Preparation for charm analysis

Activities of the PWG3-D2H group

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(INFN Padova)

D2H – Charm (D mesons) → Hadrons

TWiki: https://twiki.cern.ch/twiki/bin/view/ALICE/PWG3Hadron

Charm to Hadrons *D2H* paper preparation subgroup of ALICE PWG3

Welcome to the TWiki page of the hadronic charm subgroup of the ALICE heavy flavour working group (PWG3).

This subgroup focuses on the preparation of the first charm production measurements using hadronic decay channels (D0->Kpi, D0->Kpipipi, D*+->D0pi, D+->Kpipi, Ds->KKpi, Lc->pKpi, ...).

We meet every month, just before the PWG3 meeting.

The next meeting is scheduled for Tuesday September 22 at 10:30 (room 160-R-009 at CERN).

Calendar and agendas of our meetings (PWG3 Paper Preparation (D2H)).

Mailing list: **alice-charm-hadronic at cern.ch**

People:
PD, BA, TS, TO,
Utrecht, CERN,
Heidelberg, GSI, ...

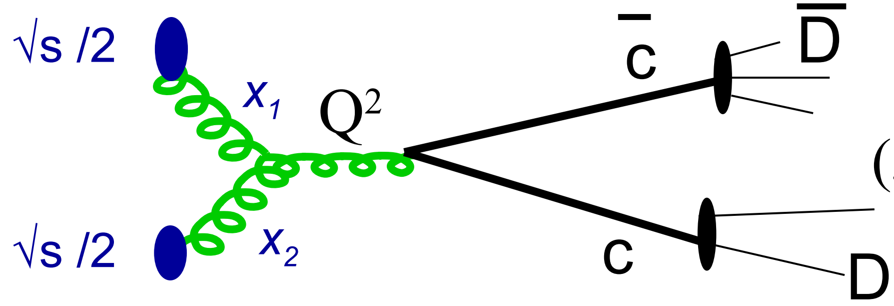
Activities and tasks

- ITS alignment and tracking performance
- Heavy flavour vertexing software
- D2H analysis train
- Visualization
- MC datasets
- Signal significance maximisation
- Background evaluation and subtraction
- PID
- Corrections (acceptance, efficiency)
- Correction for feed-down from beauty
- Cross section normalisation

Introduction: Heavy quarks production in pp collisions at LHC

Heavy-flavour production: pp

proton-proton collisions: factorised pQCD approach



$(x_1 x_2 s \sim Q^2 \sim M^2_{c\bar{c}})$

$$\frac{d\sigma^D}{dp_T^D}(\mu_F, \mu_R) =$$

$$= PDF(x_1) PDF(x_2) \otimes \frac{d\hat{\sigma}^c}{dp_T^c} \otimes D_{c\to D}(z = p_D / p_c)$$

$\mu^2_{F,R} \sim Q^2$

PDF:

- Q^2 evolution calculated in pQCD
- initial condition from data (HERA)

FF:

- non-perturbative
- phenomenolgy
  + fit to data (e^+e^-)

calculable as perturbative series of strong coupling $\alpha_s(\mu_R)$

$pp \rightarrow Q\overline{Q}+X$: pQCD calculations vs data

- Calculation of partonic cross section $\hat{\sigma}$
  - classic: Fixed Order (NLO) Massive (e.g. MNR code)

$$\frac{d\sigma}{dp_T} = A(m)\,\alpha_s^2 + B(m)\,\alpha_s^3 + O(\alpha_s^4) \qquad B(m) = \beta(m) + \gamma(m)\log(\mu/m)$$

  - state-of-the-art: Fixed Order Next-to-Leading Log (FONLL) $\quad \mu \approx p_T$

$$\frac{d\sigma}{dp_T} = A(m)\,\alpha_s^2 + B(m)\,\alpha_s^3 + G(m,p_T)\left[\alpha_s^2 \sum_{i=2}^{\infty} a_i [\alpha_s \log(\mu/m)]^i + \alpha_s^3 \sum_{i=1}^{\infty} b_i [\alpha_s \log(\mu/m)]^i\right]$$

→ more accurate at high p_T

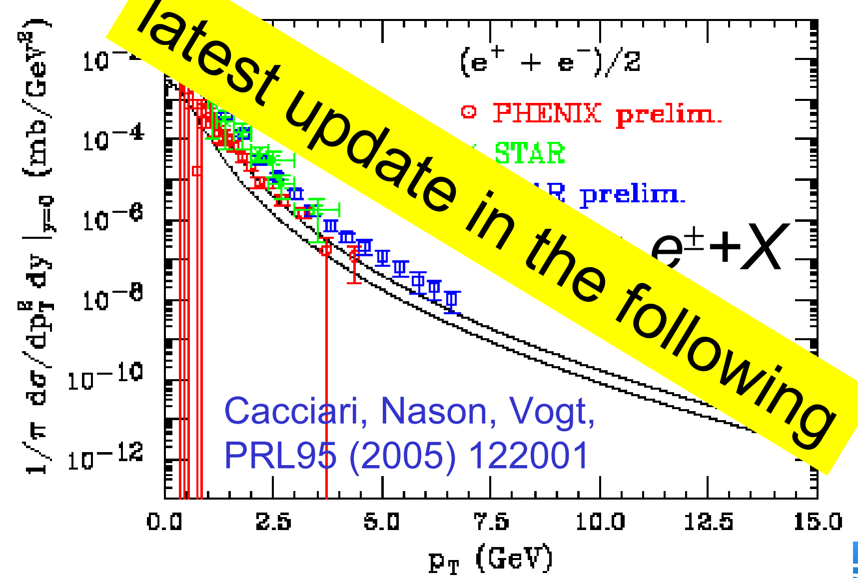
B production at Tevatron (1.96 T...

Charm production slightly underpre... at Tevatron (1.96 TeV)

is well described by FONLL

& at RHIC (200 GeV)

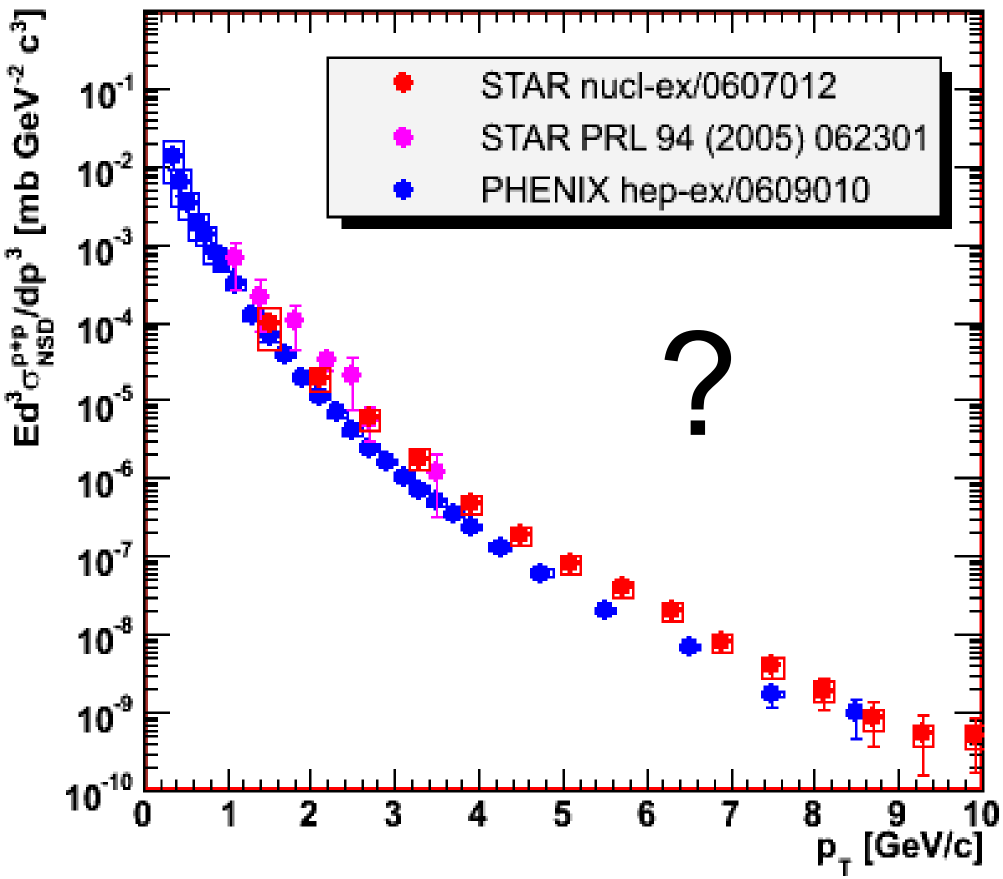
FONLL: Cacciari, Frixione, Mangano, Nason and Ridolfi, JHEP0407 (2004) 033



Cacciari, Nason, Vogt, PRL95 (2005) 122001

Heavy-flavour electrons at RHIC (pp baseline)

QM06



FONLL:
electron spectrum may be ~50% c + ~50% b for $3 < p_T < 8$ GeV

Large uncertainty on b/c crossing point in p_T: from scales/masses variation it changes from 3 to 9 GeV

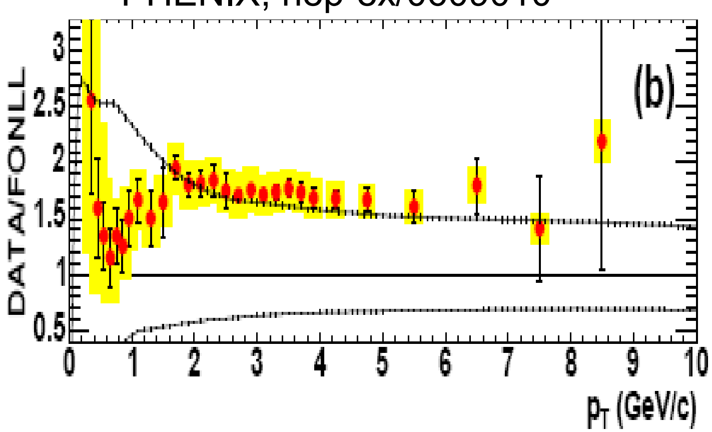
PHENIX electron cross section in pp now *quite* OK also at high p_T

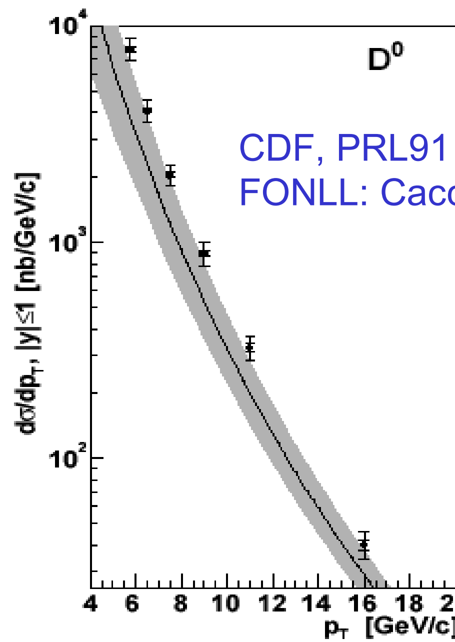
FONLL calculation: Cacciari, Nason, Vogt, PRL95 (2005) 122001
Drell-Yan from: Gavin et al., hep-ph/9502372
Comparison: Armesto, Cacciari, Dainese, Salgado, Wiedemann, PLB637 (06) 326

What have we learnt from Tevatron and RHIC?

