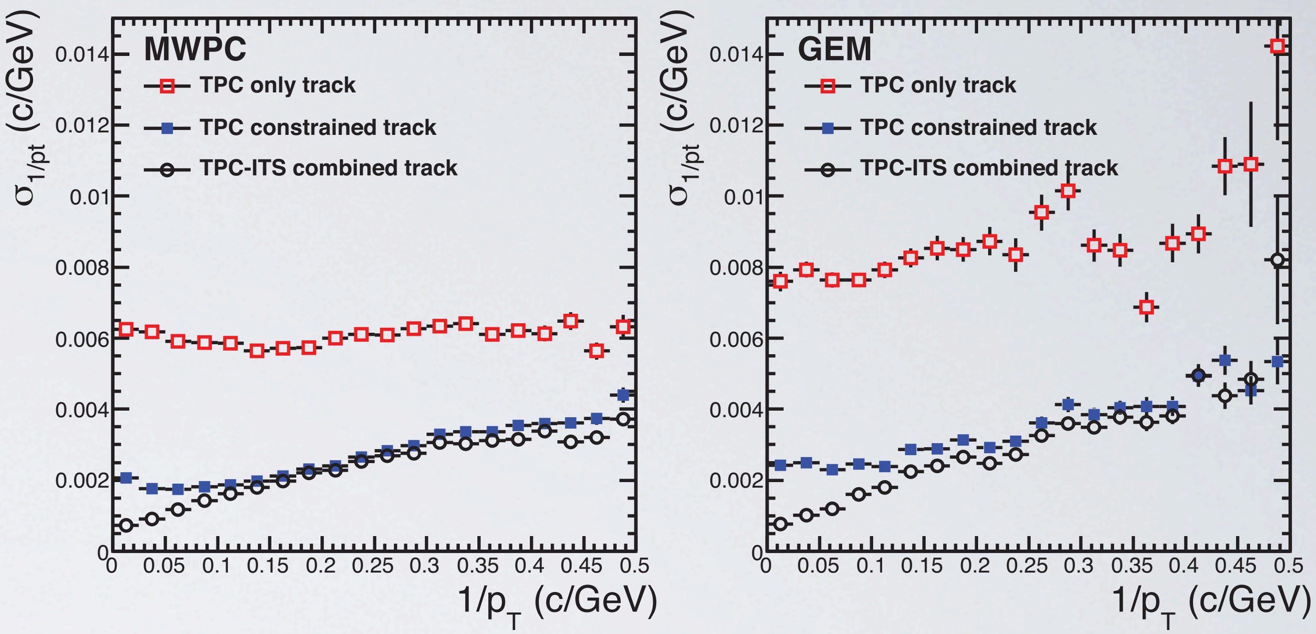

continuous sampling at 10 MHz, ship data unsuppressed off detector

- needs new electronics (FE chip joint project with muon arm)

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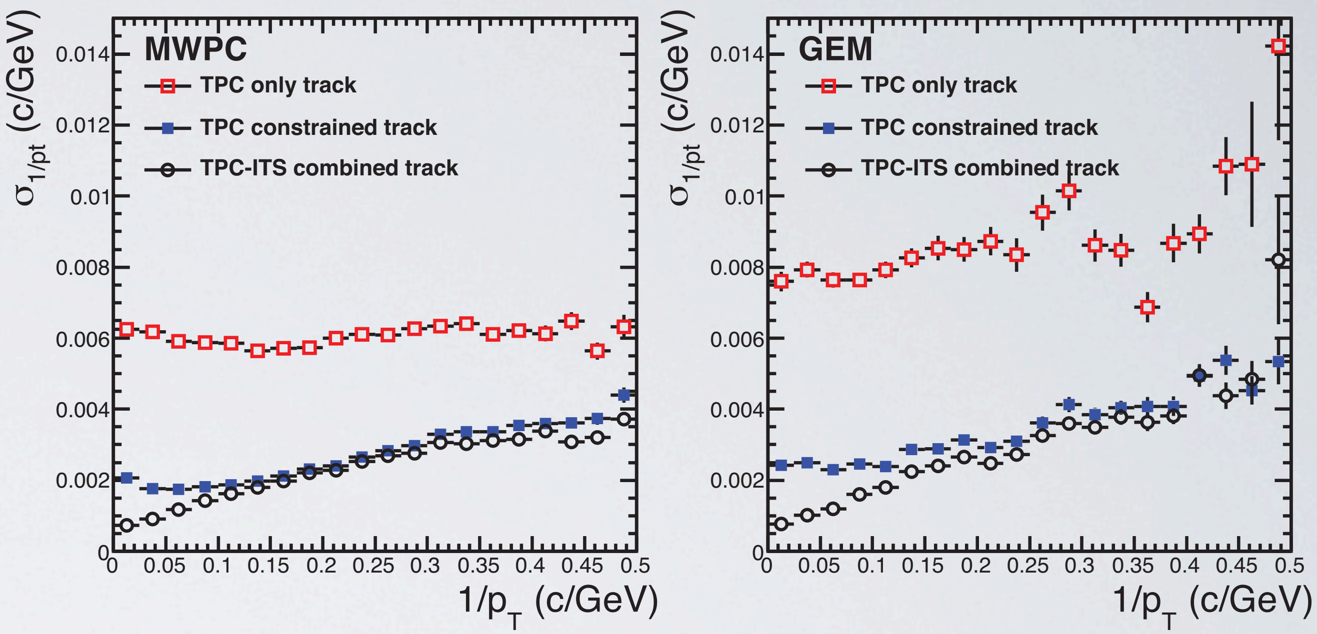
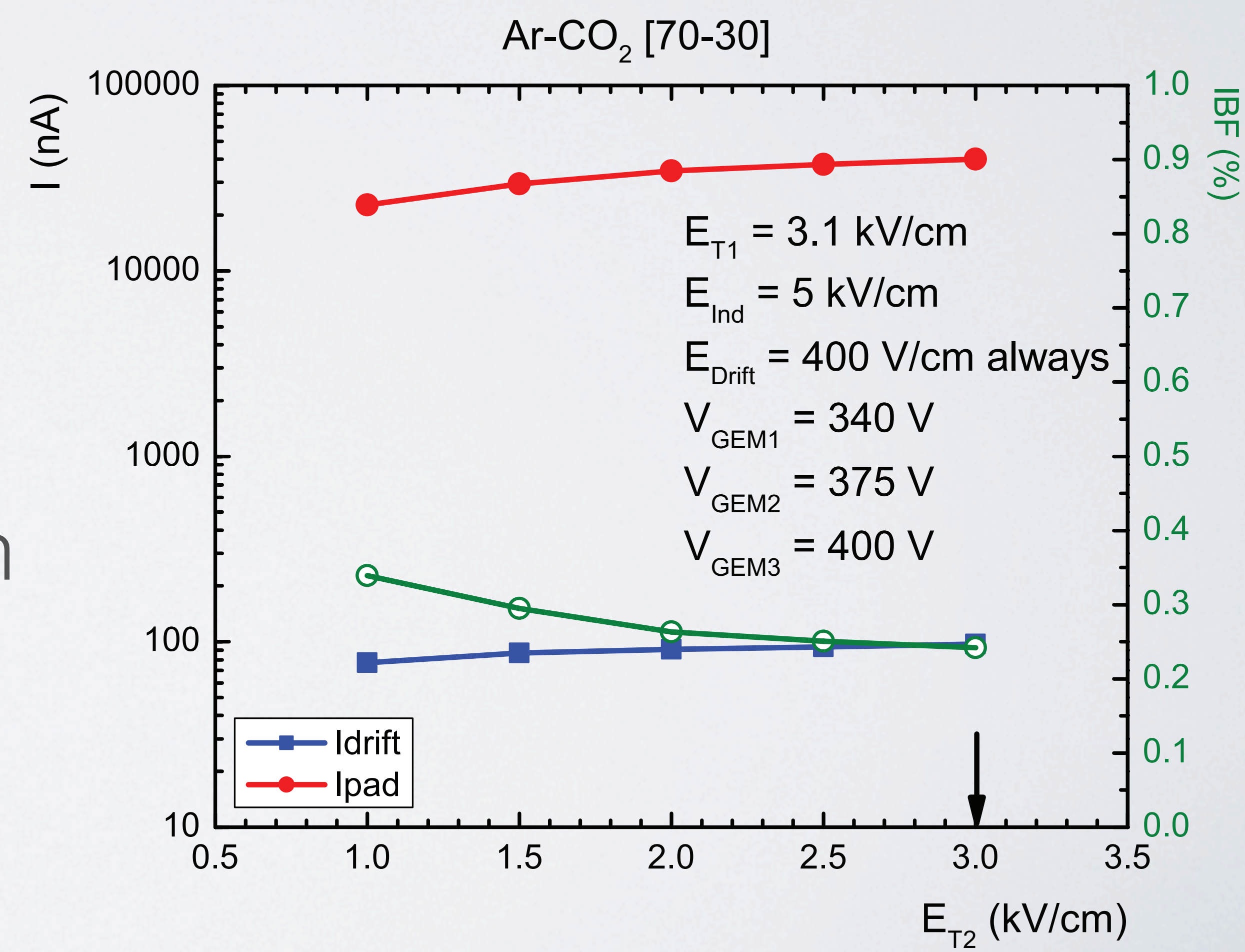


continuous sampling at 10 MHz, ship data unsuppressed off detector

- needs new electronics (FE chip joint project with muon arm)

extensive R&D program ongoing with lab tests

- confirm low ion feedback
  - goal: 0.25% at gain of 2000
- investigate gain stability



DAQ: Event Size and Rates

- upgrade of all readout electronics and new DAQ/HLT
- need huge bandwidth to data storage assuming:
  - event size of major systems, I/O rates of online system
  - assume average minbias rate to tape of 20 kHz
- requires data reduction for TPC: clustering, reconstruction

Detector	Event Size (MByte)		Input to Online System (GByte/s)	Compressed Output to data storage (GByte/s)	
	After Zero Suppression	After Data Compression		Peak	Average
ITS	0.8	0.2	40	10.0	4.0
TPC	20.0	1.0	1000	50.0	20.0
TRD (20 kHz)	0.3	0.1	6	2.0	2.0
Others (1)	0.5	0.25	25	12.5	5.0
Total	**21.6**	**1.55**	**1071**	**74.5**	**31.0**

Performance: Heavy Flavour

- thermalization of heavy quarks
  - baryon/meson ratio for charm and beauty
  - azimuthal anisotropy
- heavy quark energy loss
  - nuclear modification factor of identified D and B mesons
    - mass hierarchy of energy loss: smaller energy loss expected for heavy quarks due to dead cone effect
- benchmark channels:

