Measurement of Electrons from Beauty-Hadron Decays in p-Pb Collision at $\sqrt{s_{NN}}$ = 5.02 TeV with ALICE at the LHC

Minjung Kim, Inha University

Advised by: Prof. MinJung Kweon, Prof. Jin-Hee Yoon

Dec 5th 2014, Heavy Ion Meeting

Motivation

- ## Heavy Flavour in Heavy-Ion Collisions

Heavy quarks (charm and beauty) are produced in the **initial hard scattering processes,** experience the full evolution of the system

➡**Natural probe of the hot and dense medium created in heavy-ion collisions**

Motivation

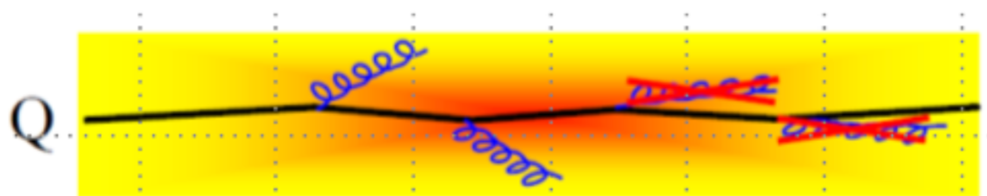
- **Heavy quark Energy Loss in Medium**
  - Collisions with medium constituents
  - Medium-induced gluon radiation depends on :

    ✓ Casimir colour factor (C_R)

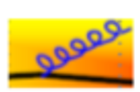
    $$\omega\frac{dI}{d\omega} \propto \alpha_s C_R f(\omega)$$

    $$\text{where} \quad C_R = 3 \ \text{for}\ g,\ \frac{4}{3}\ \text{for}\ q$$

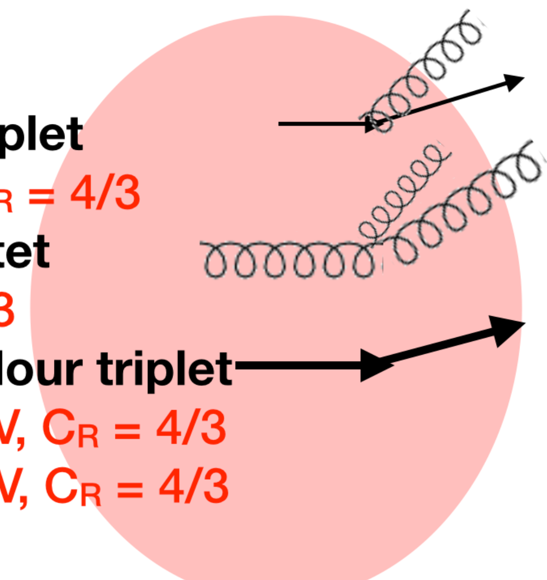
    ✓ Mass



✓ Gluonsstrahlung Probability

 $\propto \dfrac{1}{[\theta^2 + (\frac{M}{E})^2]^2}$

quarks : colour triplet
u,d,s : m~0, C_R = 4/3
gluons: colour octet
g : m=0, C_R = 3
heavy quarks : colour triplet
c : m ~ 1.5 GeV, C_R = 4/3
b : m ~ 4.5 GeV, C_R = 4/3



"Quark Matter"

- In vacuum, gluon radiation is suppressed at angles smaller than M_Q/E_Q
- In medium, this implies lower energy loss for massive partons