- **Tevatron:** c and b production relatively well understood
  - theory: leading log resummation (FONLL); parton shower matched to NLO (MC@NLO); accurate treatment of fragmentation (Cacciari et al.: matching of pert. σhat and non-pert. fragm. from ee to pp)
  - experiment: exclusive (or less inclusive) is better (D mesons, B→J/ψ+X), publish what you measure (not only extrapolations)
- **RHIC:**
  - data at upper limit of theory prediction
  - need separation of c and b

PHENIX, hep-ex/0609010



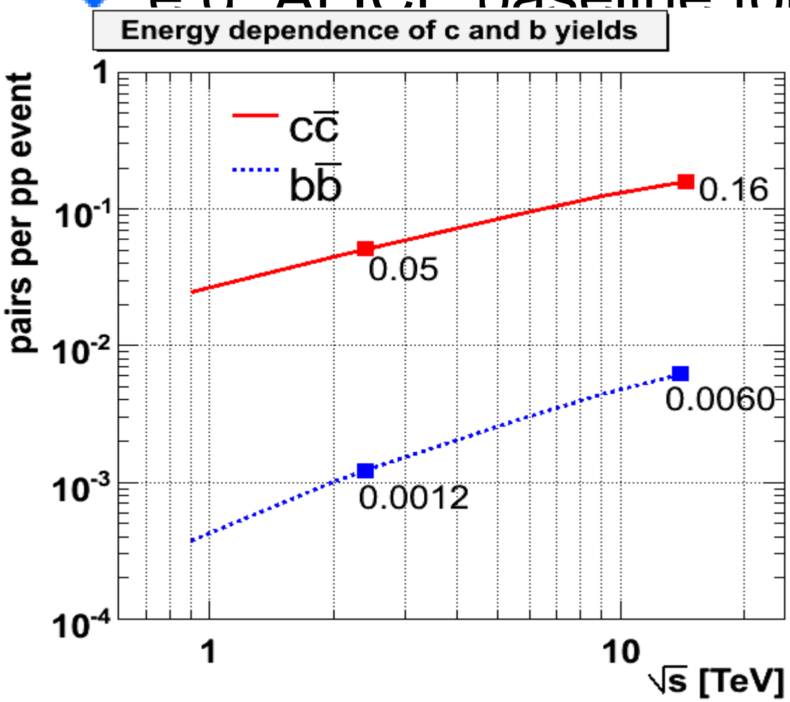


CDF, PRL91 (2003) 241804
FONLL: Cacciari, Nason

Heavy-quark production at the LHC

- pp: Important test of pQCD in a new energy domain
- Remember the "15-years saga of b production at Tevatron"*

- Baseline predictions: NLO (MNR code) in pp + binary scaling (shadowing [EKS98] included for PDFs in the Pb)
- e.g. ALICE baseline for charm / beauty:



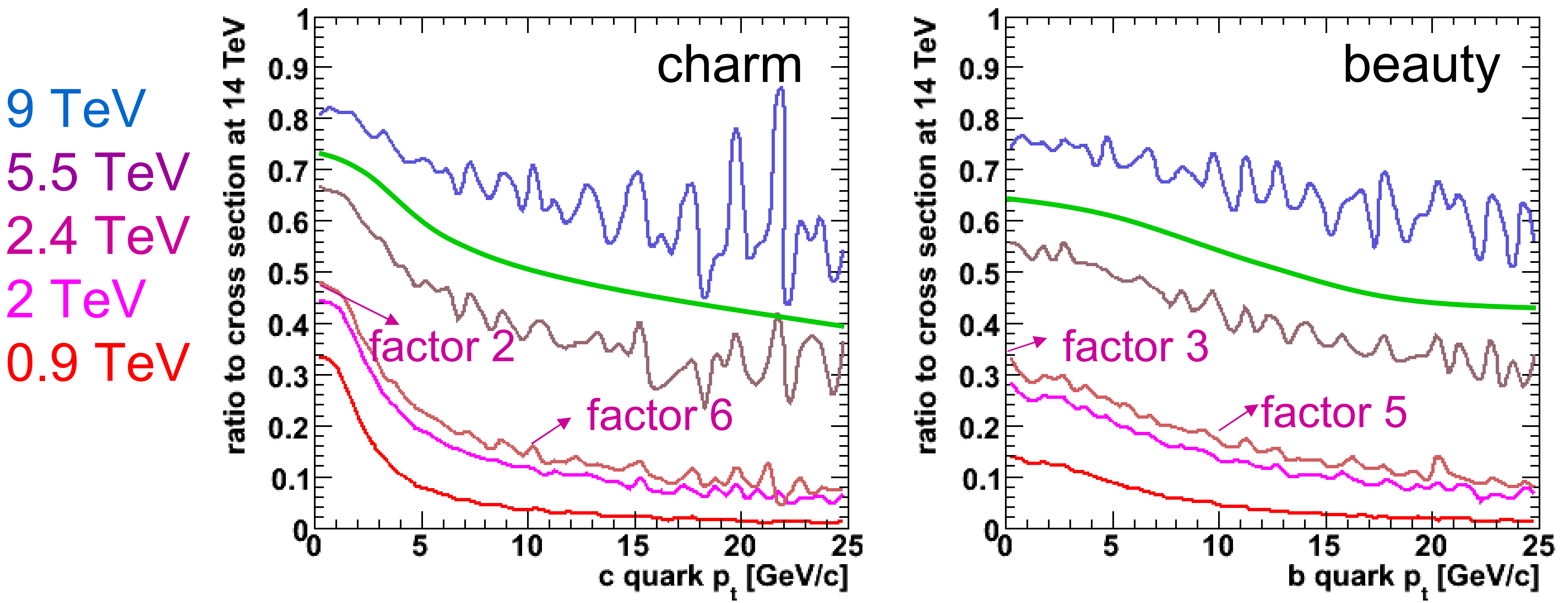
LHC startup at $\sqrt{s}$ = 7 TeV?
→yields lower by ≈30-35% (next slide)

pp 14 TeV
11.2 / 0.5
0.16 / 0.007
--

2—3 (next slide)

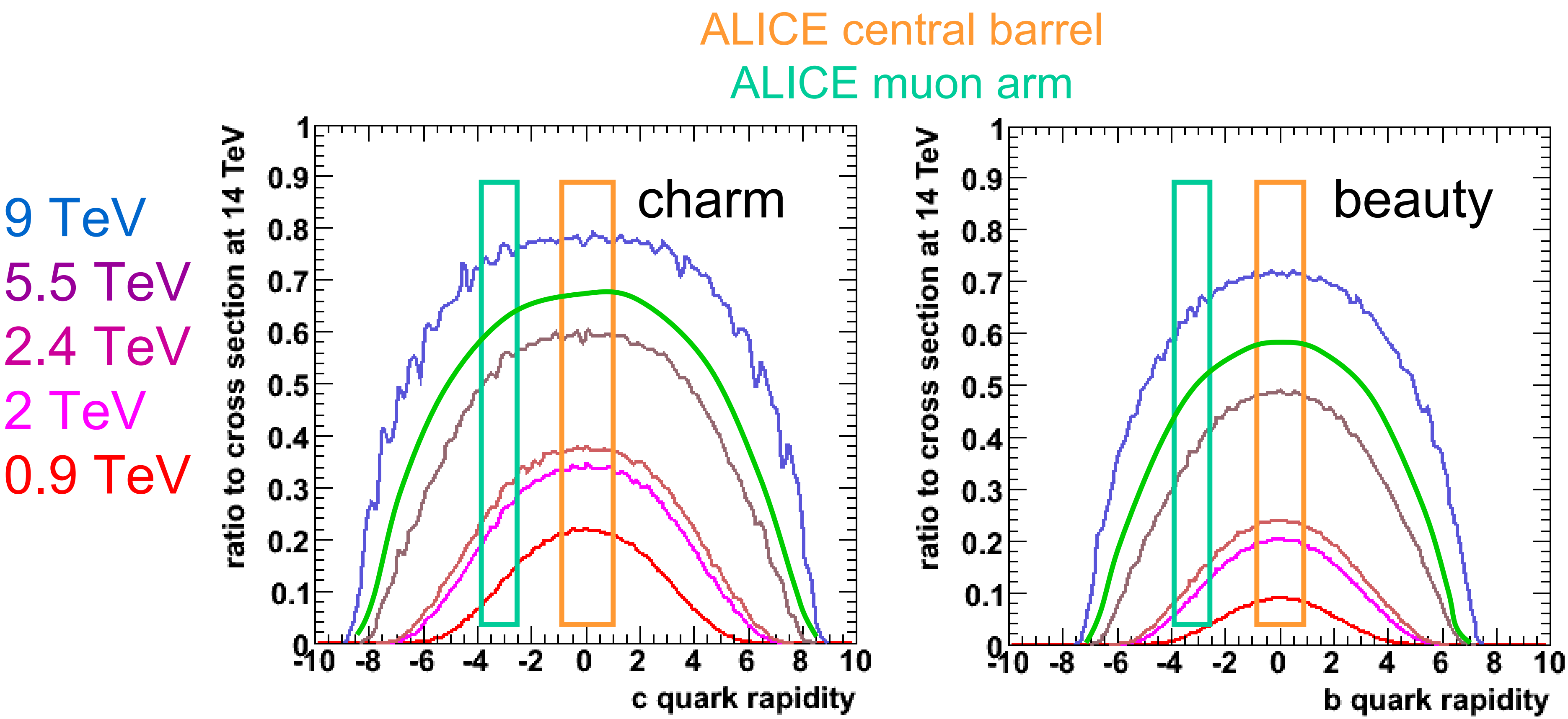
Single inclusive p_t (ratios to 14 TeV)

|y| < 1



Ratio decreases with increasing p_t;
more strongly for charm

Single inclusive y (ratios to 14 TeV)

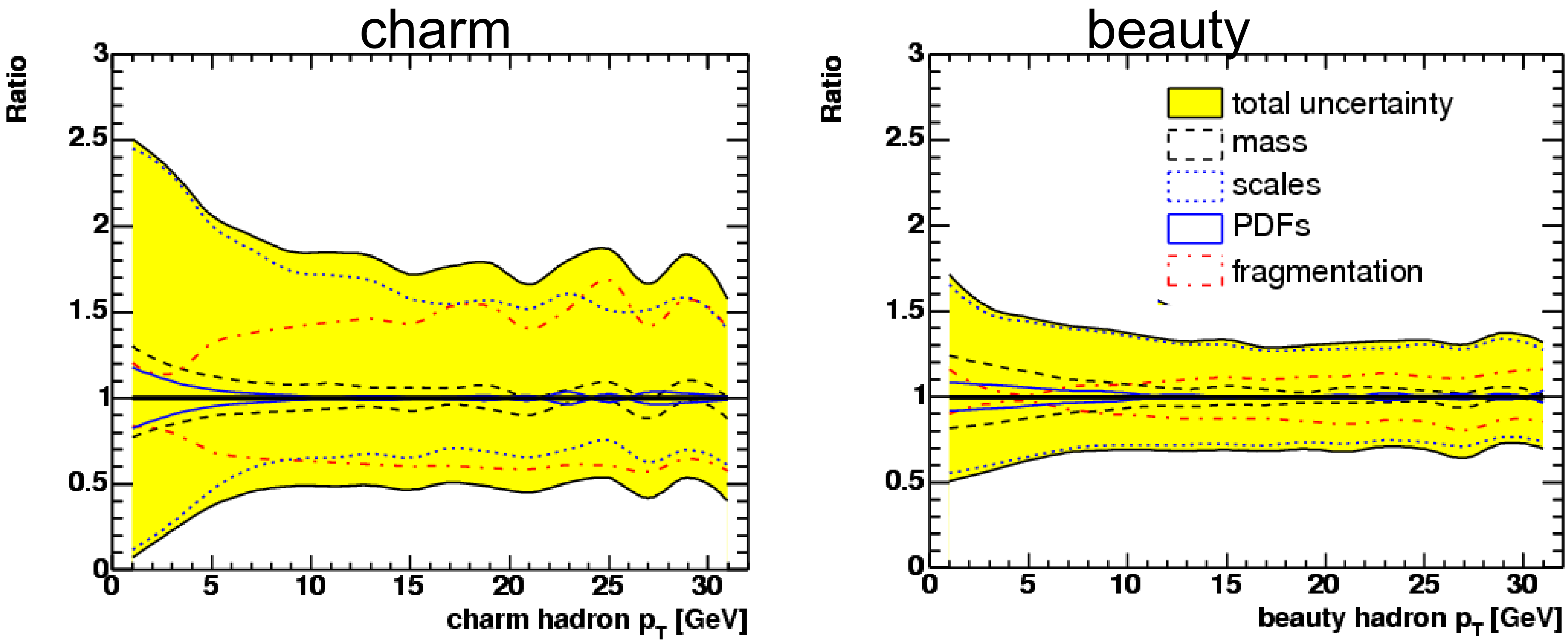


Decrease larger at forward rapidity, which is dominated by small *x*

Theoretical Uncertainties
(HERA-LHC Workshop)