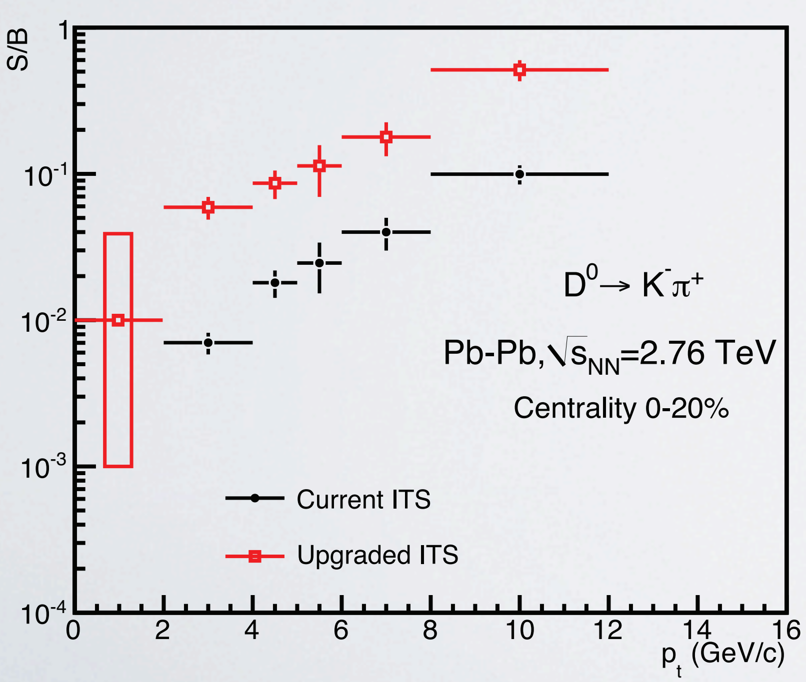
$$D^0 \to K^- \pi^+$$

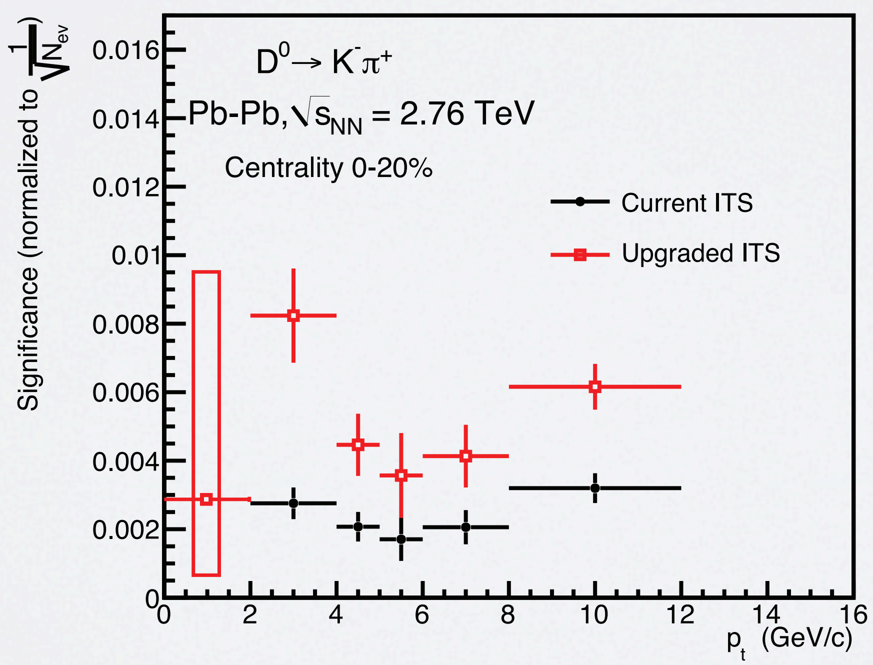
$$B \to D^0 + X$$

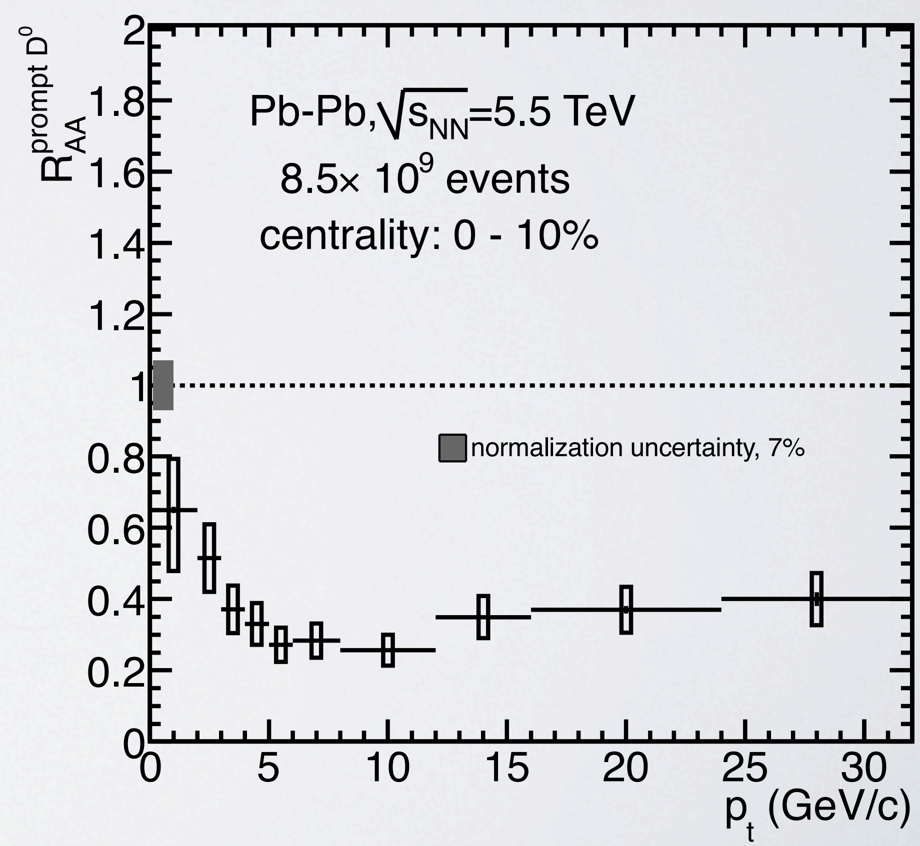
$$\Lambda_c \to p K^- \pi^+$$

$D^0 \rightarrow K^- \pi^+$

- basic benchmark for all D meson studies
- example: current D meson R_{AA}
    - large uncertainties at low p_T
- with upgrade: strongly improved bkg rejection, signal significance
- higher precision on R_{AA}

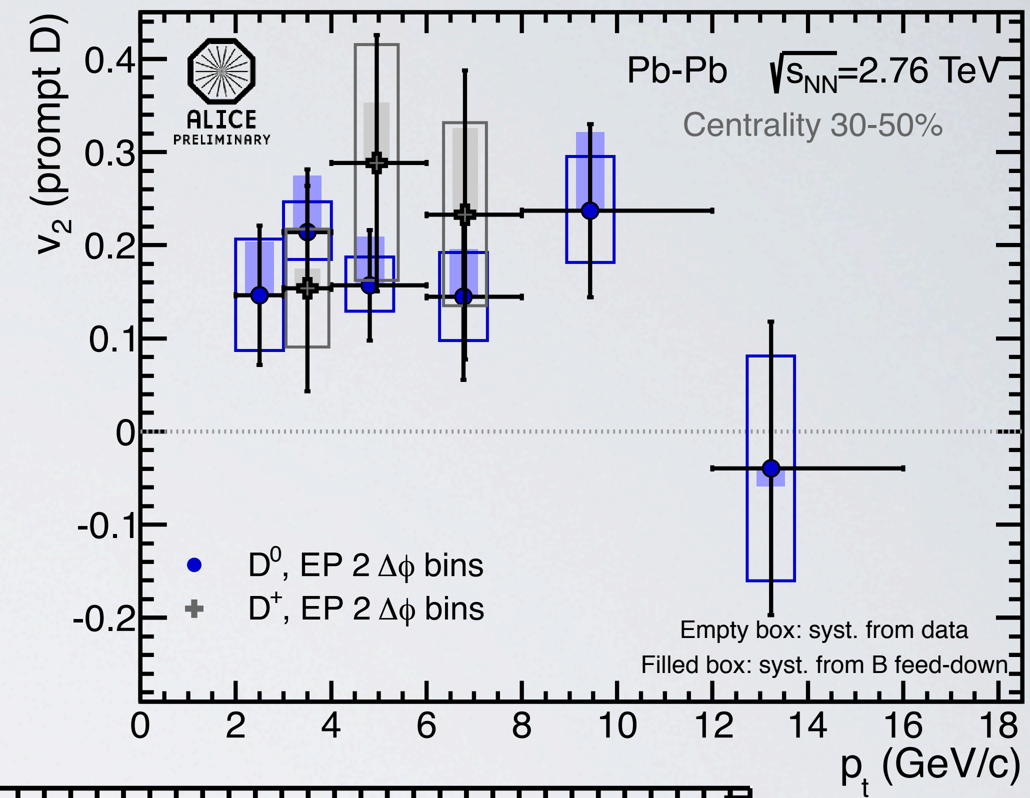


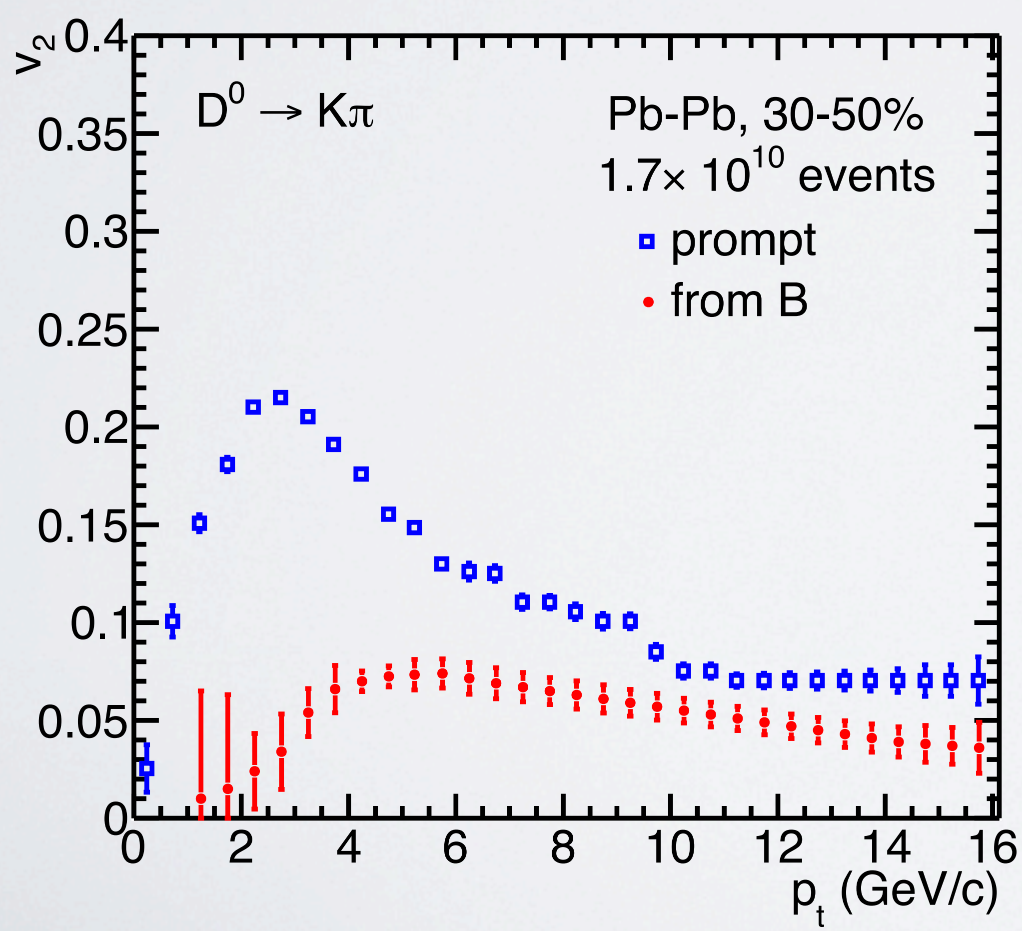


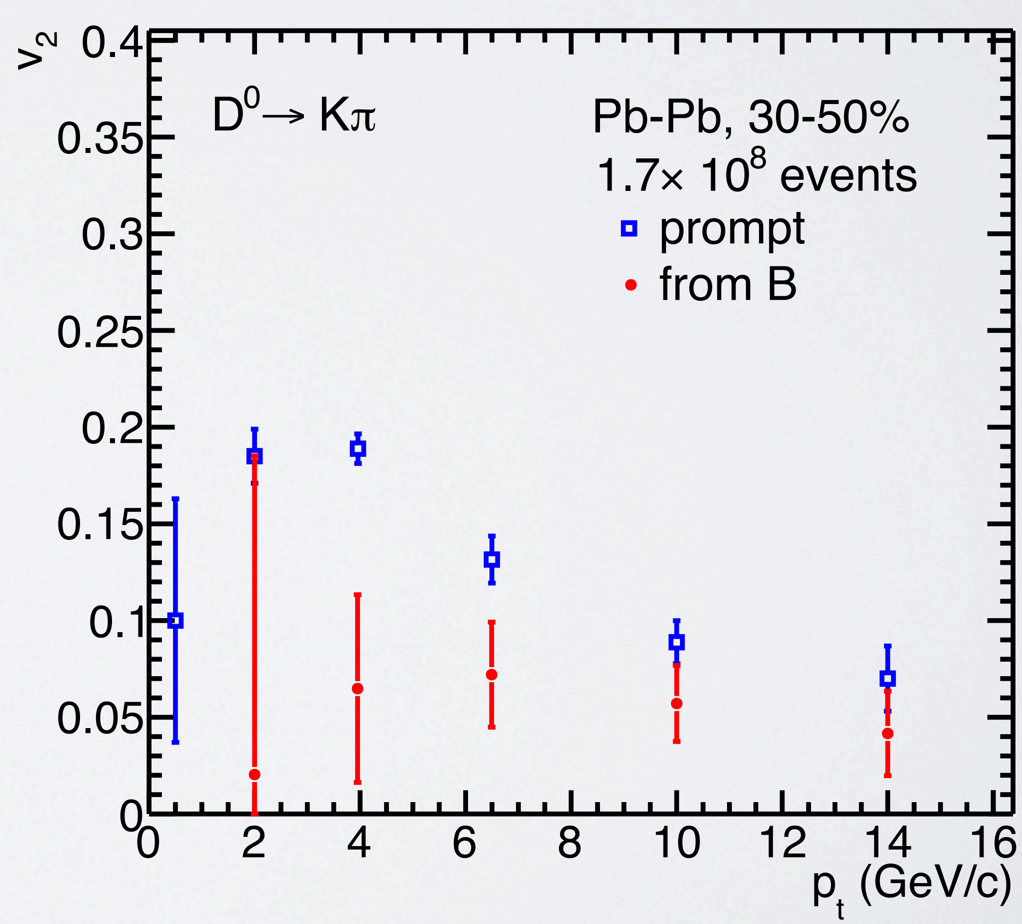


Heavy Flavour Elliptic Flow

- current D-meson v_2 measurement:
  - large uncertainties
- ITS upgrade and large luminosity required for high precision v_2 measurement of primary and secondary D-mesons