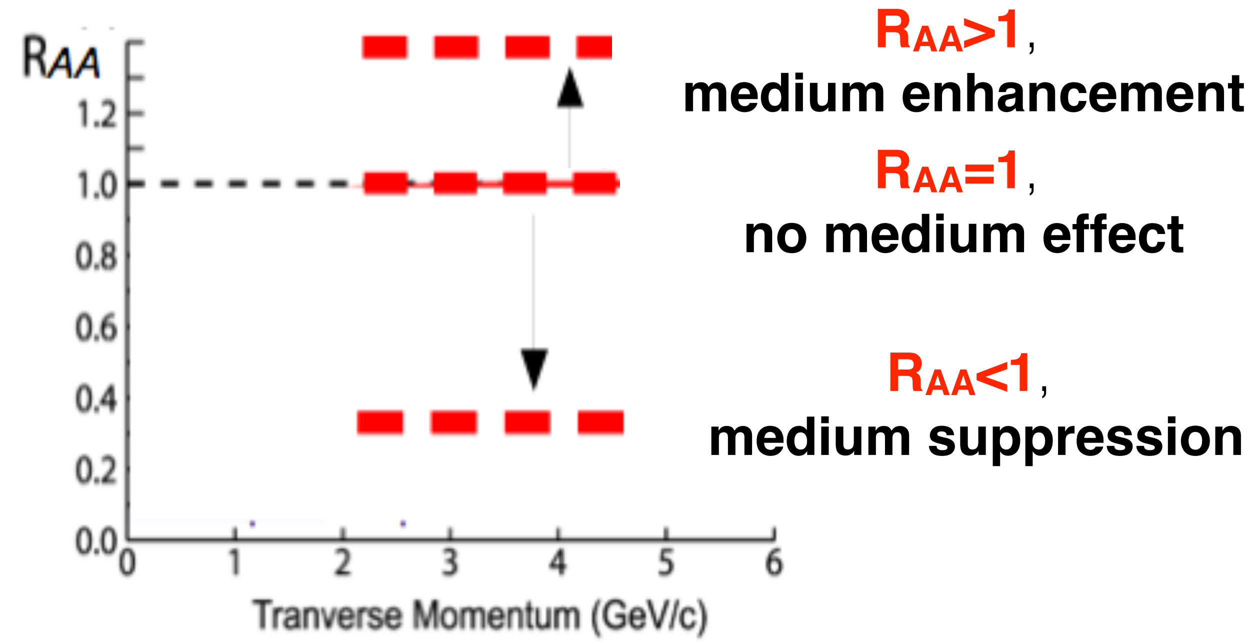
➡ Prediction for ΔE: **$\Delta E_g > \Delta E_{light\ quark} > \Delta E_c > \Delta E_b$**

↳ **measurement of b quark and c quark separately is needed**

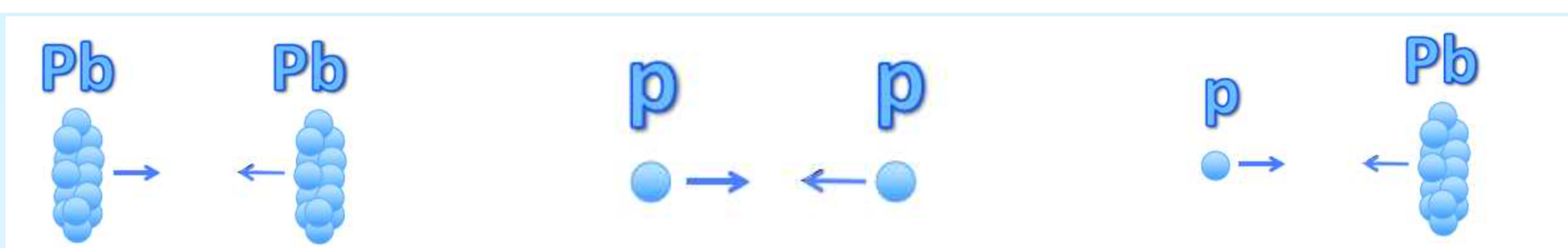
Motivation

- ## Nuclear Modification Factor

$$R_{AA} = \frac{dN_{AA}/dp_T}{\langle N_{coll} \rangle \times dN_{pp}/dp_T}$$



- ## Measurement in p-Pb collisions
  - Control experiment for the Pb-Pb measurement
  - Address cold nuclear matter effects