CERN/LHCC 2005-014
hep-ph/0601164

Evaluation of theoretical uncertainties



$1.3 < m_c < 1.8$ GeV $\quad 0.5 < \mu_{F,R}/m_T < 2 \quad 0.002 < \varepsilon_c < 0.11$

$4.5 < m_b < 5.0$ GeV $\quad 0.5 < \mu_F/\mu_R < 2 \quad 0.0002 < \varepsilon_b < 0.004$

PDFs : CTEQ4, CTEQ5, CTEQ6, MRST2001

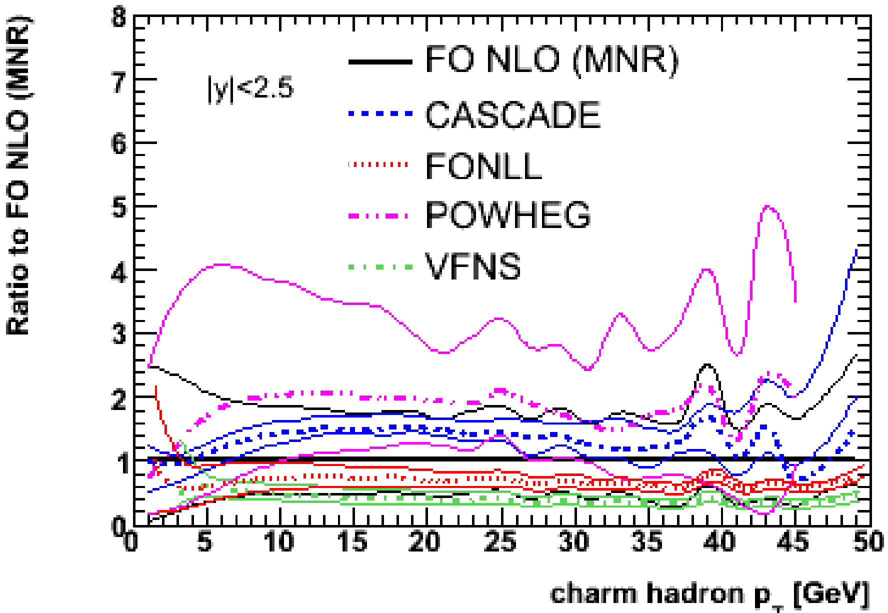
MNR code: Mangano, Nason, Ridolfi, NPB373 (1992) 295.

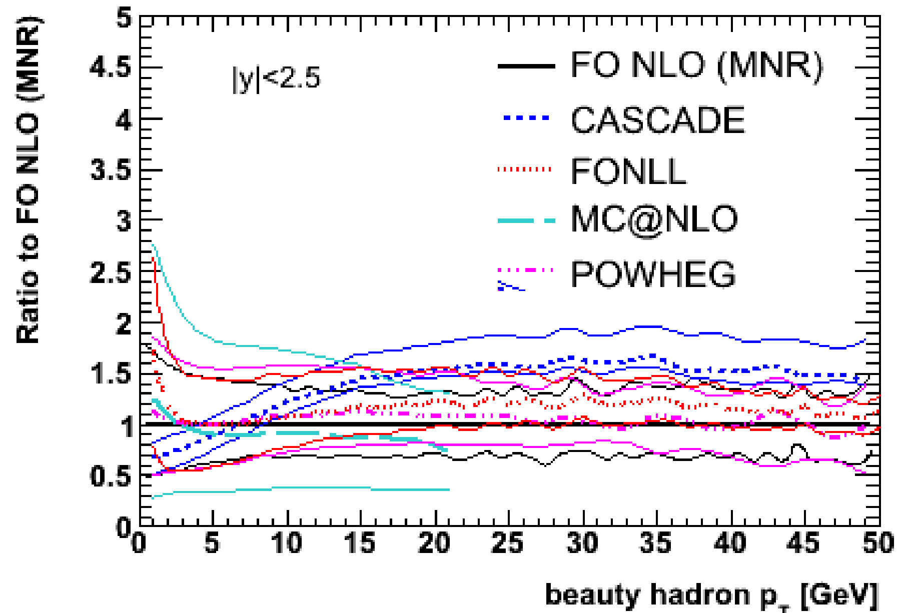
Model Comparisons (HERA-LHC Workshop)

CERN/LHCC 2005-014
hep-ph/0601164
+ updates (R.Guernane)

Compare predictions by several different models

charm | beauty





- General agreement between collinear factorisation based calculations: FO NLO, FONLL, POWHEG, MC@NLO
  - problem with POWHEG charm?
- k_T factorization (LO MC CASCADE) higher at large p_T
- VFNS lower at high p_T