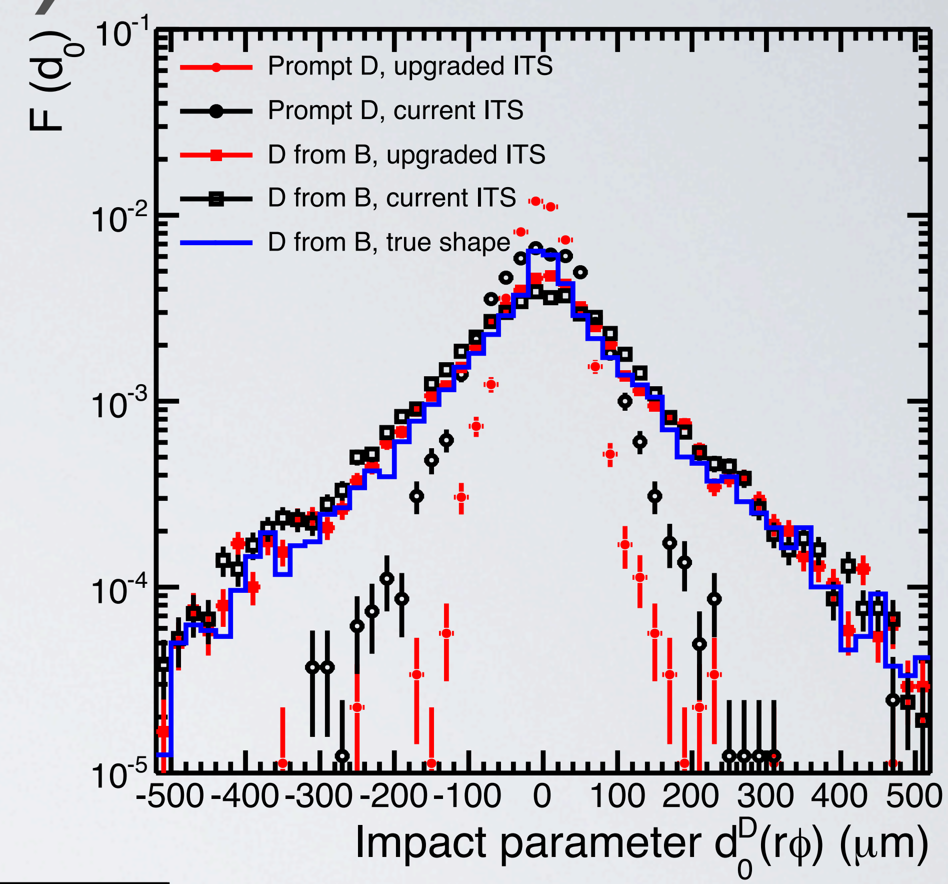


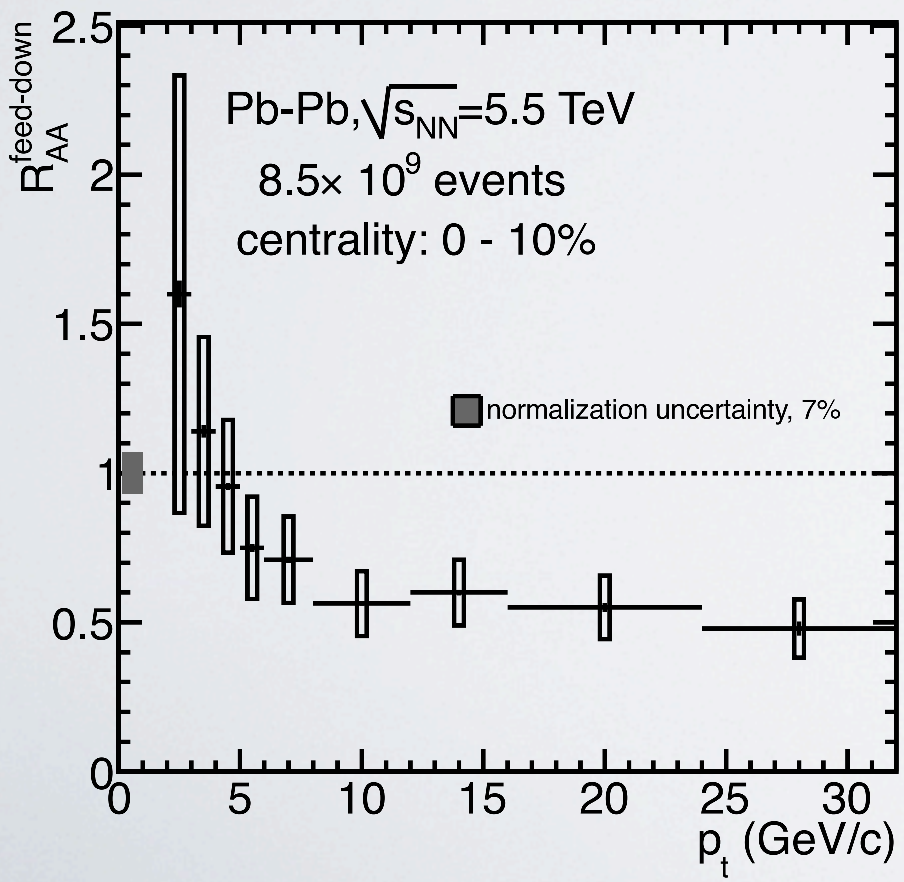


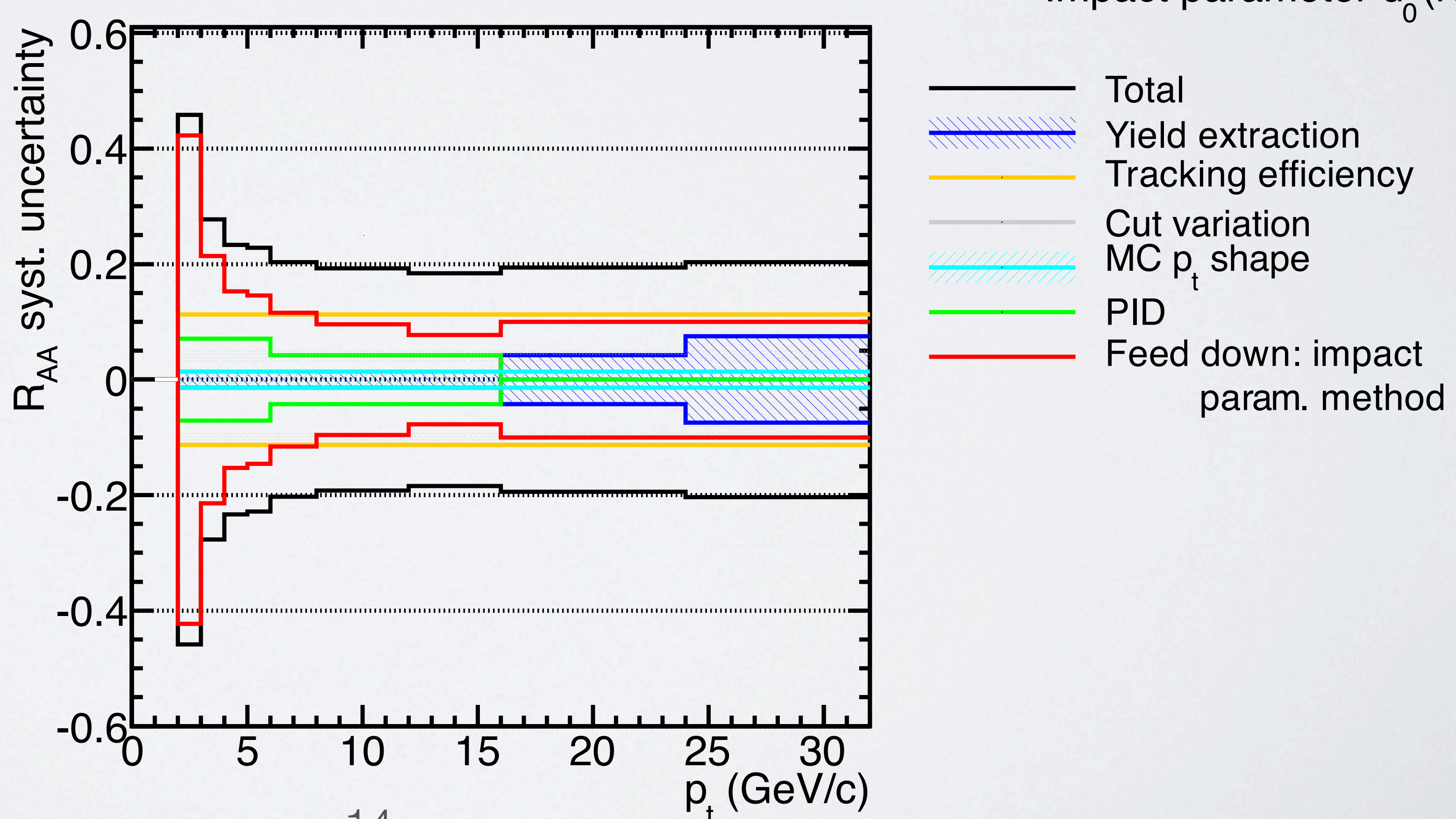


$B \rightarrow D^0 (\rightarrow K^- \pi^+) + X$

- discriminate primary and secondary D-mesons
- long lifetime of B meson ($c\tau \approx 500\mu m$): measure via impact parameter
  - significantly improved by upgrade
- e.g. measurement of R_{AA} ($B \rightarrow D^0$)