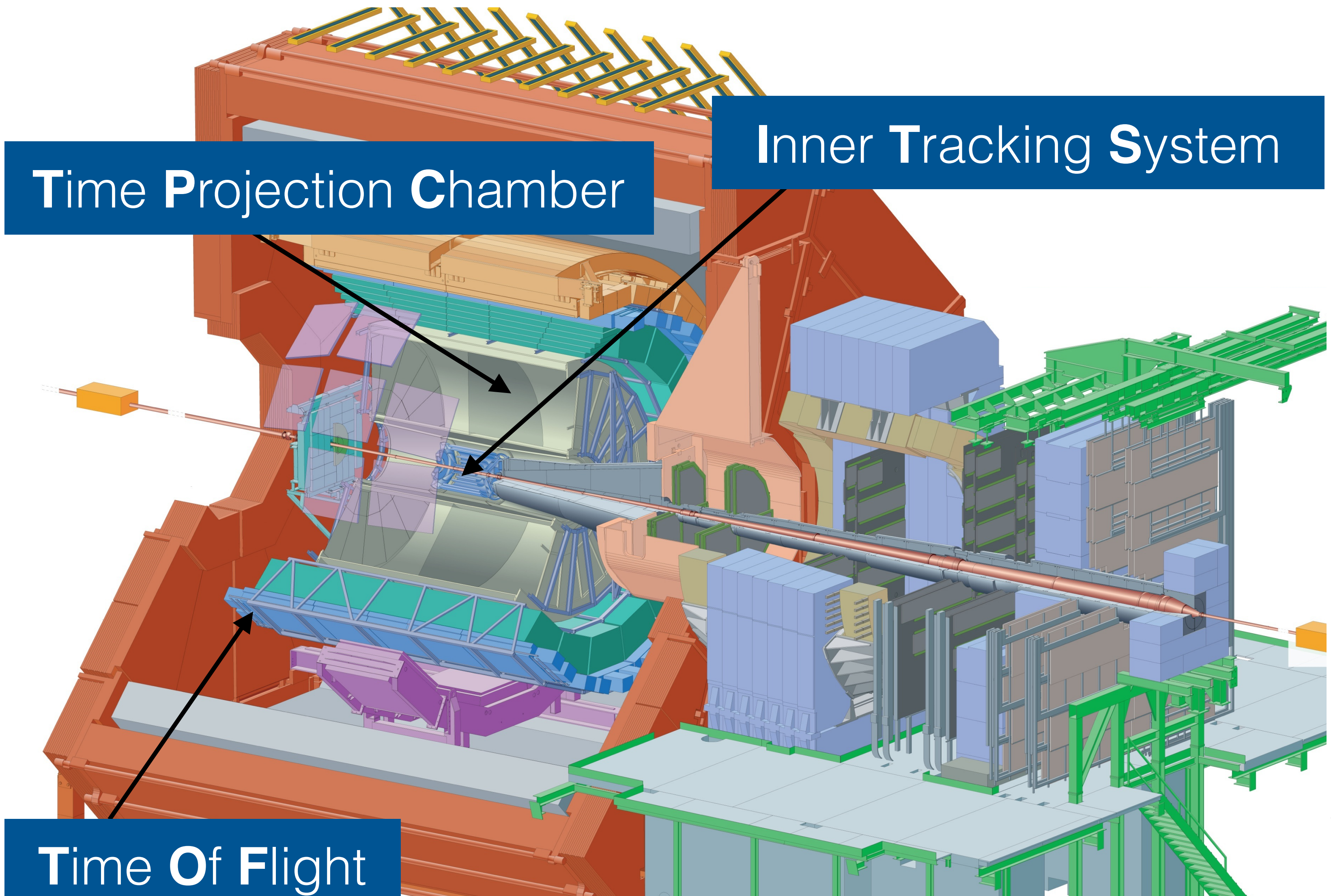
Cold nuclear matter effects
+ hot nuclear matter effects
(related to the Quark-Gluon Plasma)