Open Charm measurements in preparation

$D^0 \rightarrow K\pi$

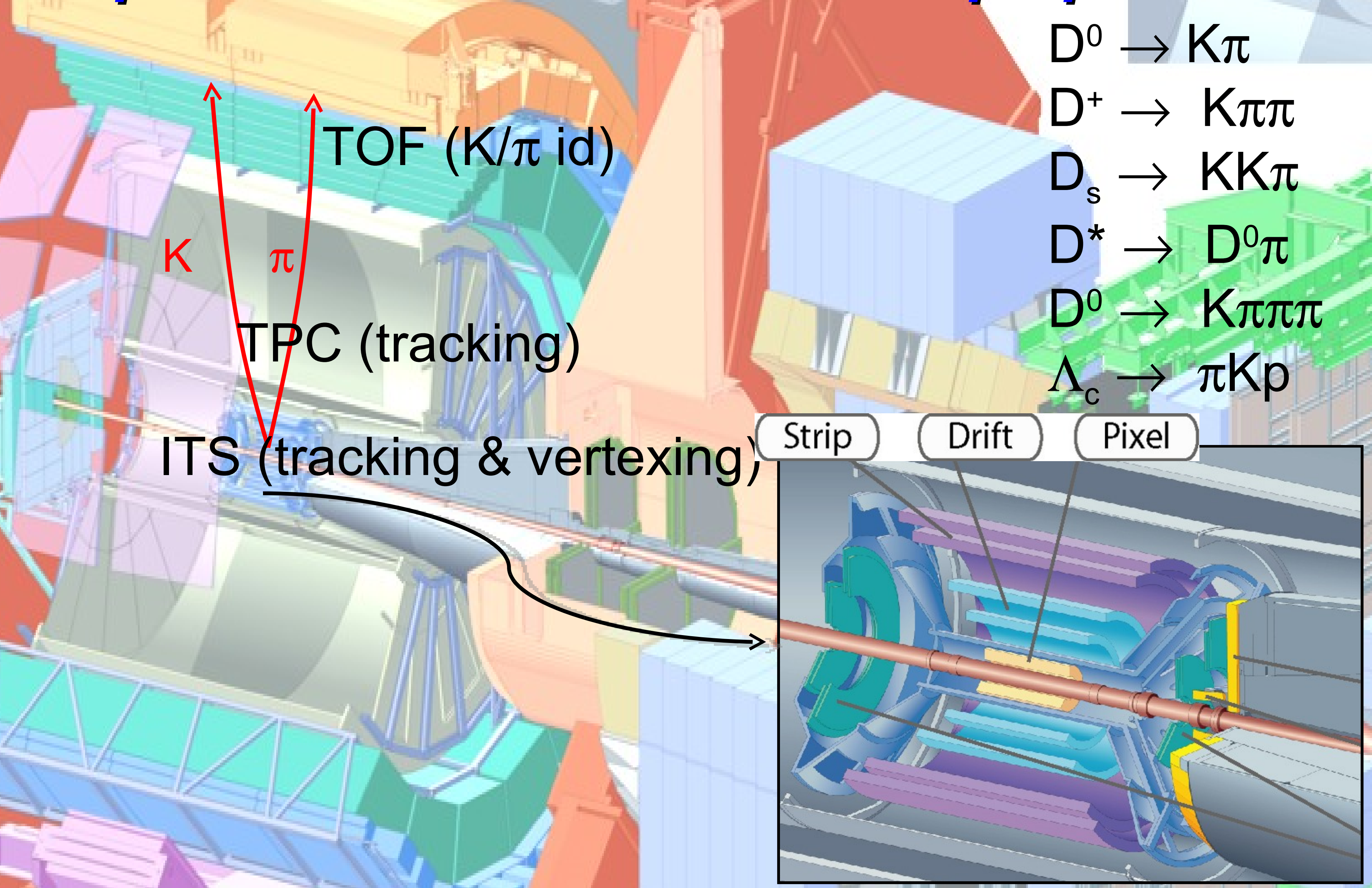
$D^+ \rightarrow K\pi\pi$

$D_s \rightarrow KK\pi$

$D^* \rightarrow D^0\pi$

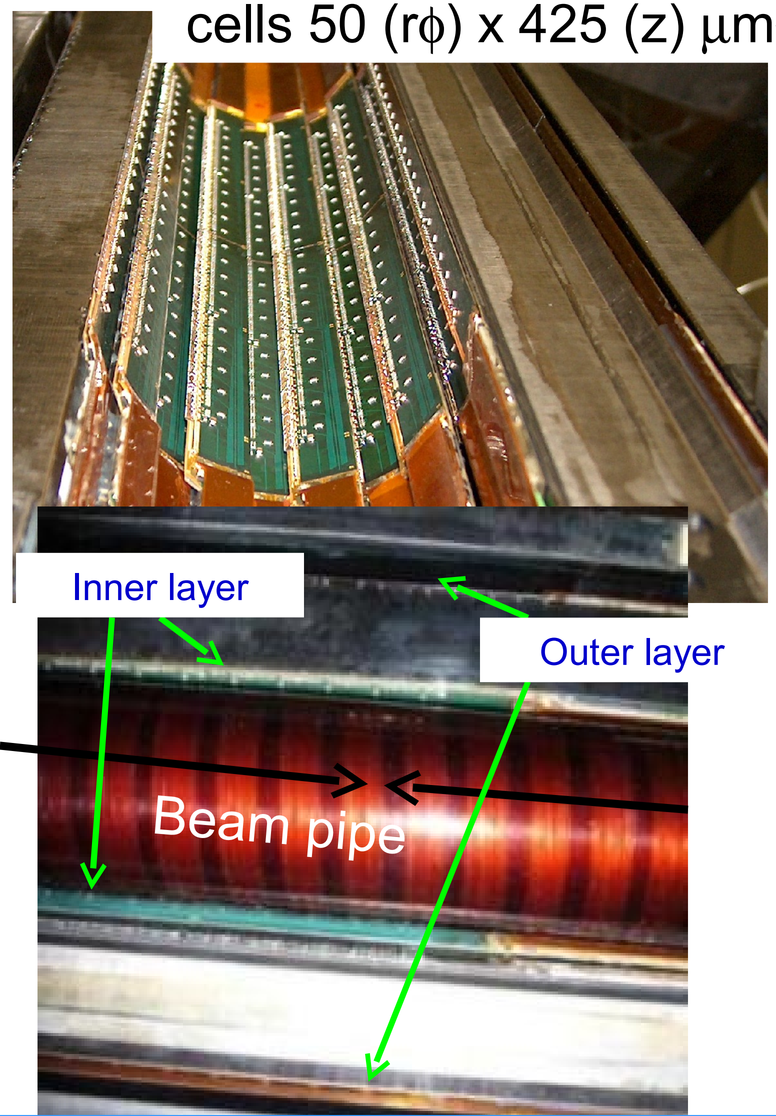
$D^0 \rightarrow K\pi\pi\pi$

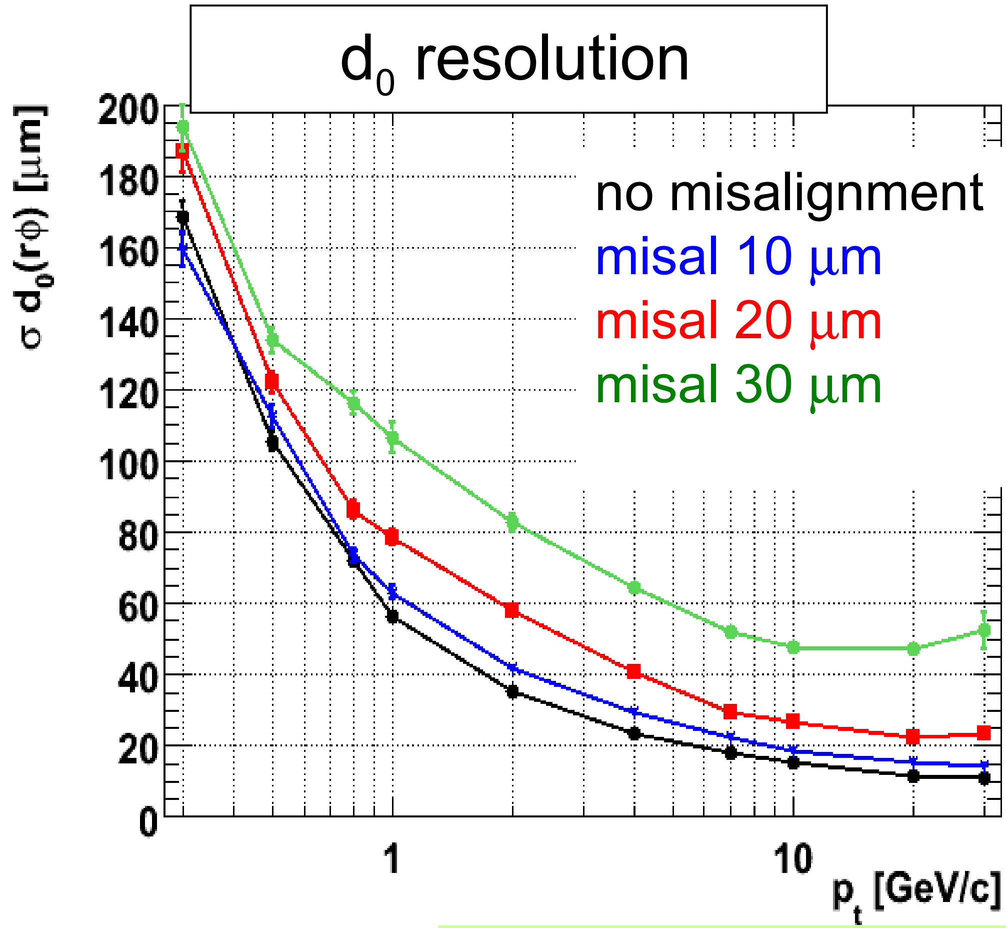
$\Lambda_c \rightarrow \pi K p$



Vertexing: track d_0 resolution

Resolution mainly provided by the 2 layers of silicon pixels --9.8 M cells 50 (rϕ) x 425 (z) μm^2-- at 4 and 7 cm from the beam line





Alignment is crucial for HF!
→ Marcello, Andrea

HF vertexing
Analysis Scheme & Activities

Charm "production" (ESD/AOD ➔ AOD for Charm)

⬇

Signal selection

Invariant mass analysis and significance maximization (in bins of p_t, y, $\phi - \Phi_{RP}$…)

⬇

Corrections

Feed-down from B, Eff&Acc corrections

⬇

Systematics

$$N_{selected}^{D^0 \to K\pi}$$

⬇

$$\left.\frac{dN_{produced}^{D0\ \mathrm{from\ c}}}{dp_t dy}\right|_{|y|<1}$$

⬇

$$\left.\frac{dN_{produced}^{D0\ \mathrm{from\ c}}}{dp_t dy}\right|_{|y|<1} \pm err$$

HF vertexing
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Invariant mass analysis and significance maximization (in bins of p_t, y, $\phi - \Phi_{RP}$…)

$N^{D^0 \to K\pi}_{selected}$

⬇

Corrections

Feed-down from B, Eff&Acc corrections

$\left.\frac{dN^{D0 \text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1}$

⬇

Systematics

$\left.\frac{dN^{D0 \text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1} \pm err$

Heavy-flavour vertexing: production of candidates

- Produce all the candidate charm decays in go: 2-prong, 3-prong, 4-prong, cascades.
  - $D^0 \rightarrow K\pi$
  - $D^+ \rightarrow K\pi\pi$, $D_s \rightarrow KK\pi$, $\Lambda_c \rightarrow pK\pi$
  - $D^0 \rightarrow K\pi\pi\pi$
  - $D^{*+} \rightarrow D^0\pi$
  - like-sign background for 2-prong and 3-prong
- Implemented in a task that is a wagon of the Official Analysis Train
- Input can be either ESD or AOD (same software)
- Output written to AOD event
- Candidates produced for 3 PDC09 pp productions:
  - LHC09a4 pp minimum bias 100 M
  - LHC09a5 pp with charm, D2H 7 M
  - LHC09a6 pp with beauty, D2H 1 M

AliAnalysisVertexingHF class

single-track cuts on p_t and d_0, (PID...)
[common cuts for all analyses]

build all (+,-) and like-sign pairs and compute secondary vtx

for $D^0 \to K\pi$, $J/\psi \to ee$

create AliAODRecoDecayHF2Prong
apply reco cuts

for $D^{*+} \to D^0\pi$

tight D0 mass cut
loop on all tracks
for D* candidates

store D^0

store D^{*+}

store J/ψ

for D^+, D_s^+, Λ_c^+

loop on all tracks (+ & -):
build triplets, and like-sign triplets
create AliAODRecoDecayHF3Prong,
apply reco cuts (common for the 3 particles?)

store D^+, D_s^+, Λ_c

for $D^0 \to K\pi\pi\pi$

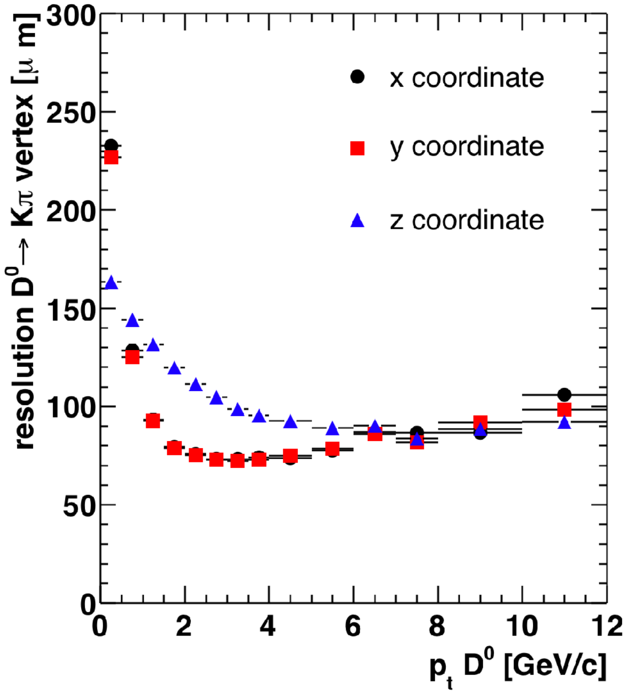
loop on all tracks (+ & -) …
create AliAODRecoDecayHF
…

store D^0

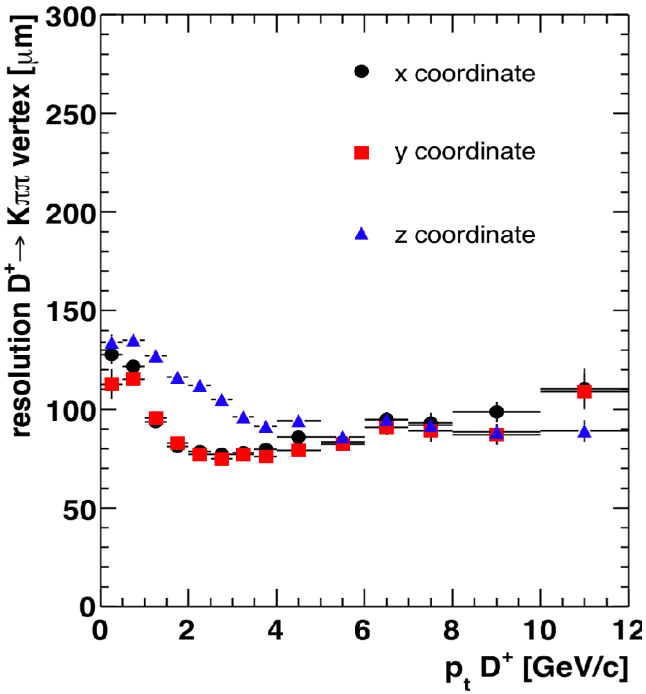
Secondary vertex reconstruction

- Possibility to choose between two vertexers:
  - AliVertexerTracks (default; same used for primary vertex reco)
  - Kalman-filter vertexer
- Secondary vertex resolutions: D^0 vs D^+

$D^0 \rightarrow K\pi$



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



Secondary vertex reconstruction

- Possibility to choose between two vertexers:
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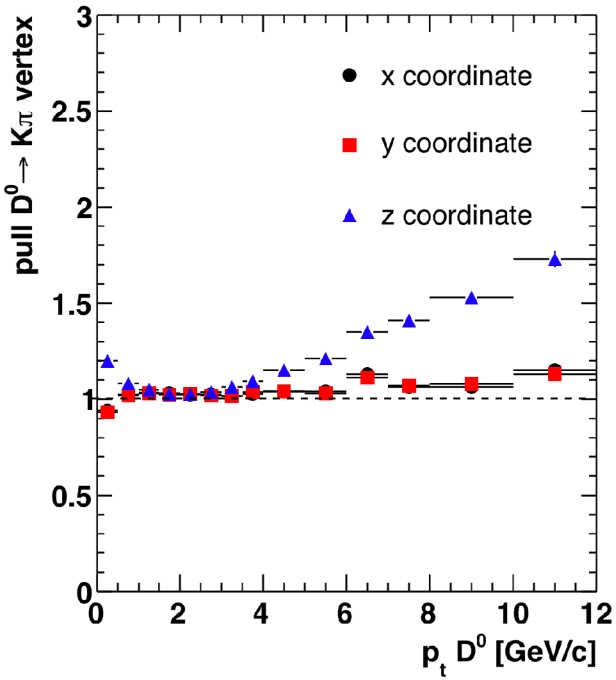
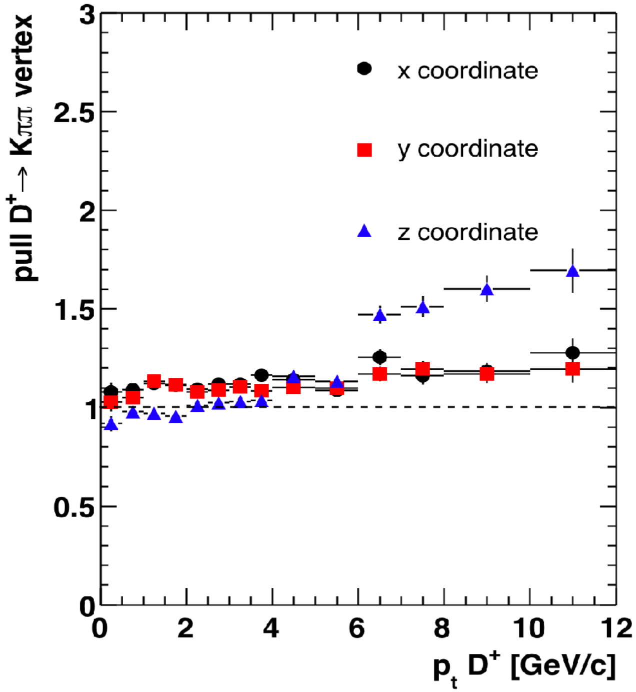
  - Kalman-filter vertexer
- Secondary vertex pulls: D^0 vs D^+