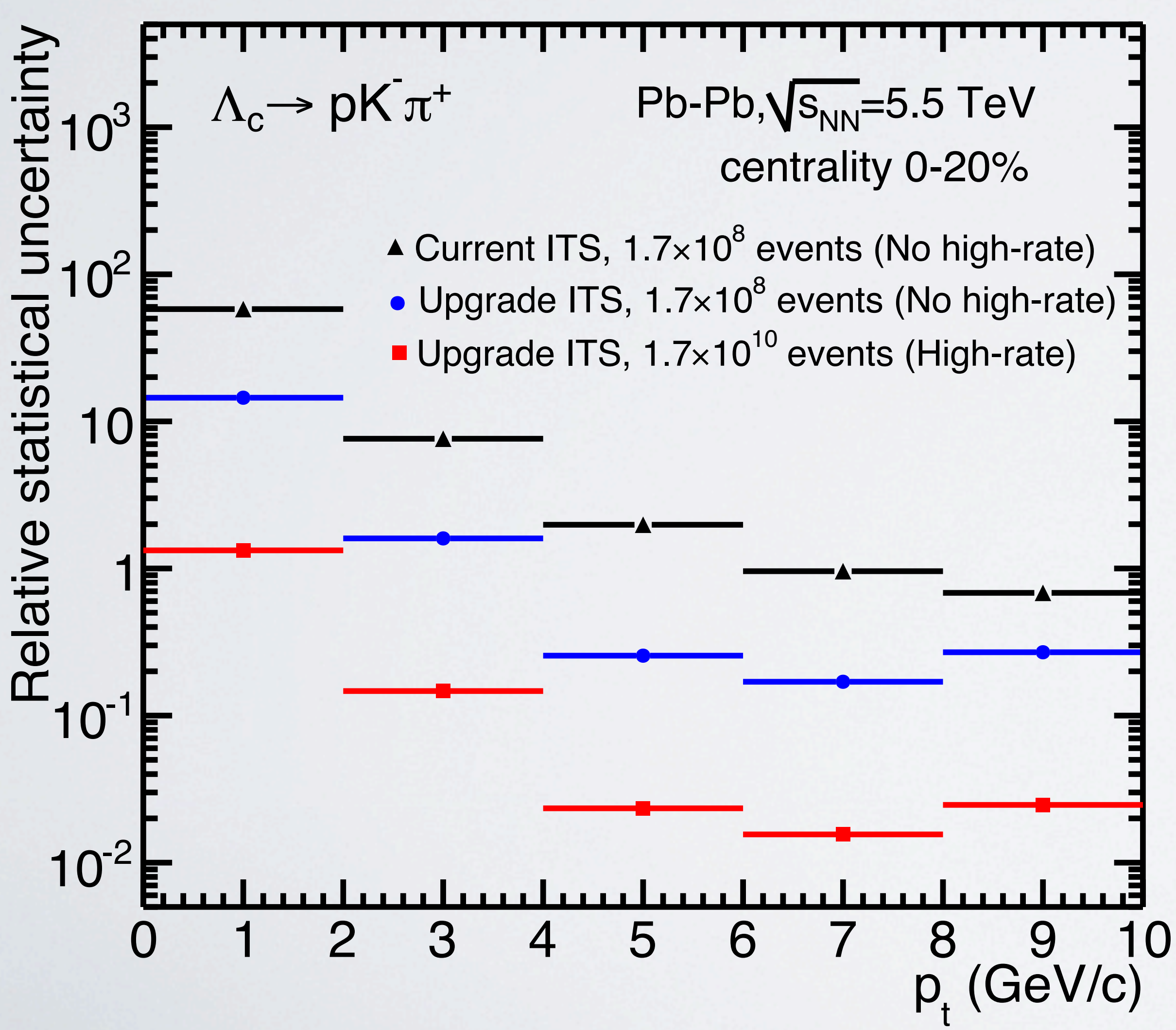


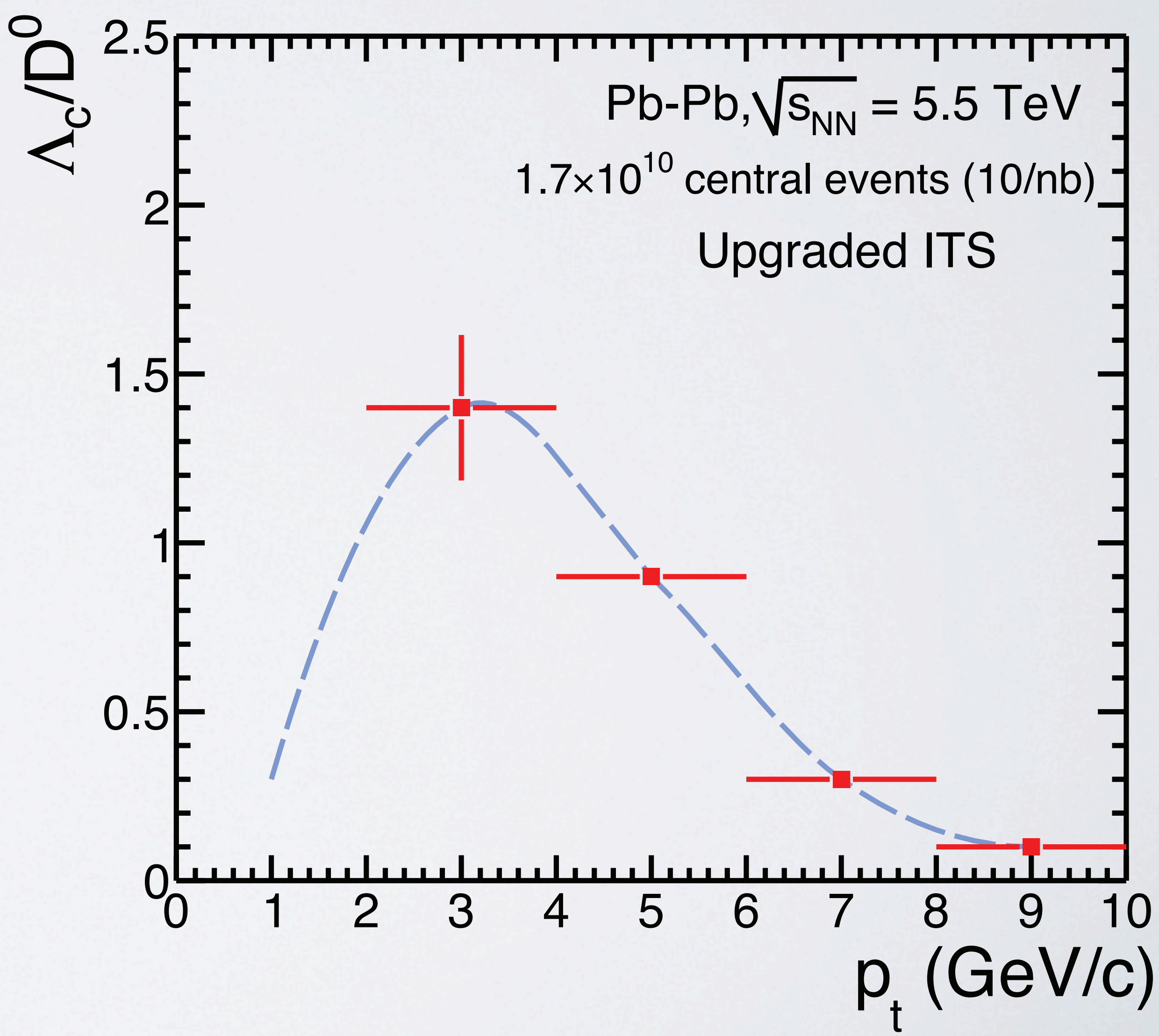




$\Lambda_c \rightarrow pK^-\pi^+$

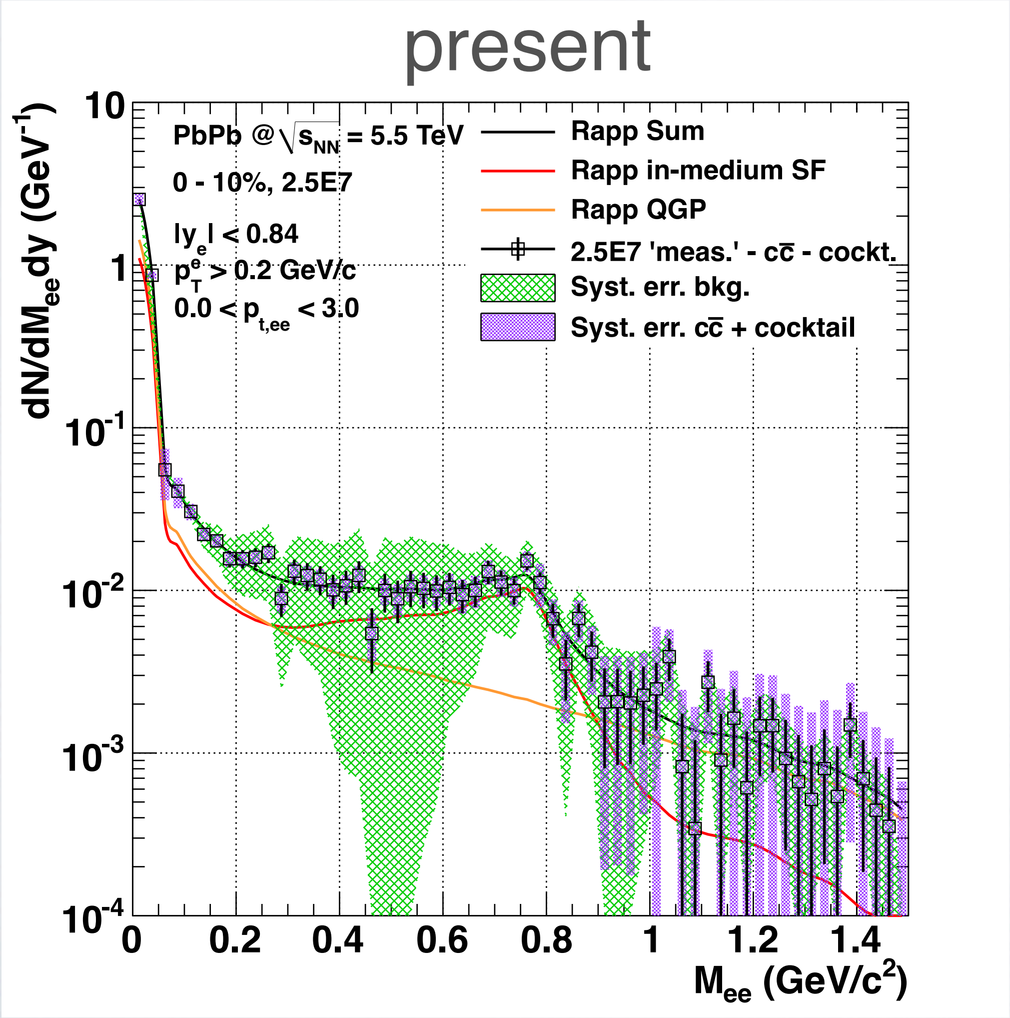
- challenging measurement:
  - small branching ratio, short decay length ($c\tau \approx 60\mu m$), large combinatorial background in Pb+Pb
- measurement possible at low p_T only with upgrade and high rate