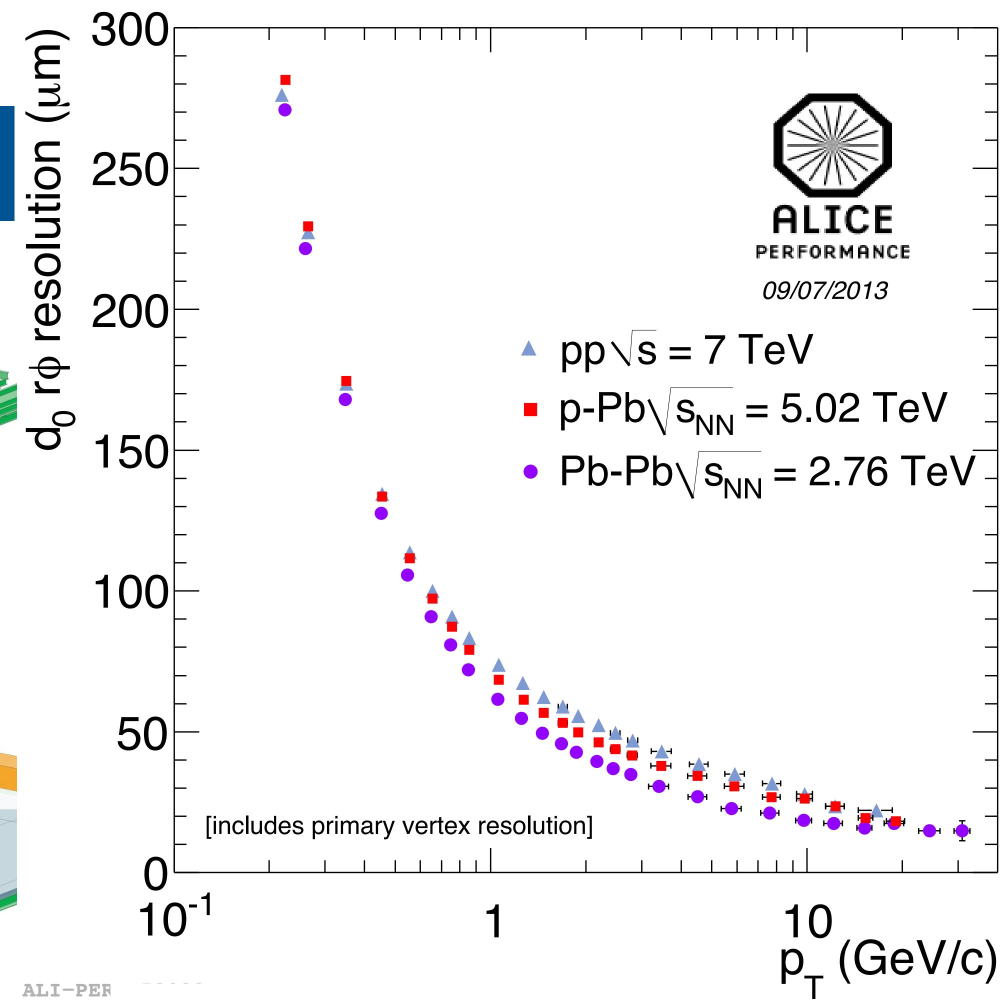
Elementary collision
No nuclear matter effects

Cold nuclear matter effects -
without Quark-Gluon Plasma

Electron Analysis in ALICE

- **Measurement of b quark production via electron from semi-leptonic decays of beauty-hadron(B)**
  - Substantial branching ratio :~11% [B→e] , ~10% [B→D→e]
  - Excellent **vertex and impact parameter resolution of ITS** and **eID capability** in ALICE





Rapidity Coverage (this analysis)

$-0.60 < y_{lab} < 0.60$

$-1.06 < y_{CMS} < 0.14$

Data Sample

system	p-Pb
$\sqrt{s_{NN}}$ (TeV)	5.02
when	2013
L_{int} (μb^{-1})	49

Electron Identification at low p_T

TOF(Time Of Flight) PID :