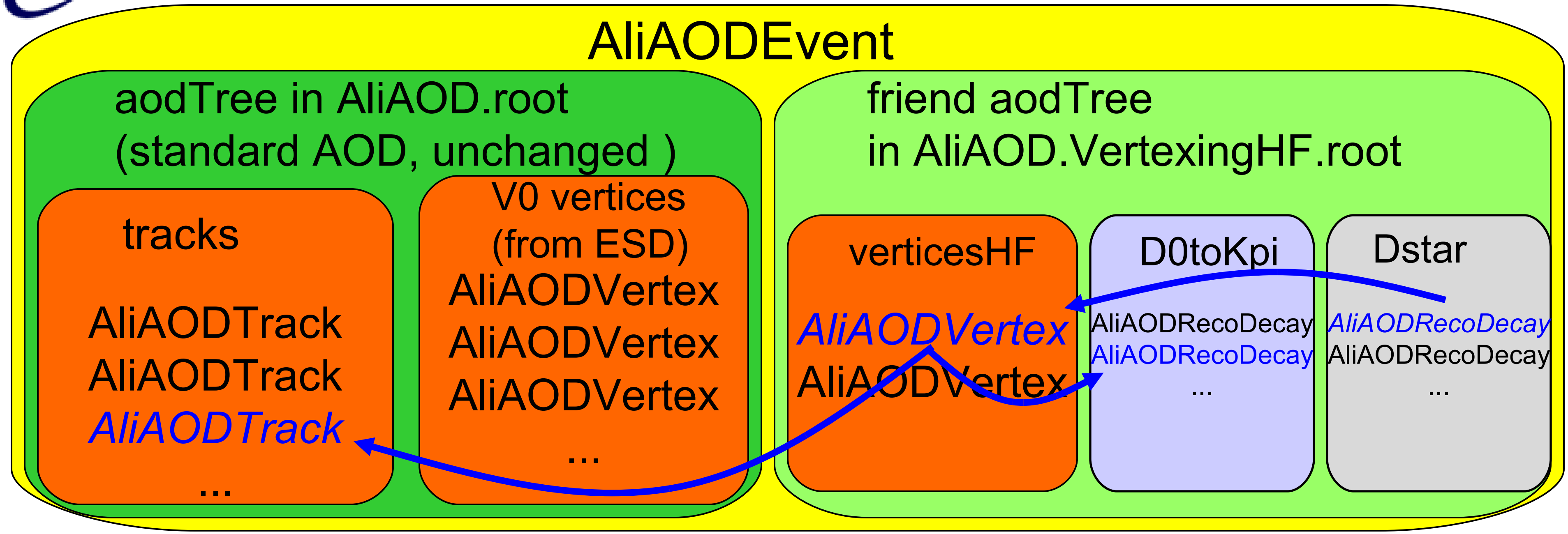
$D^0 \rightarrow K\pi$



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



HF candidates in AliAODEvent



HF vertexing
Analysis Scheme & Activities

Charm "production" (ESD/AOD → AOD for Charm)

Signal selection

Invariant mass analysis and significance maximization (in bins of p_t, y, $\phi - \Phi_{RP}$…)

$N^{D^0 \to K\pi}_{selected}$

Corrections

Feed-down from B, Eff&Acc corrections

$\left.\frac{dN^{D0\text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1}$

Systematics

$\left.\frac{dN^{D0\text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1} \pm err$

Heavy-flavour vertexing: Analysis of candidates from AOD

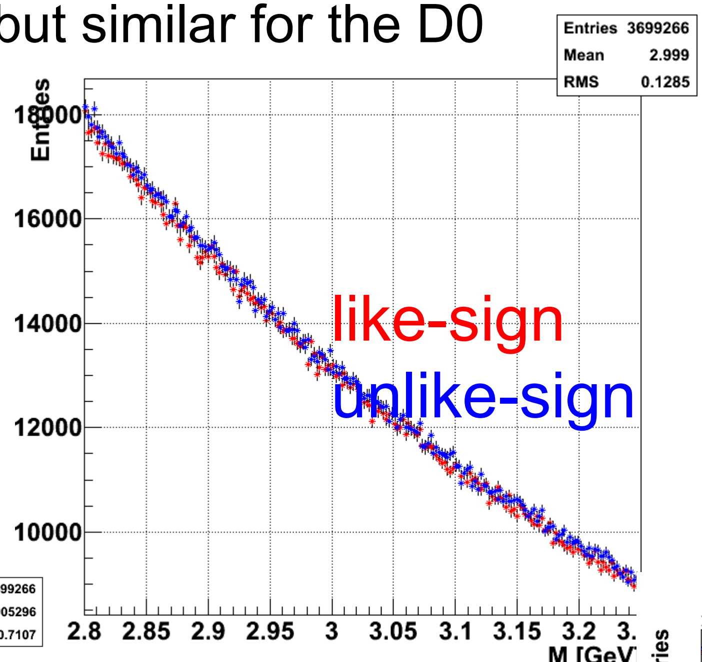
- Input: AliAOD.root + AliAOD.VertexingHF.root
- Prepared "D2H" analysis train:
  - Steering macro RunAnalysisAODVertexingHF.C
  - 12 wagons (Task, TaskSE) up to now
    - CompareHF (vertex resolutions)
    - D0 inv mass
    - Dplus analysis
    - Like-sign bkg D0→Kpi
    - Like-sign bkg Jpsi→ee
    - Analysis for Jpsi from B
    - D0→Kpi CORRFW task
    - 5 x Prompt D0 fraction (with 5 sets of cuts)
  - runs on the grid with Alien plugin (up to 38 M min-bias events)
  - runs on CAF

Signal raw yield extraction

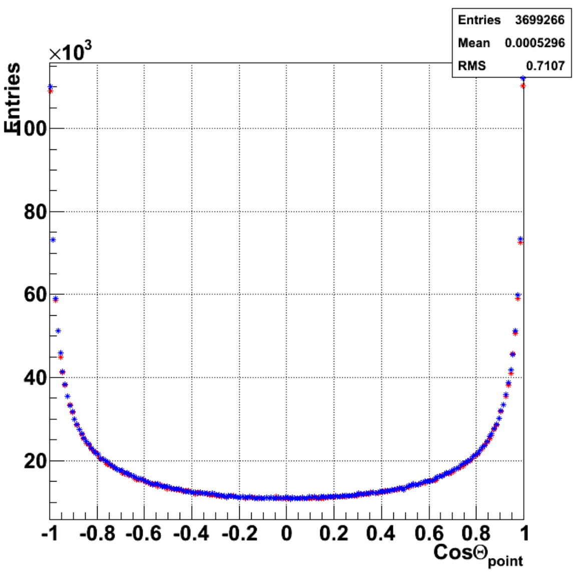
- Invariant mass fitter to extract S and B (→ Chiara)
- Cut study (→ Chiara)
- If S/B is small (<< 50%), need to subtract background to increase significance
- 3 subtraction methods being prepared:
  - like-sign
    - LS pairs and triplets stored by default
  - event mixing
    - use AliAnalysisTaskME and AliMixedEvent → ongoing integration in the “core” class AliAnalysisVertexingHF
    - tests at the track level (no vertexing)
  - rotated events (rotate negative tracks about z axis)

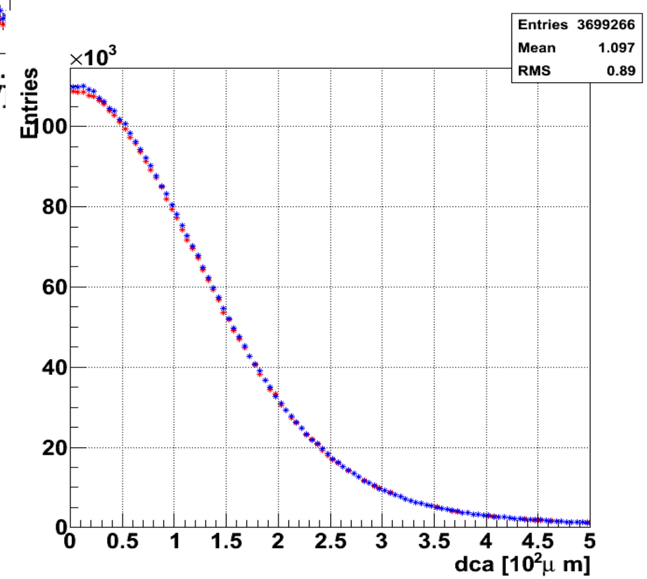
Background subtraction: like-sign pairs

plots for the J/psi, but similar for the D0



17M evts
LHC09a4
Jpsi bkg
C.DiGiglio





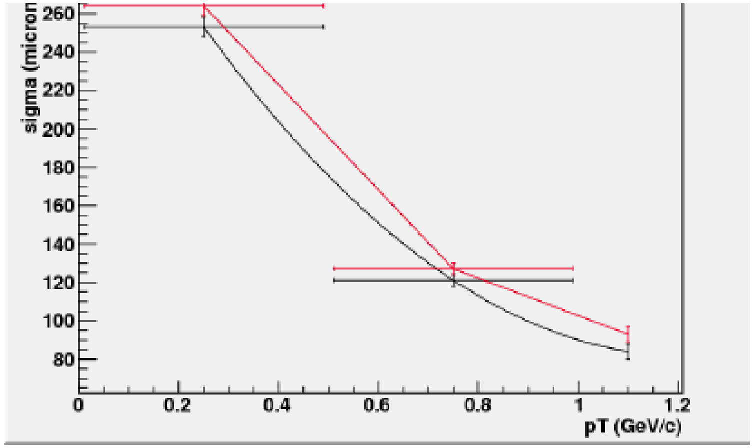
Background subtraction: event mixing

- Use standard event mixing framework to mix AOD events (AliAnalysisTaskME)
- Use abstract event interface also for mixed events
  - exactly the same code for single-event and mixed-events
- Use event pools binned in
  - z-vertex
  - multiplicity
  - “jettiness” (still to defined, e.g. ϕ angle of highest p_t particle)
- Since we have to do vertexing, need to define a common primary vertex for the mixed event (weighted average) and refer (translate) all tracks to this common vertex

Background subtraction: event mixing

- Test of impact parameter distribution for tracks in mixed events (R. Romita)
  - Example: 2 events mixed
  - 3 pT bins:
    - pT > 0.5 GeV/c
    - 0.5 < pT < 1 GeV/c
    - pT > 1 GeV/c

σ of d_0 distr. for primaries



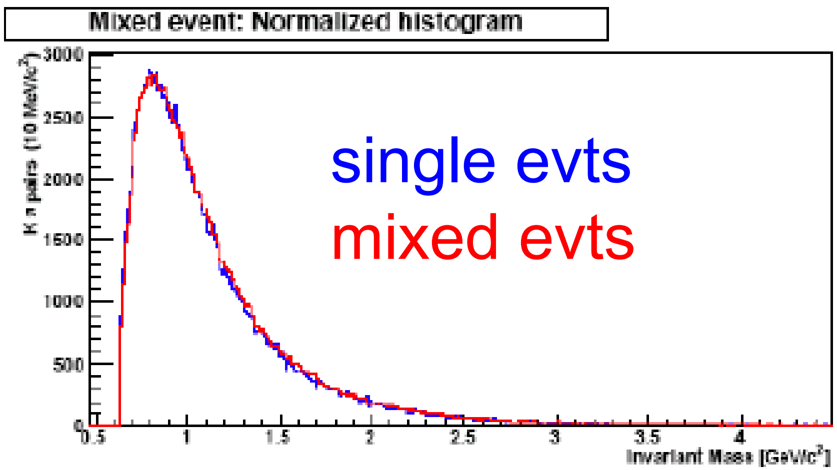
: *d0 to the original primary vtx, before the translation*