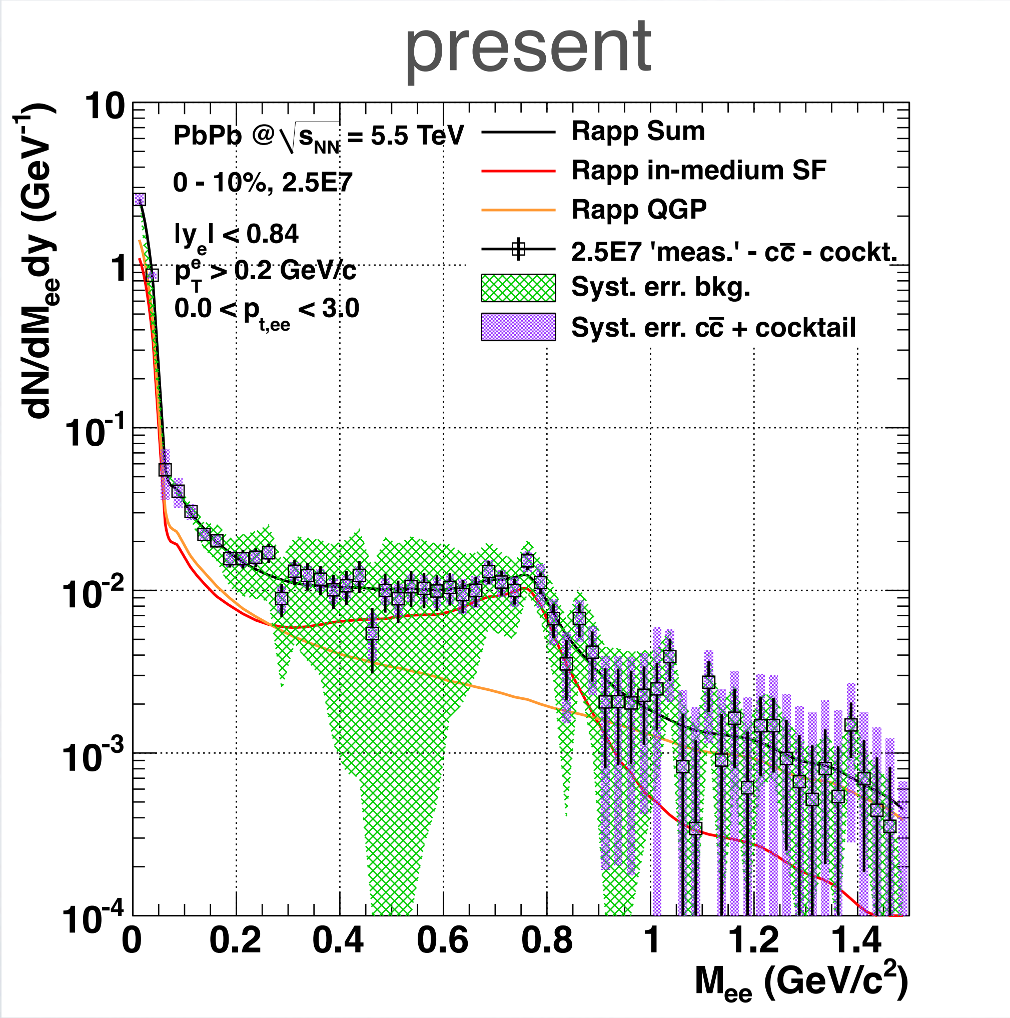
Low-Mass Dielectrons

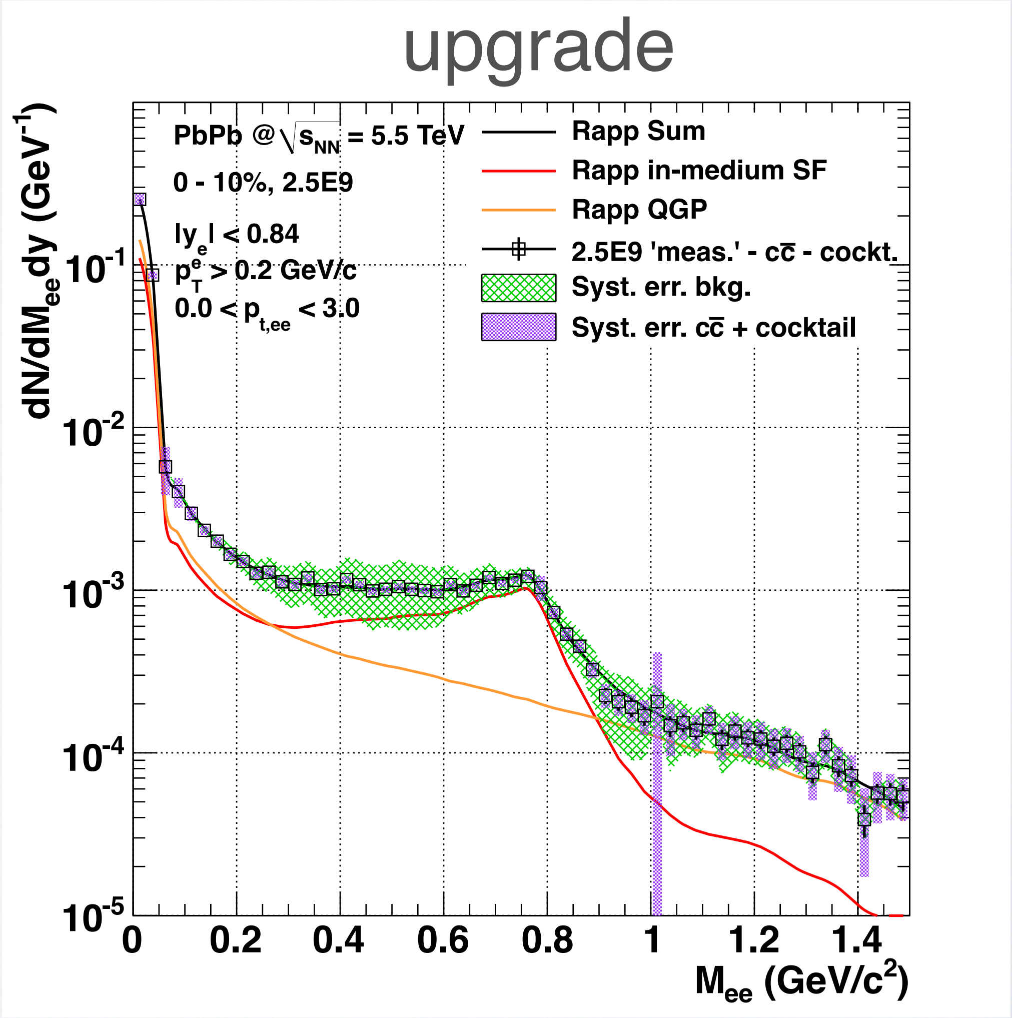
- uncertainties with current ITS
  - limited by background subtraction and statistics



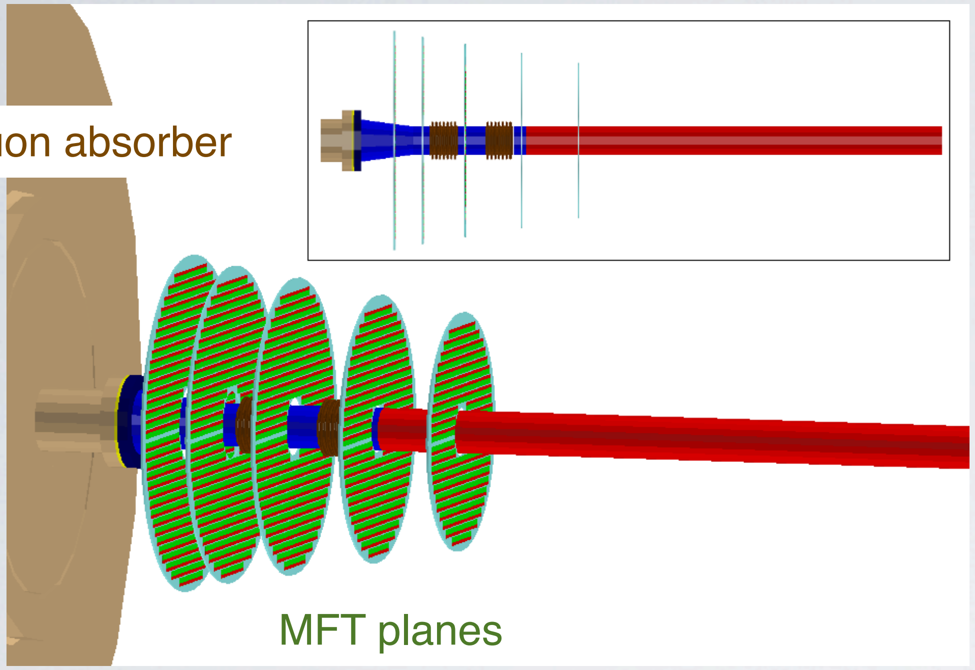
Low-Mass Dielectrons

- uncertainties with current ITS
  - limited by background subtraction and statistics
- high rate measurement with new ITS (using B = 0.2T)
  - more efficient cuts to reduce background, high statistics: allows detailed measurement of low-mass dielectrons





Muon Forward Tracker



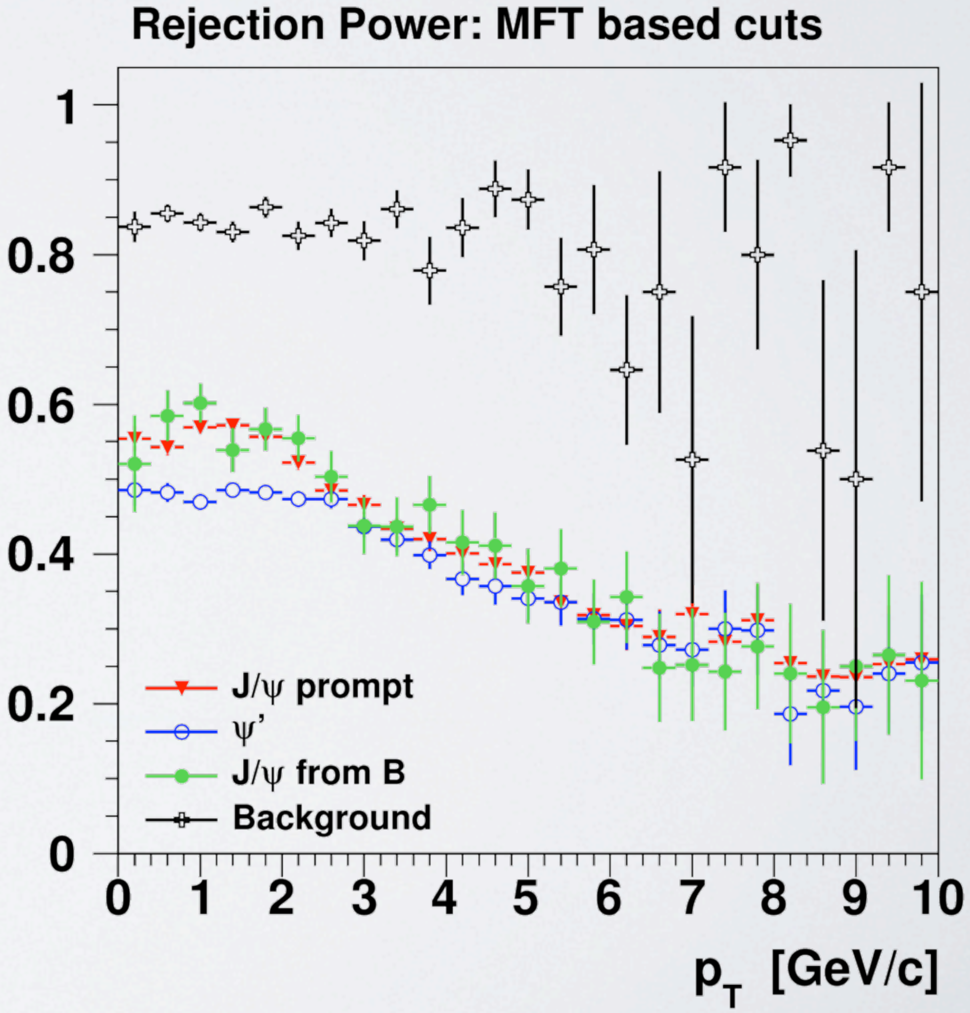
5 circular Si-pixel planes covering (most of) muon arm acceptance: -3.6 < η < -2.5

pixel size ≈ 25 μm x 25 μm

technology of choice: monolithic active pixels

complement muon arm with tracking in front of absorber

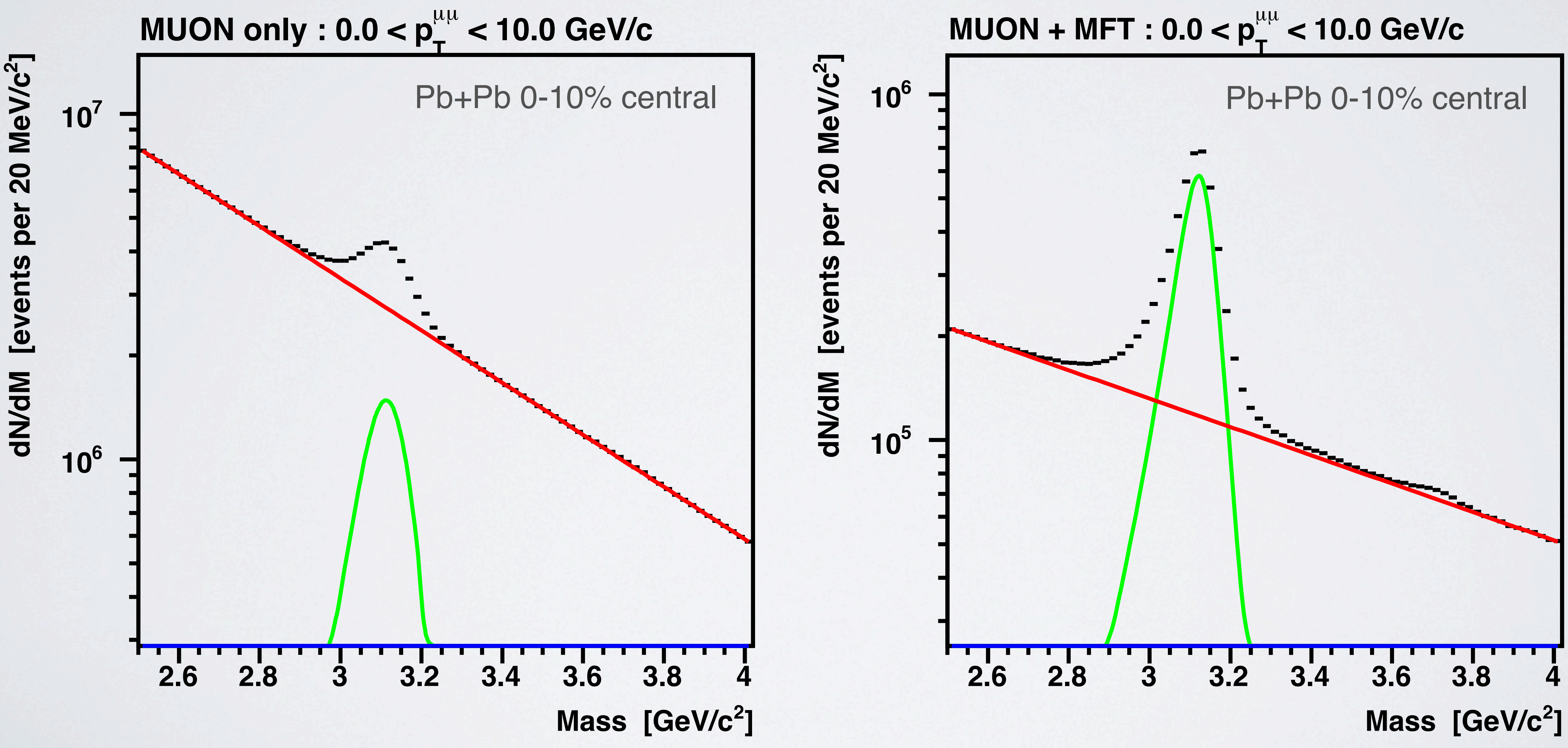
- secondary vertex measurement
- better background rejection
- improved mass resolution



access prompt vs. secondary J/ψ, possible sensitivity to chiral symmetry via low-mass dileptons