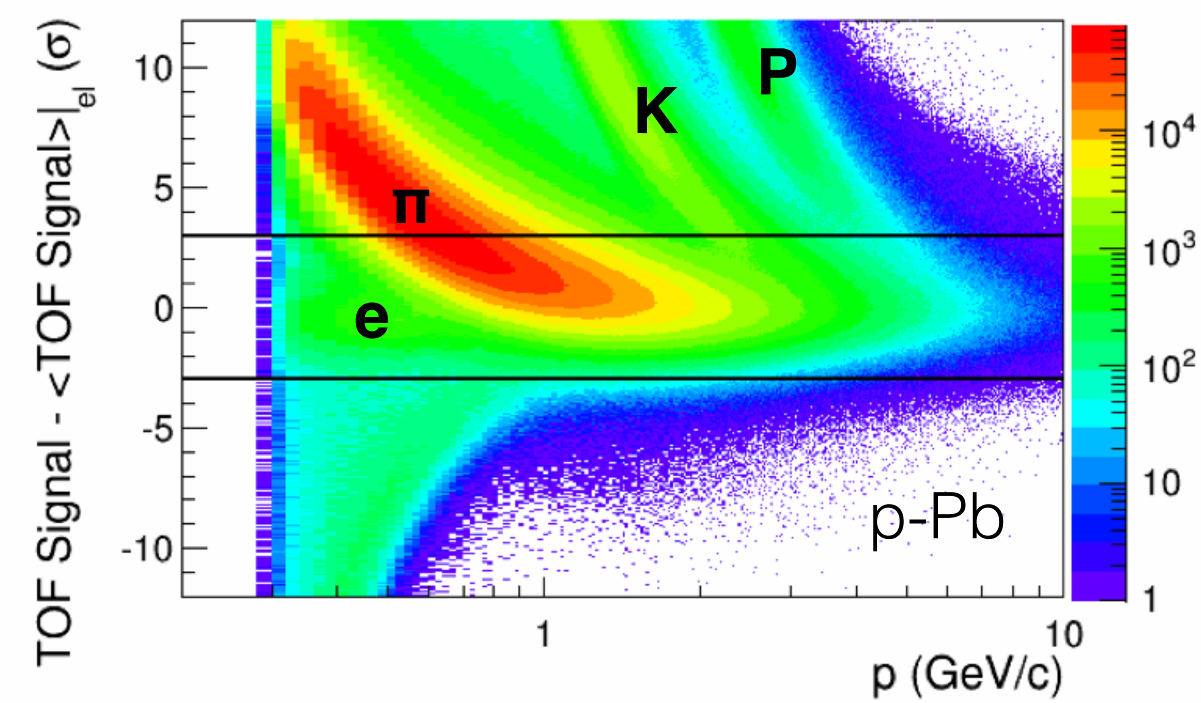
Symmetric 3σ cut around electron hypothesis