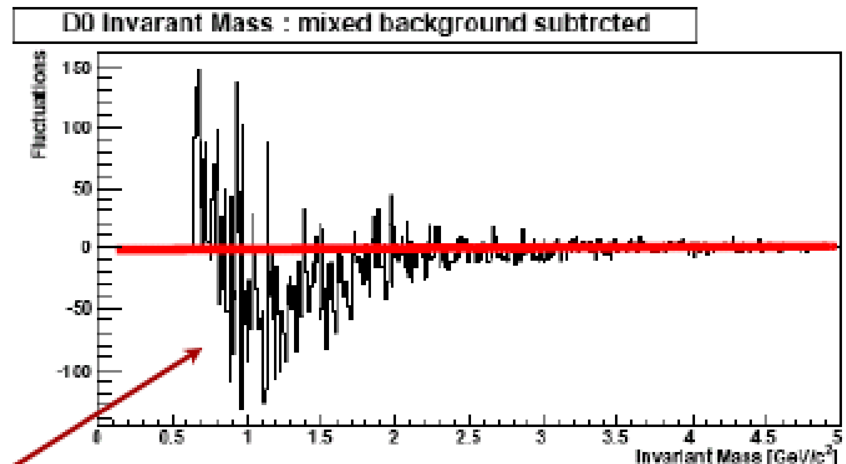
: *d0 to the mean primary vtx, after the translation*

- Small broadening ~5 μm: OK
  - it is expected because tracks are translated using the reco vtx, not the MC vertex

Background subtraction: event mixing

- First tests on mixed events
- $D^0 \rightarrow K\pi$ background mass distribution (without vertexing)



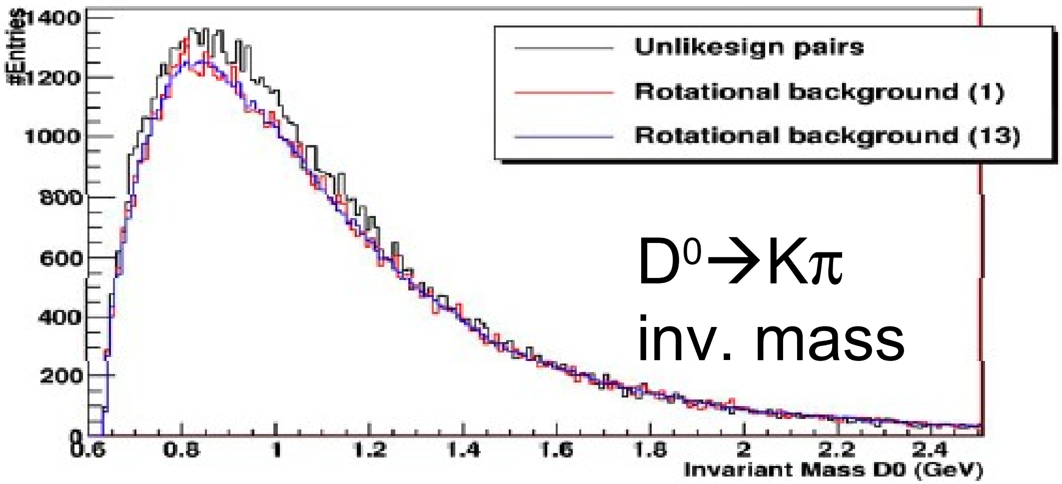


We are mixing different event topologies

- After subtraction of the mixed-evt background, there is a structure for masses < 1.5 GeV/c
  - probably due to the “jettiness” of the events

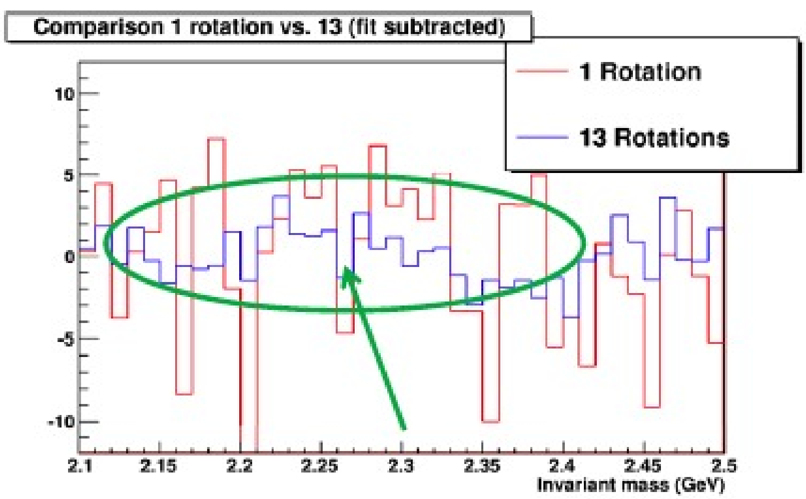
Background subtraction: sub-event rotating

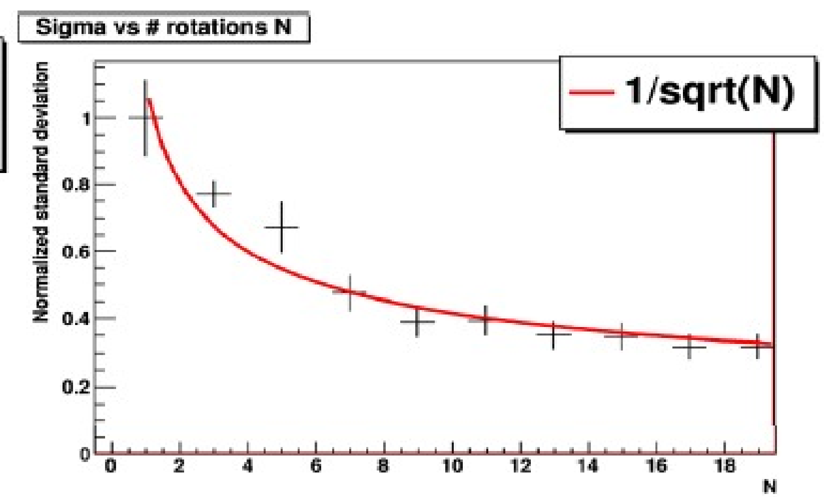
- Rotate the negative tracks by (180+i*5) deg, i=1, ... N



Figures:

- Increasing the number of rotations reduces the noise on the background
- We note a saturation at ~ 13 rotations.



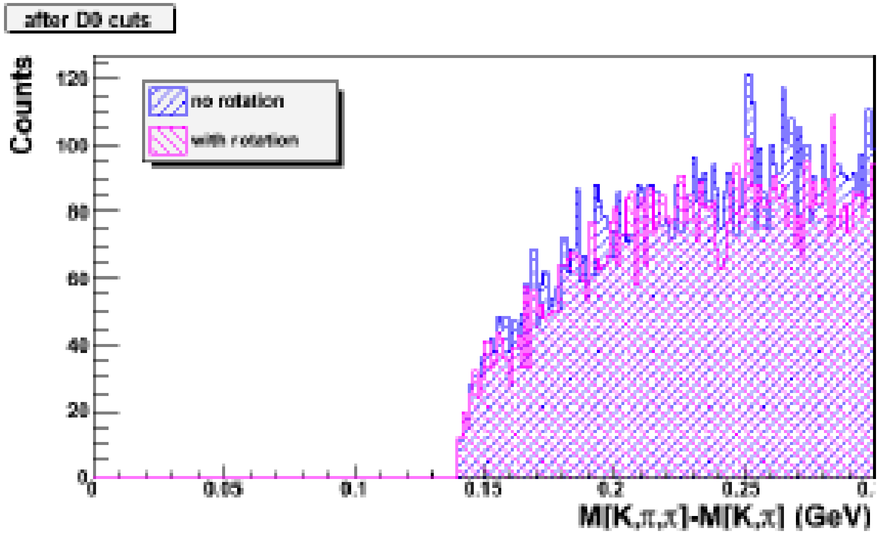


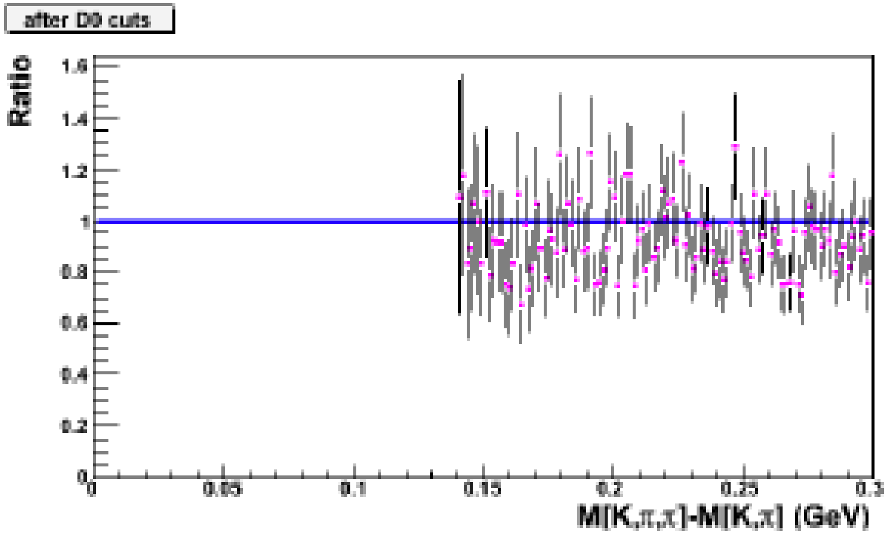
Background subtraction: sub-event rotating

- Rotate the negative tracks by (180+i*5) deg, i=1, ... N

$D^{*+} \rightarrow D^0\pi$

$M_{D^*}-M_{D0}$





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$$N^{D0 \to K\pi}_{selected}$$

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Feed-down from B, Eff&Acc corrections

$$\left.\frac{dN^{D0\ \mathrm{from\ c}}_{produced}}{dp_t dy}\right|_{|y|<1}$$

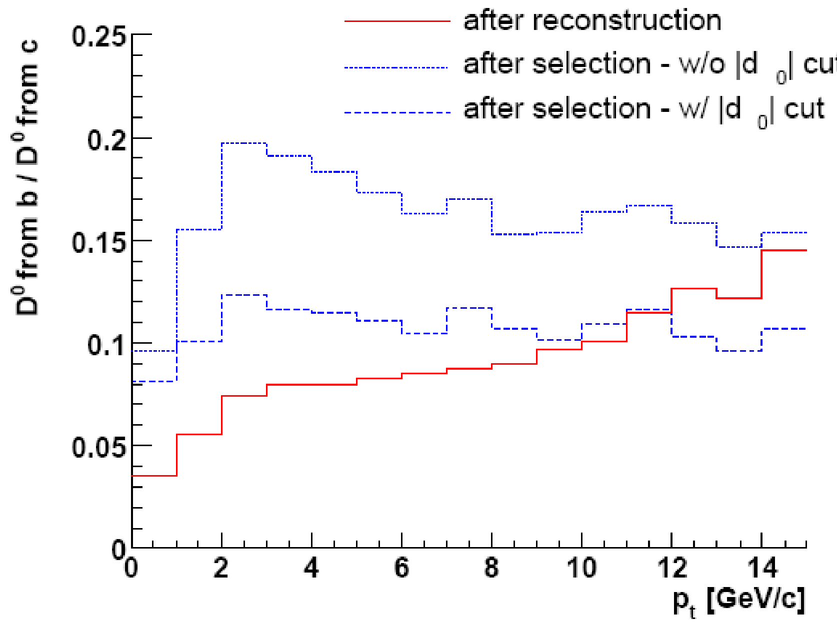
Systematics

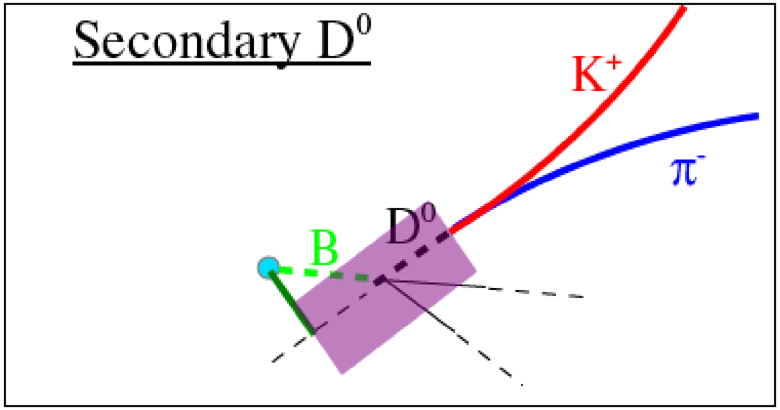
$$\left.\frac{dN^{D0\ \mathrm{from\ c}}_{produced}}{dp_t dy}\right|_{|y|<1} \pm err$$