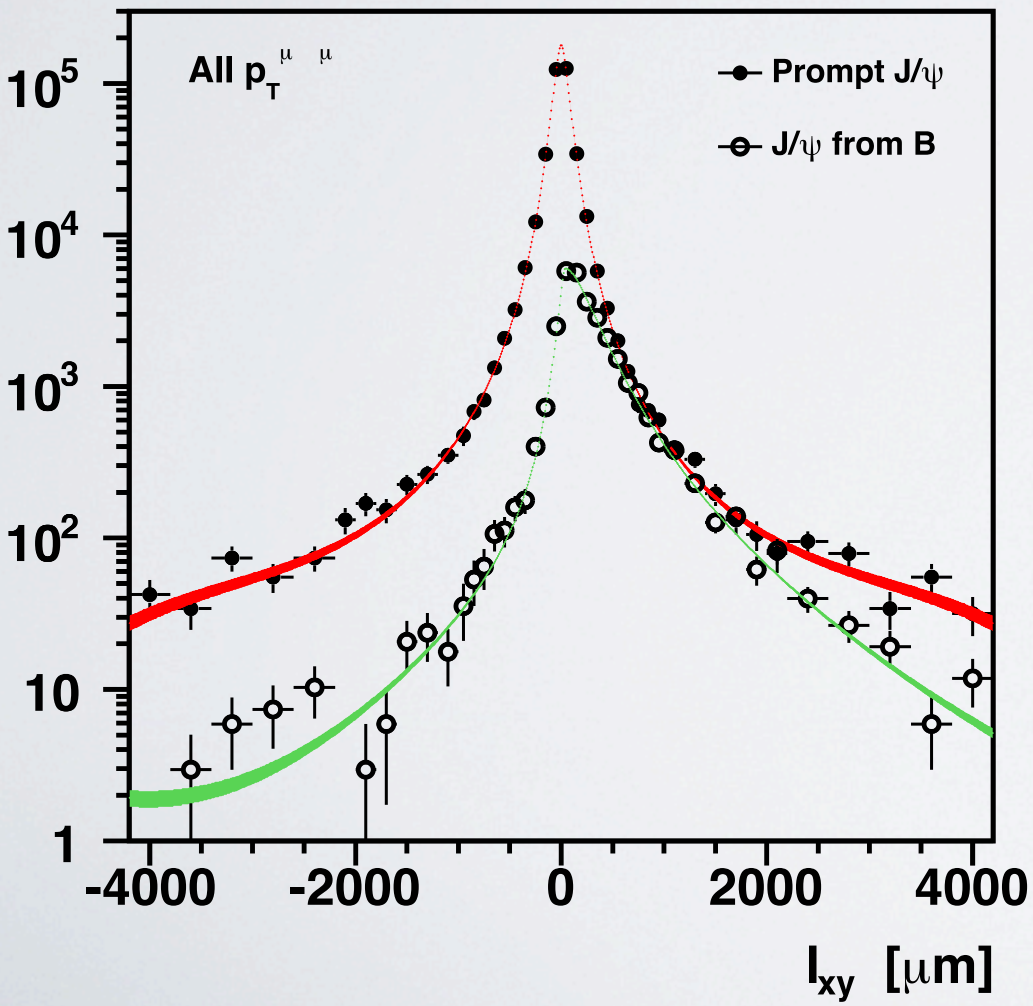
Performance: Charmonium

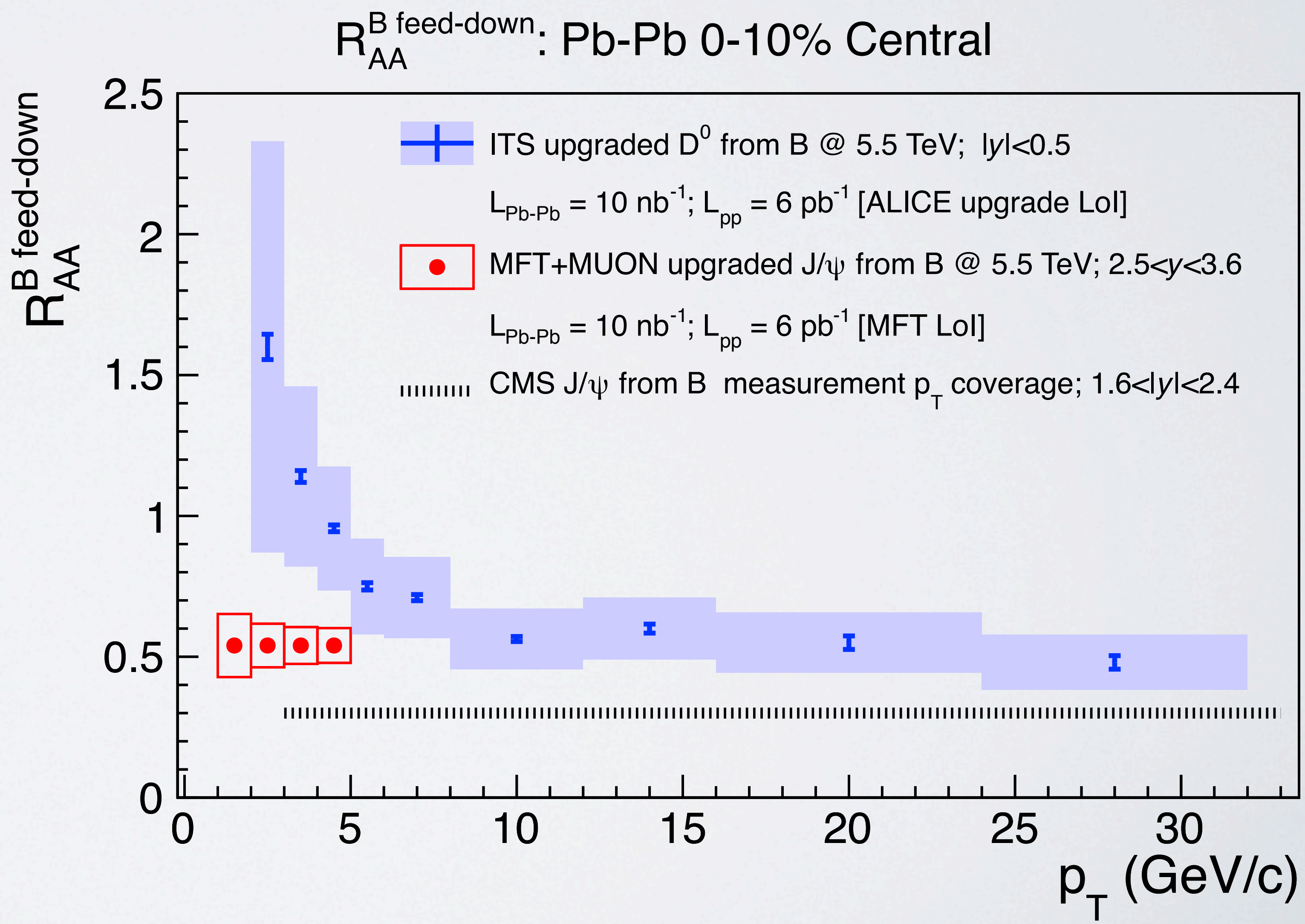
- forward charmonium measurements: better background rejection
  - improvement of signal/background
  - crucial for low p_T ψ' measurements



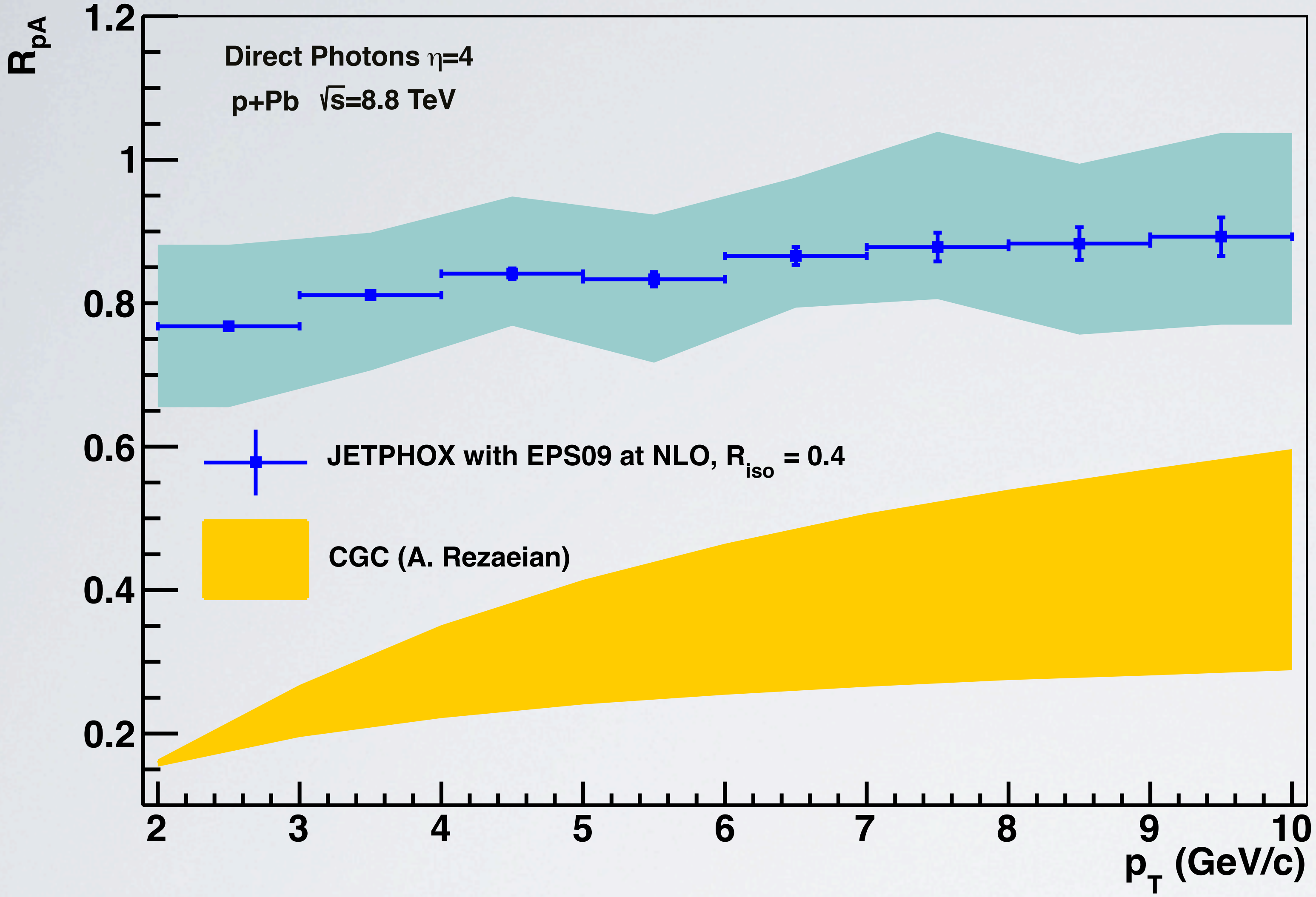
Performance: Charmonium

- MFT adds unique capability to tag secondary J/ψ
  - fit distributions of pseudo-decay length
  - measurement of B production via J/ψ
  - unique contribution at low p_T and large y