- ✓ Reject kaons for p<1.5 GeV/c
- ✓ Reject protons for p<3 GeV/c

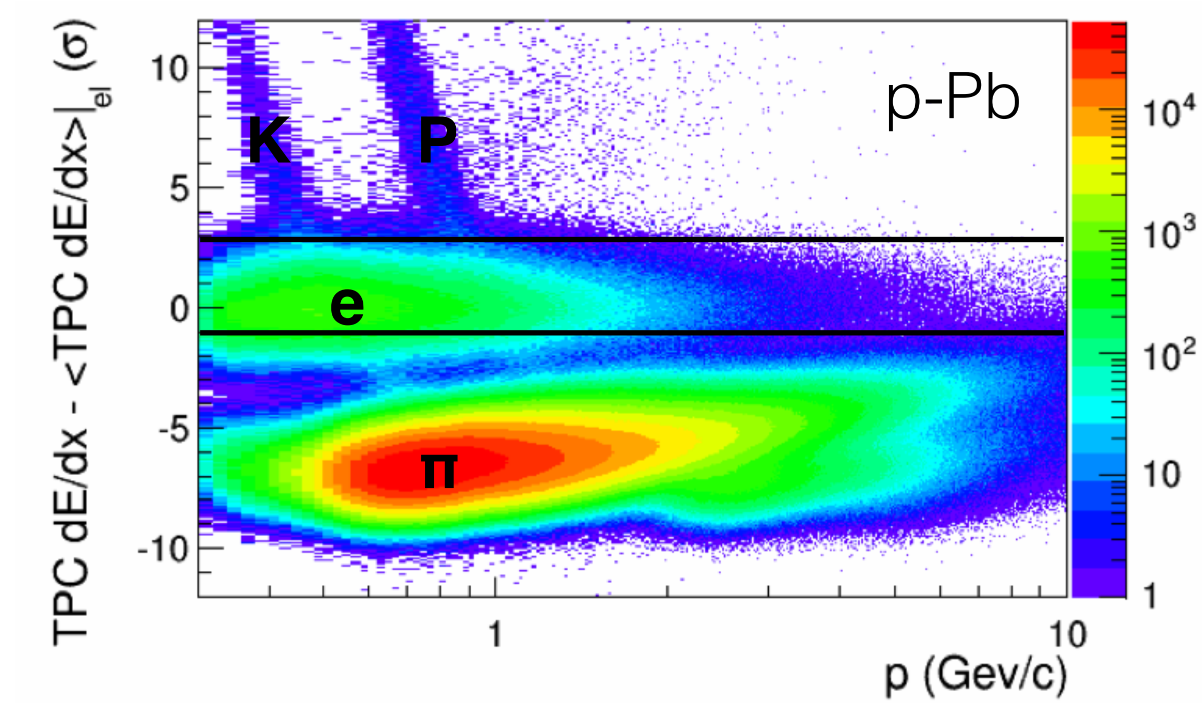
TPC(Time Projection Chamber) PID :

Select tracks in the upper half of the electrons Bethe-Bloch band($-0.5\sigma < dE/dx - \langle dE/dx \rangle_e < 3\sigma$) for further hadron(mostly pion) rejection

- ✓ electron efficiency of 69%



(a) TOF time distribution versus momentum for the electron mass hypothesis (minimum bias). The applied TOF PID selection is indicated with horizontal lines.



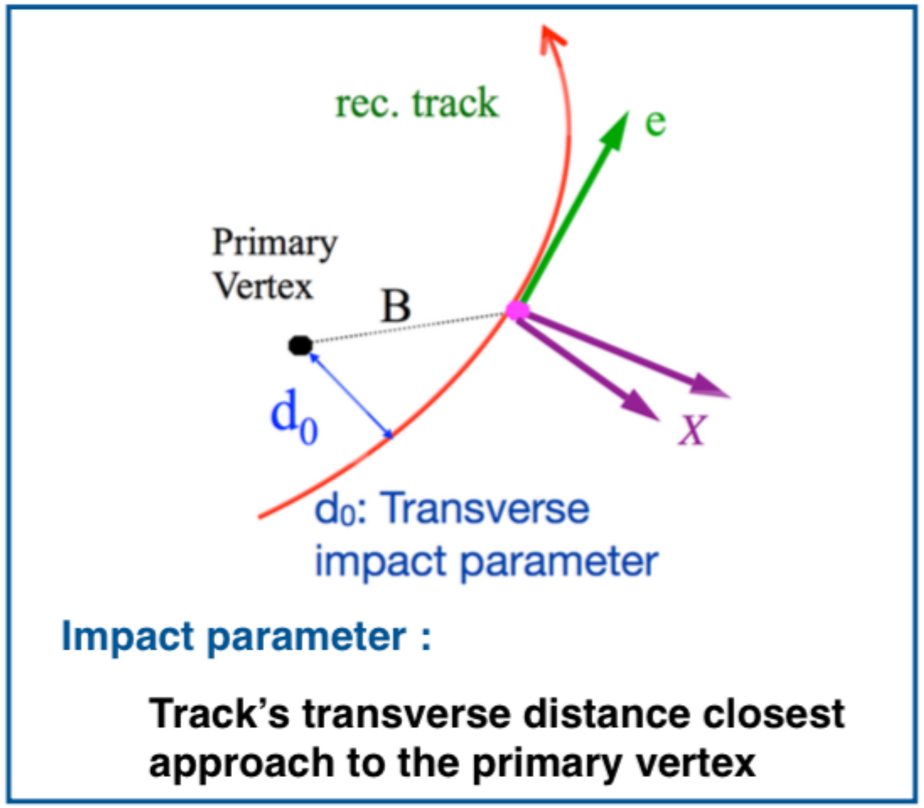
(b) TPC dE/dx expressed in number of sigmas from the electron line after TOF PID (minimum bias).