Correction for beauty feed-down

- Feed-down $B \rightarrow D^0$ can be up to 15% of measured D^0 signal, after selections
- Can use upper cut on $|d_0|$ to control it
- We are testing a method, developed by CDF, for a direct measurement of the prompt D fraction
- It is based on the impact parameter of the D to the primary vertex

  → Chiara

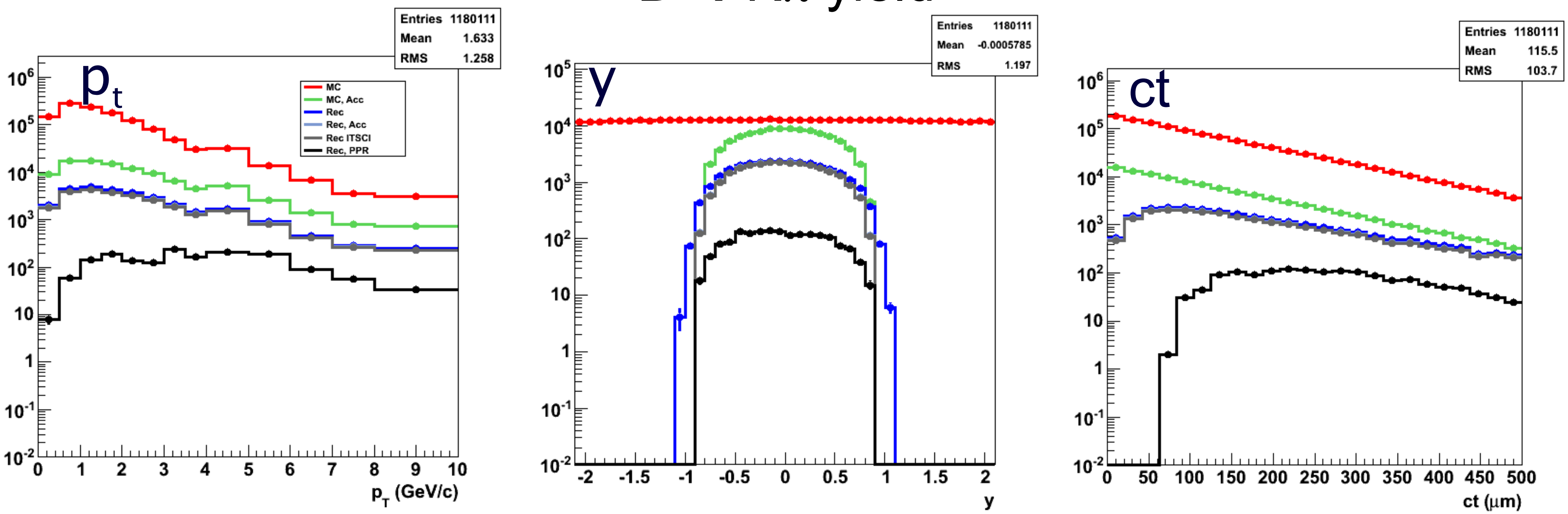




Corrections

- Use standard Correction Framework
  - charm-specific selections (# of points in ITS, ...) implemented (C.Zampolli)
- Study evolution of the signal yield at the various steps of the simulation/reconstruction

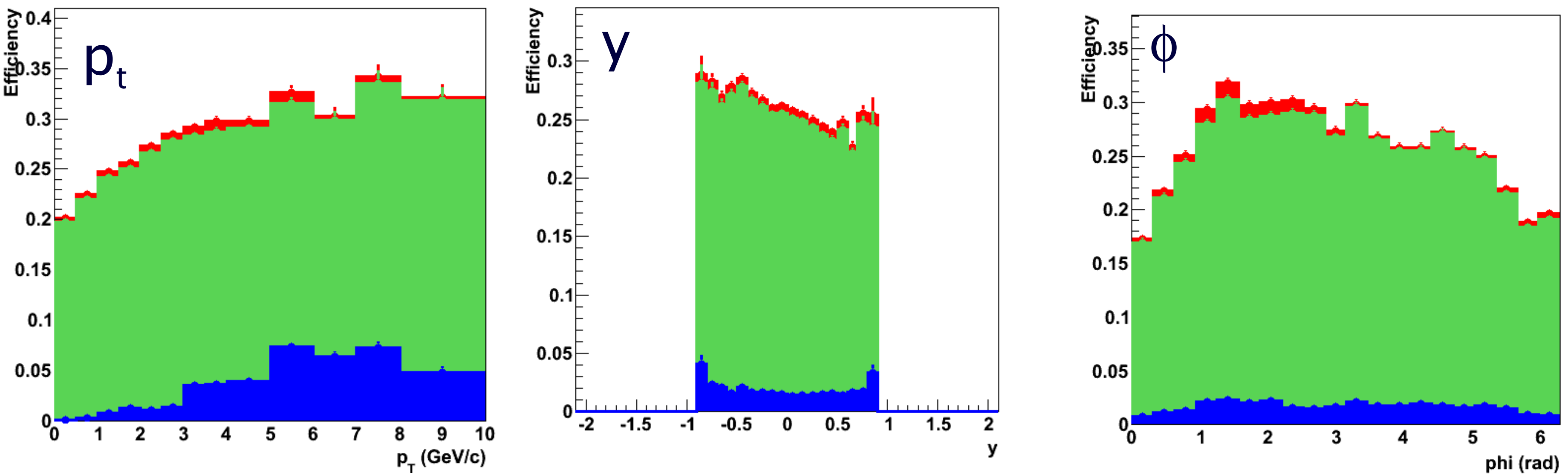
$D^0 \rightarrow K\pi$ yield



Corrections

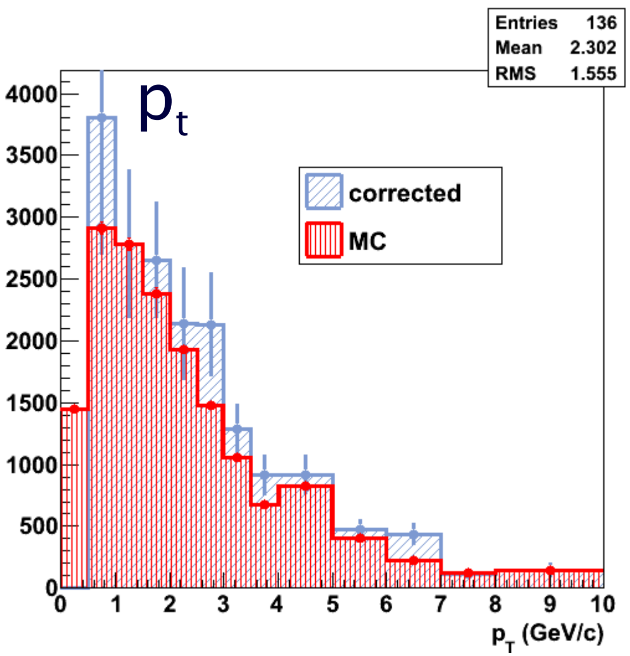
- Use standard Correction Framework
  - charm-specific selections (# of points in ITS, ...) implemented (C.Zampolli)
- Corrections for acceptance and efficiency in one go
  - however, separate correction maps for various steps available:
    - MC→ acceptance→reco tracks→sele tracks→sele candidates

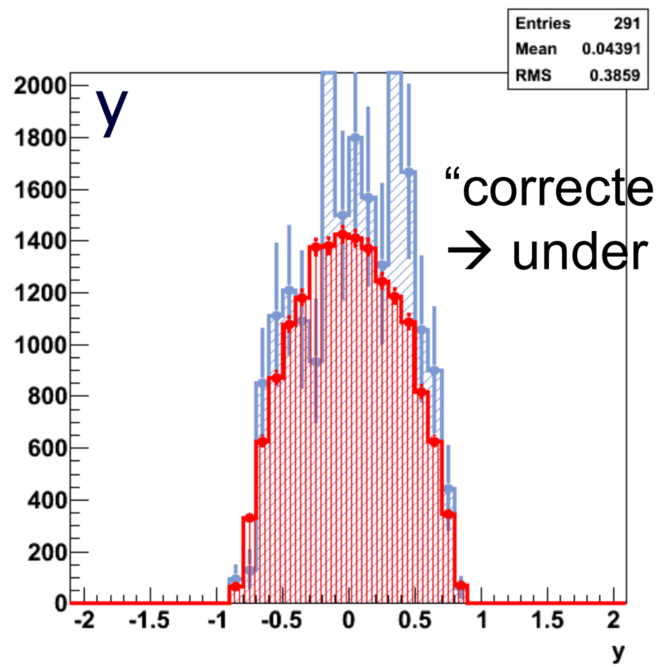
$D^0 \rightarrow K\pi$ efficiency



Corrections

- Exercising the corrections
- Try to correct signal extracted from pp min.bias sample (LHC09a4) with correction maps from pp “forced charm” sample (LHC09a5)
  - the pp “forced charm” simulation requires 100 times less events to have the same signal statistics





“corrected” is always higher
→ under investigation

HF vertexing
Analysis Scheme & Activities

Charm “production” (ESD/AOD ➔ AOD for Charm)

Signal selection

Invariant mass analysis and significance maximization (in bins of p_t, y, $\phi - \Phi_{RP}$…)