nPDF/DGLAP vs CGC

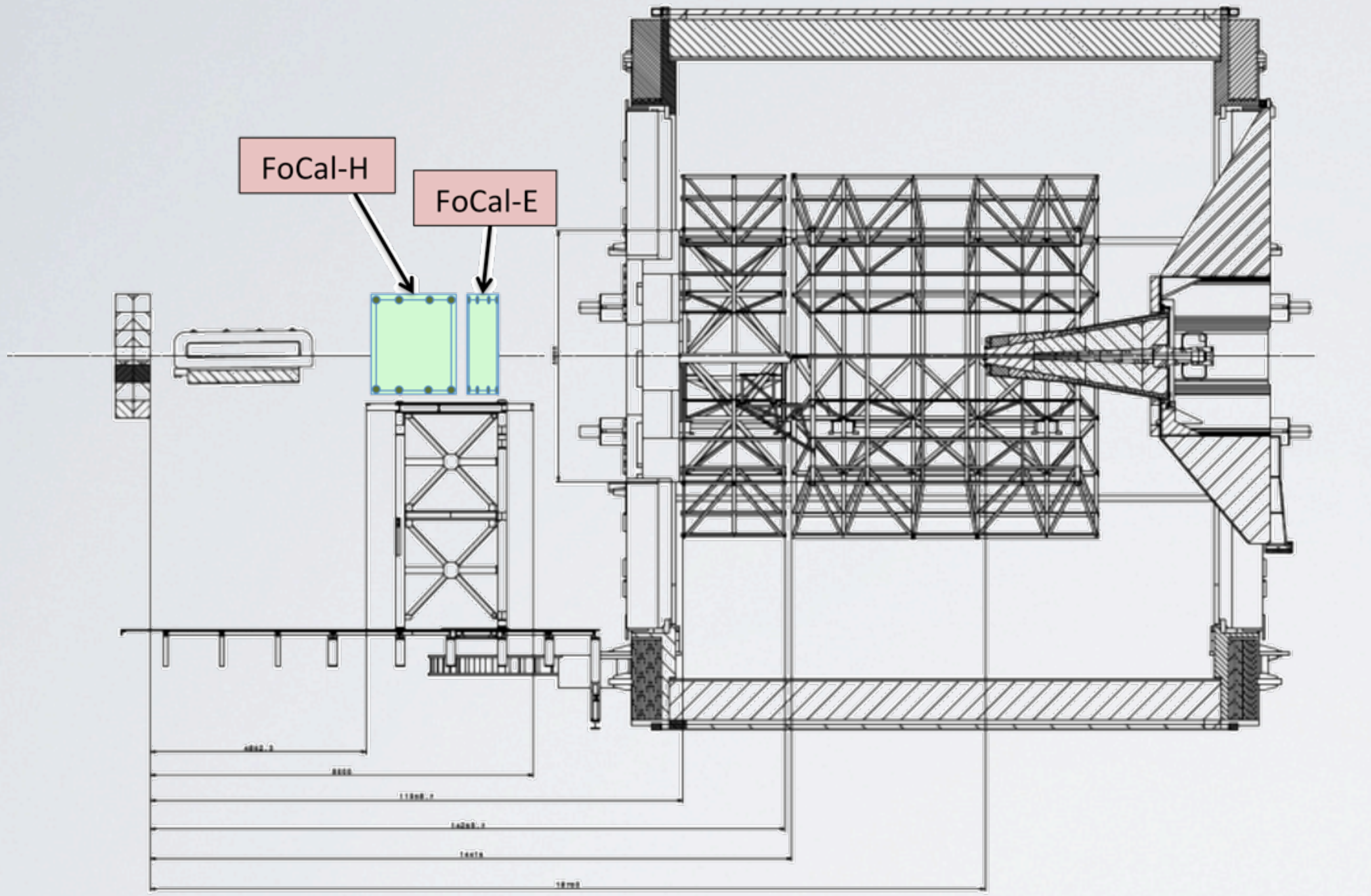


two scenarios for forward γ production in p+A at LHC:

- normal nuclear effects
  linear evolution, shadowing
- saturation/CGC
  running coupling BK evolution

- strong suppression in direct γ R_{pA}
  - clean signal for isolated photons
- signals expected at forward η, low-intermediate p

FoCal in ALICE



electromagnetic calorimeter for γ and π^0 measurement

two scenarios:

- at z ≈ 8m (outside magnet) $3.3 < \eta < 5.3$ (space to add hadr. calorimeter)
- at z ≈ 3.6m (current PMD) $2.5 < \eta < 4.5$

- main challenge: separate γ/π^0 at high energy
- need small Molière radius, high-granularity read-out
  - Si-W calorimeter, granularity ≈ $1mm^2$

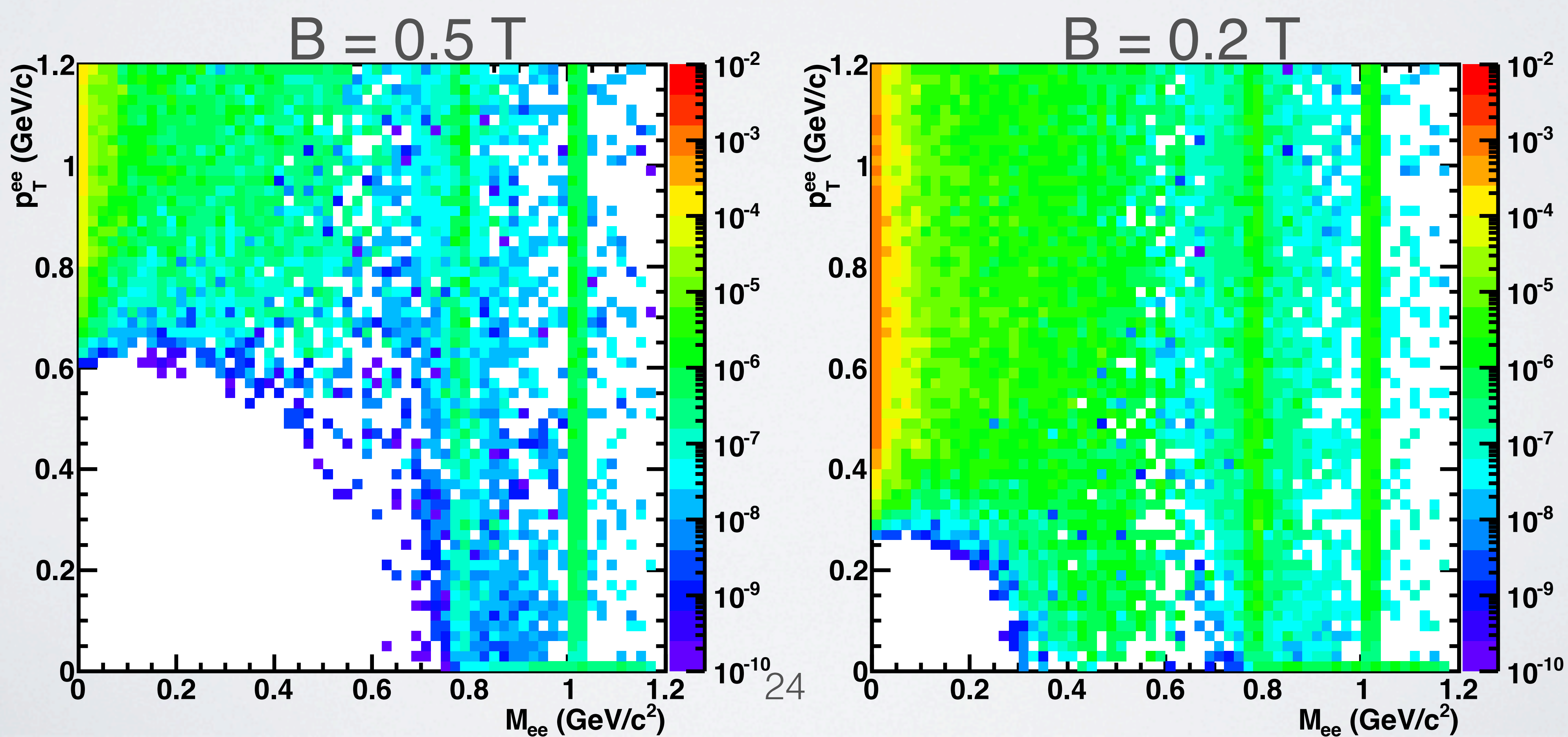
Summary

- ALICE has strong physics program for precision QGP studies
  - unique in low-p_T probes
  - requires ITS upgrade, enhanced rate capabilities (e.g. TPC) + running beyond LS3
    - significant R&D program for upgrades
  - MFT will enhance forward muon measurements
    - to be endorsed by LHCC
- further enhancement of the ALICE setup for forward physics under investigation