Analysis Approach for Electrons from B Hadron Decay

Electrons from different sources after eID :

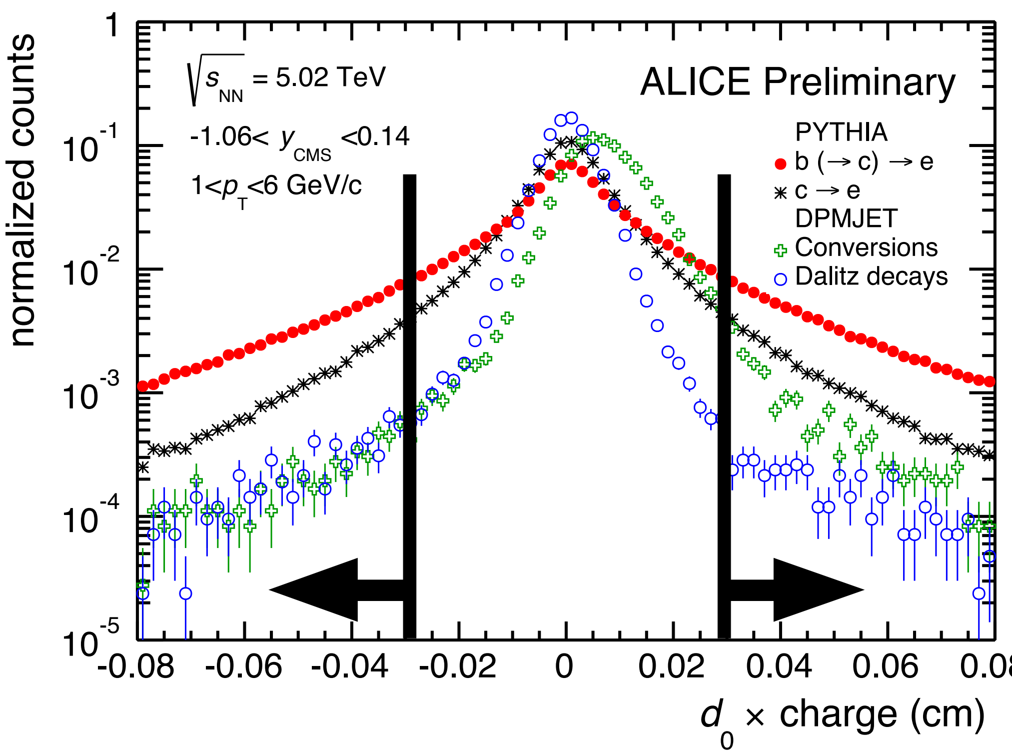
1. Dalitz decays electrons
2. Conversion electrons
3. Charm hadron decays electrons
4. **Beauty hadron decays electrons**