$N^{D0 \to K\pi}_{selected}$

⬇

Corrections

Feed-down from B, Eff&Acc corrections

$\left.\frac{dN^{D0\text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1}$

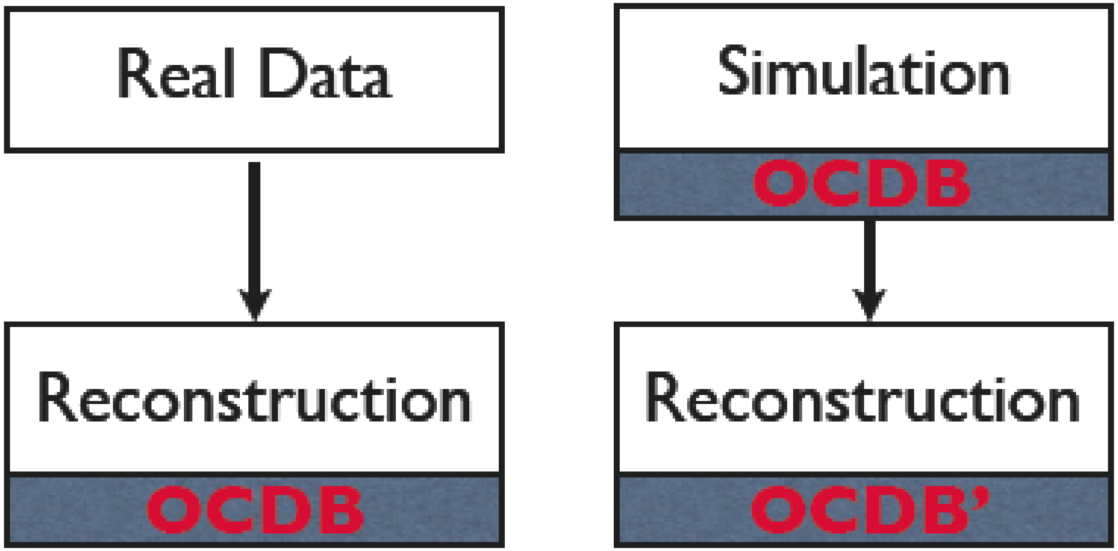
⬇

Systematics

$\left.\frac{dN^{D0\text{ from c}}_{produced}}{dp_t dy}\right|_{|y|<1} \pm err$

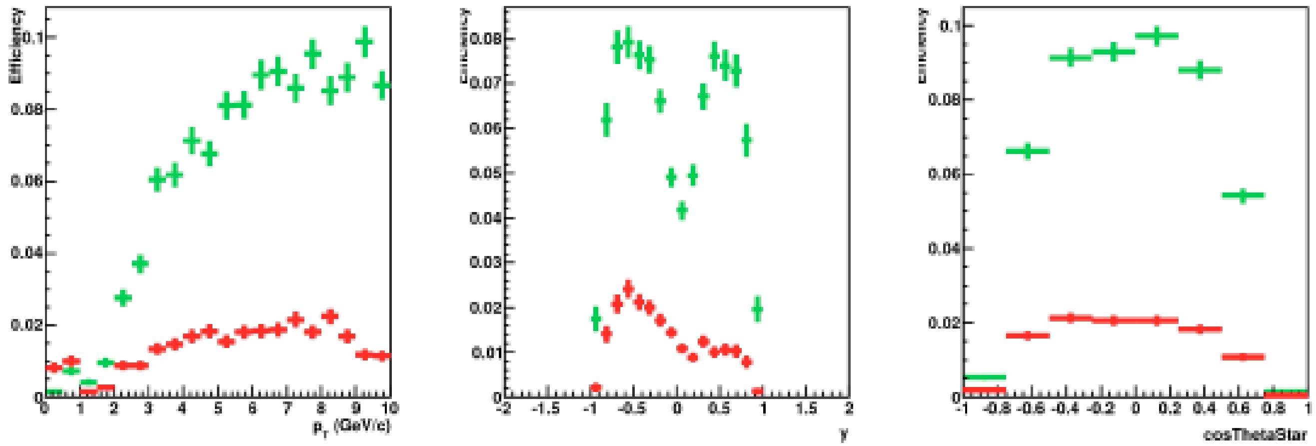
Systematics due to difference between residual misalignment/miscalibration in data and in MC

- Compute corrections (efficiency) from MC several times, using several reco passes with different OCDBs
  - discussion started also within PWG1 → try to identify most relevant parameter(s) for each detector
  - e.g. ITS alignment

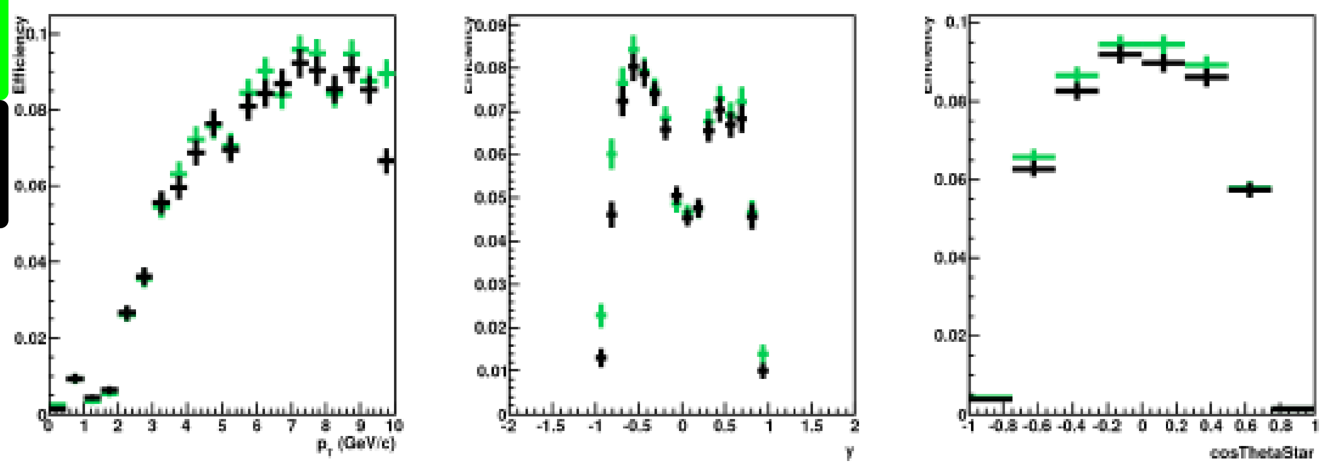


Effect of misalignment on $D^0 \rightarrow K\pi$ efficiency

- Green is zero misalignment
- Red is full misalignment



- Green is zero misalignment
- Black is residual misalignment

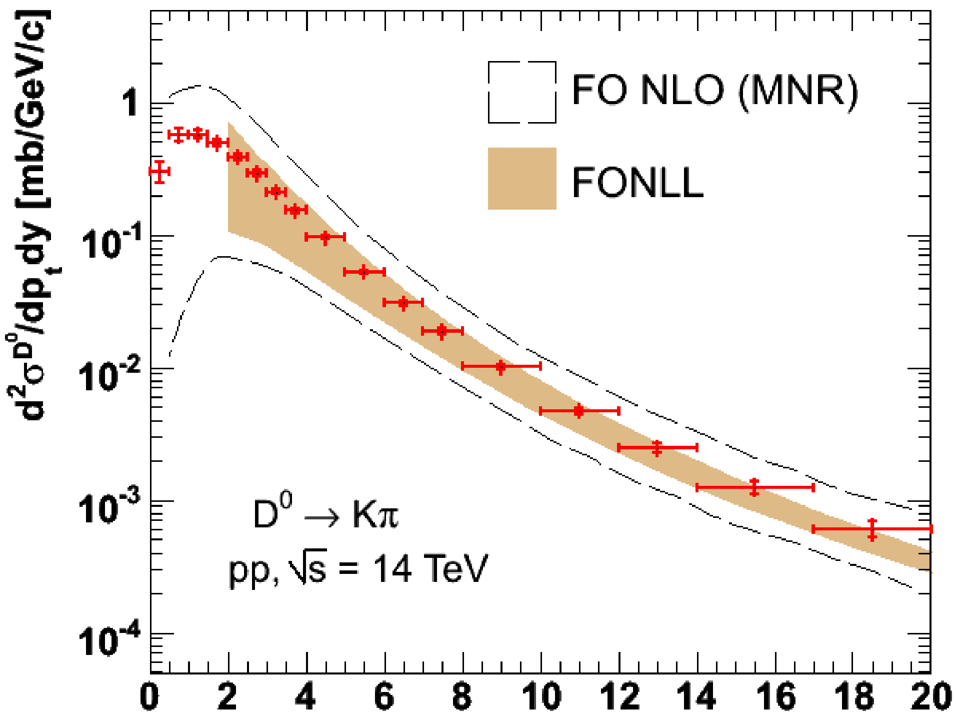


Expected Performance (PPR)

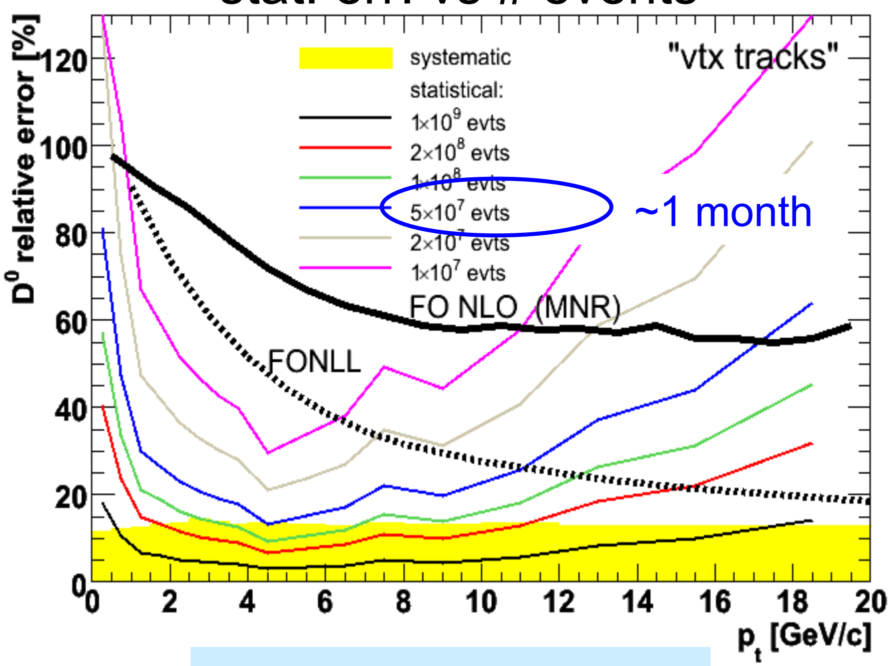
pp, $\sqrt{s}$ = 14 TeV

Expected sensitivity in comparison to pQCD:

$D^0 \rightarrow K\pi$



1 year at nominal luminosity
(10^9 pp events)



Detector configuration:
ITS + TPC + TOF

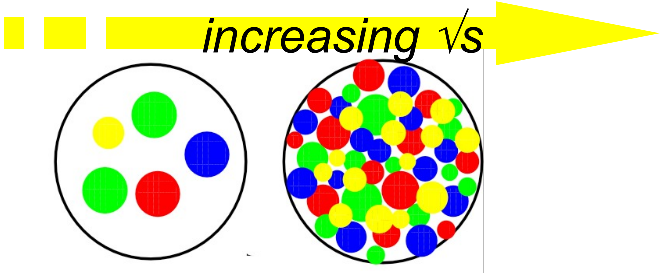
Summary

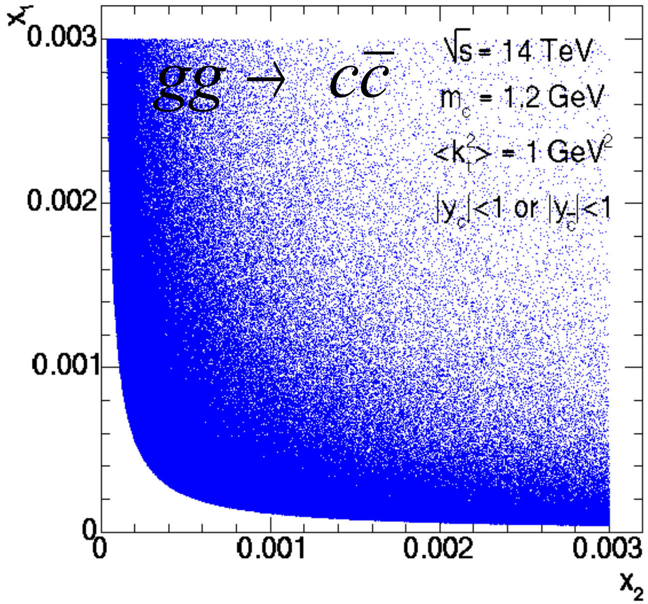
- Analysis chain is being finalized and tested on the grid
  - → results for $D^0 \rightarrow K\pi$ (→ Chiara)
  - → results for $D^+ \rightarrow K\pi\pi$ (→ Renu)
- We are already preparing for this analysis using real data
  - alignment of the ITS with cosmics (→ Marcello, Andrea)

EXTRA SLIDES

Novelties at LHC (2): Small x

- Probe unexplored small-x region with HQs at low p_T and/or forward y
  - down to x~10^{-4} with charm already at y=0





- Window on the rich phenomenology of high-density PDFs:

  gluon saturation / recombination effects

Probing small-x gluons with HQs (pp)

- Large pQCD uncertainties for charm $p_T \to 0$
  - onset of saturation ?
- Two attempts to include non-linear terms in evolution equations
  - DGLAP+GLRMQ Eskola et al., NPB660 (2003) 211
  - BK Kutak, Kwiecinski, Martin, Stasto

indicate charm as a sensitive probe in pp