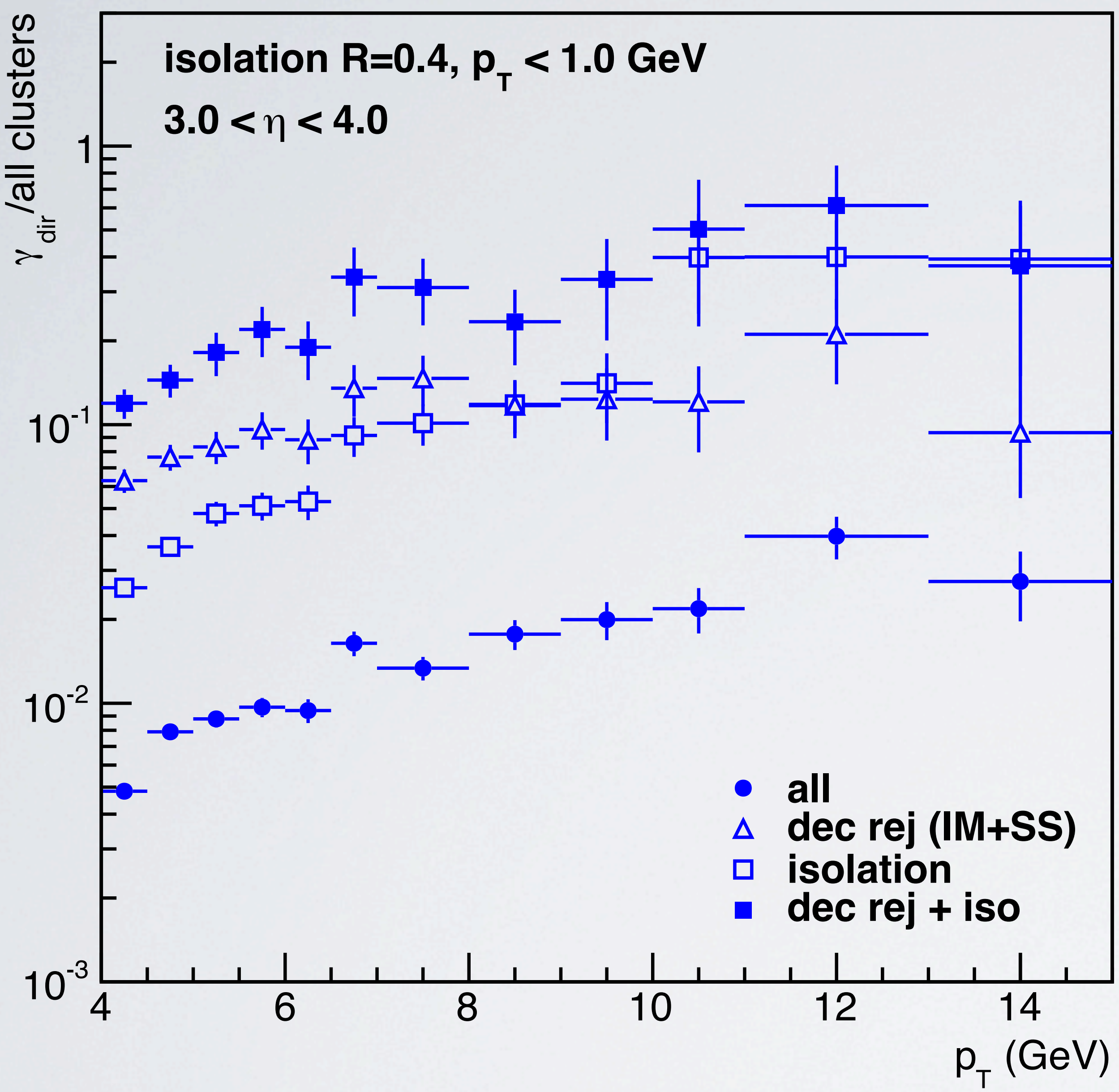
Backup Slides

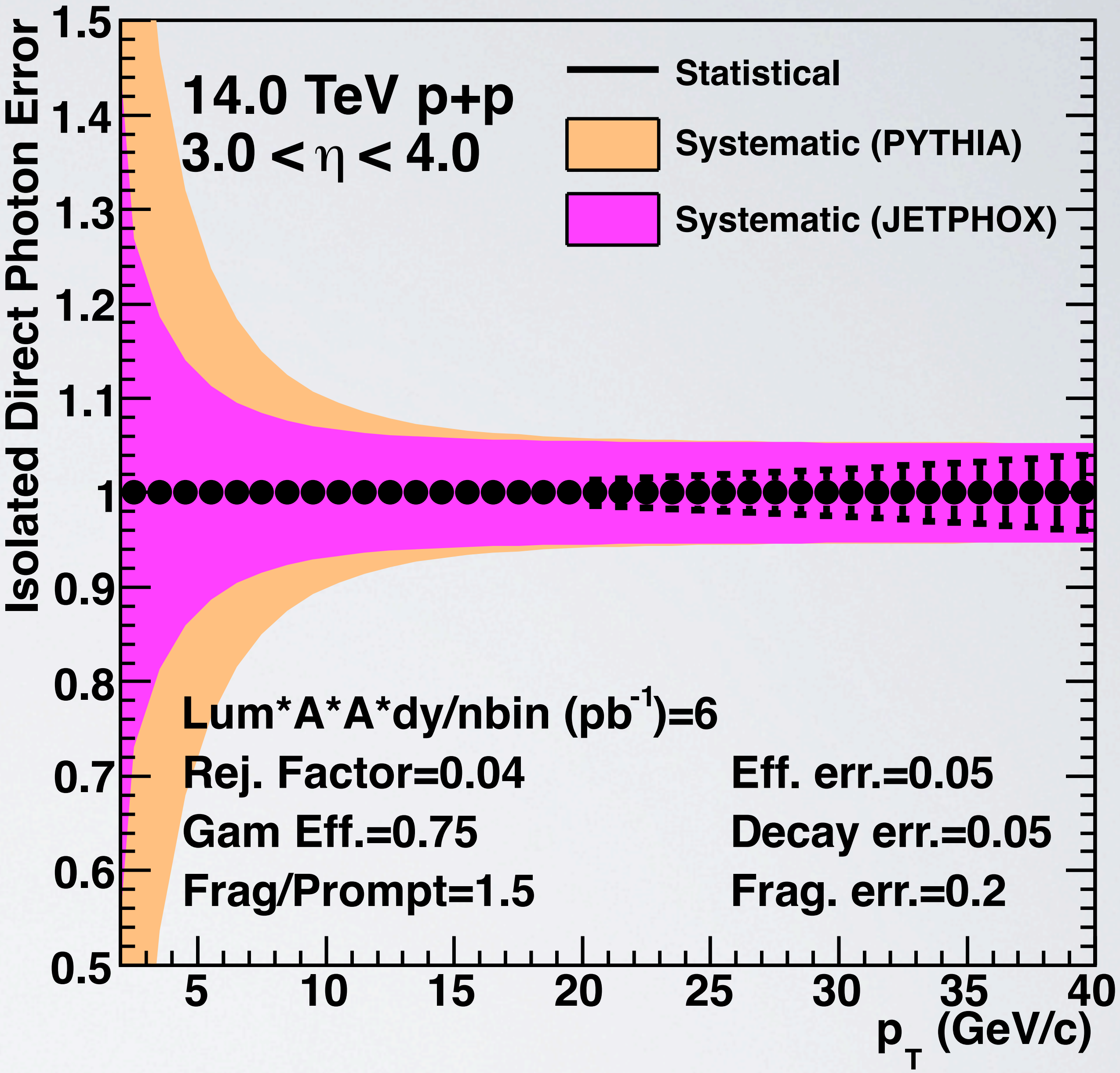
Performance: Low Mass e^+e^-

- low mass dileptons: possible access to chiral symmetry breaking, thermal photon spectrum
- very challenging measurement
    - crucial to control background
        - dominant contribution to systematic uncertainty
    - require lower field run to enhance acceptance at low p_T, m



Direct γ Performance in pp

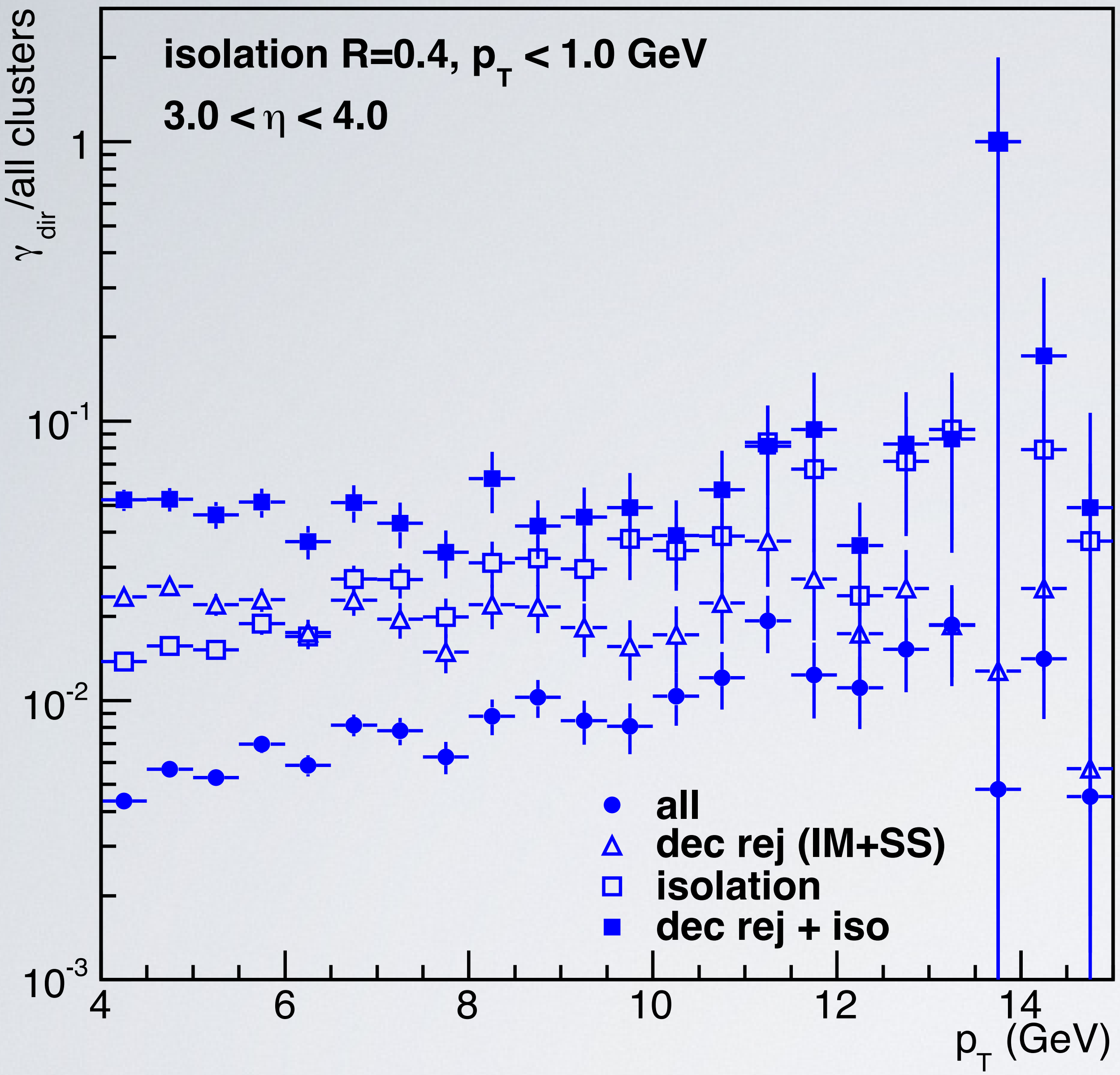


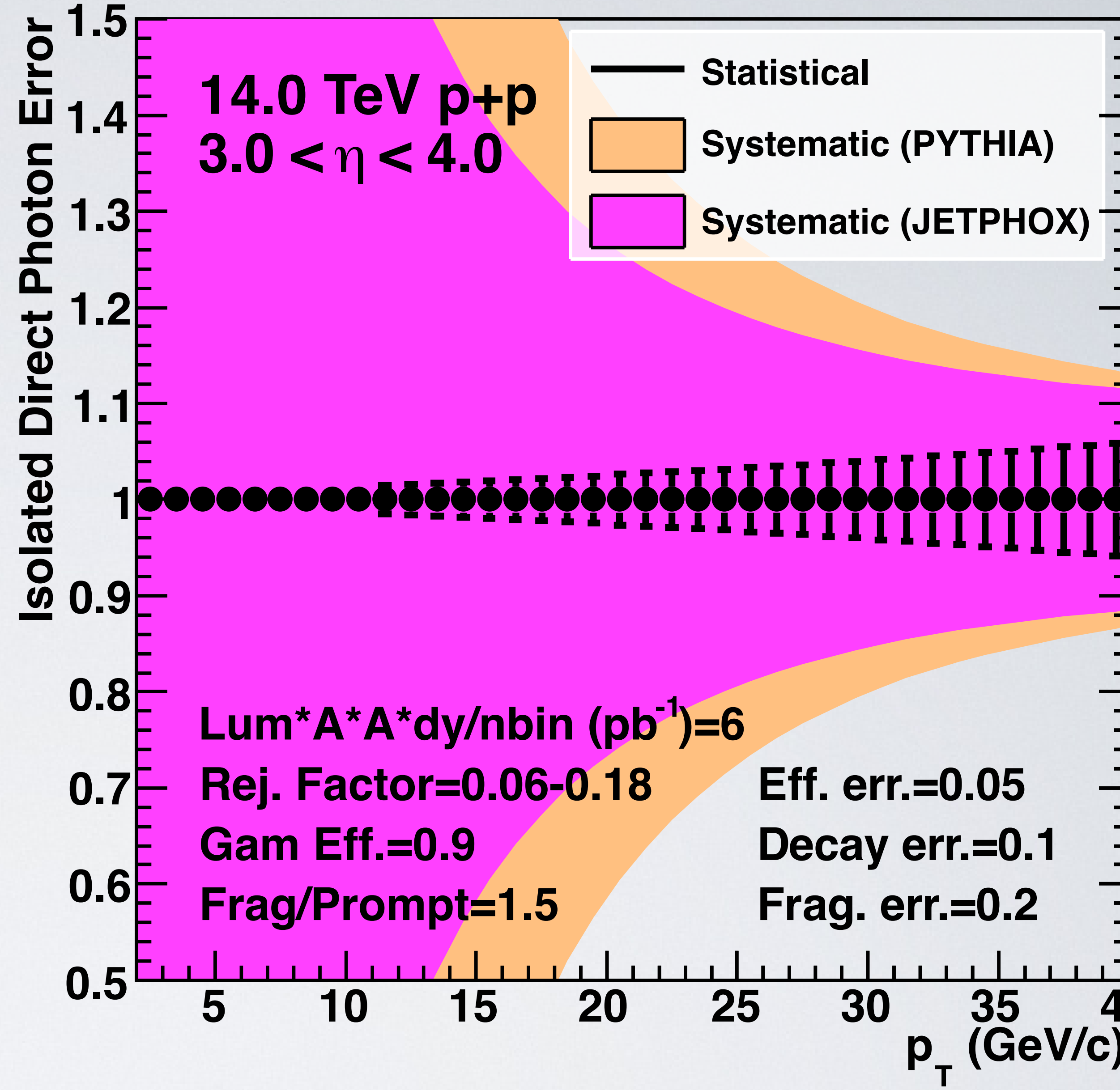


direct photon/all > 0.1
for p_T > 4 GeV/c

20-40% uncertainty
at p_T = 4 GeV/c
decreases with increasing p_T

Low Granularity Measurement





- low granularity ($1cm^2$) does not allow efficient decay rejection
- direct photon/all ≈ 0.05 for all p_T

significant measurement not possible at low p_T

NB: conditions similar to LHCb