➡ long lifetime : **cτ ≃ 500 μm → larger impact parameter**



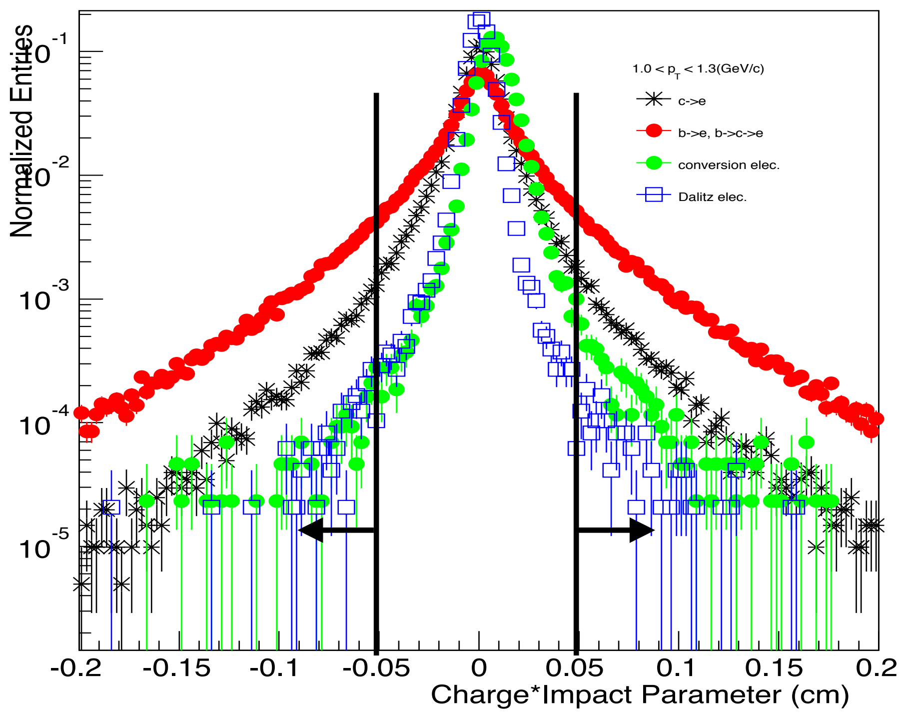
After Electron Identification :

1. **Minimum impact parameter cut to increase S/B ratio**
2. Subtract remaining background(non-heavy flavour electrons & charm hadron decay electrons) based on ALICE measurement
3. Correct subtracted electron spectra for acceptance and efficiency

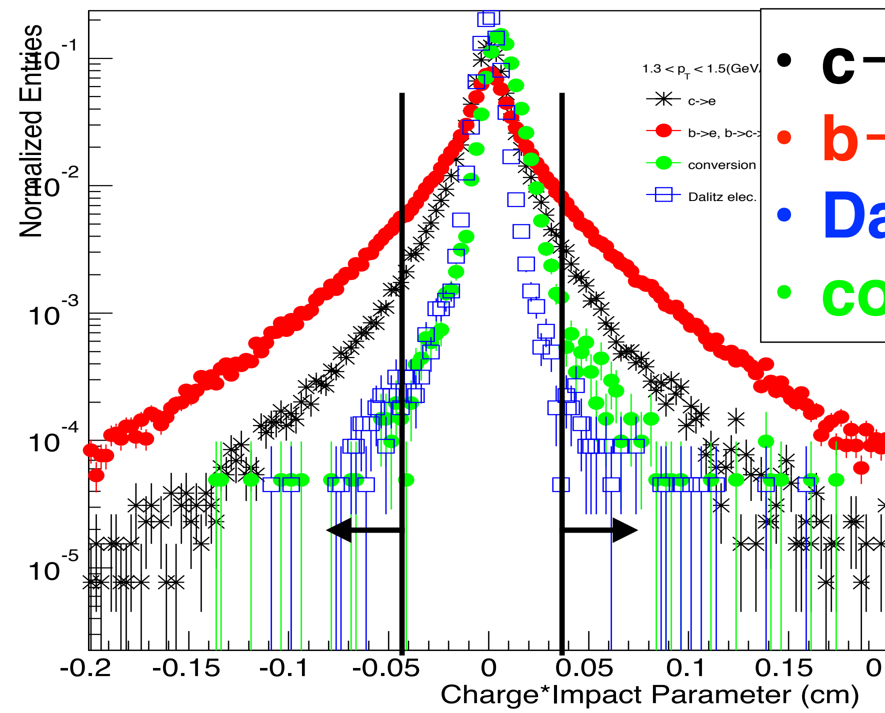


Impact Parameter Distributions for p_T

$1.0 < p_T < 1.3$ (GeV/c)

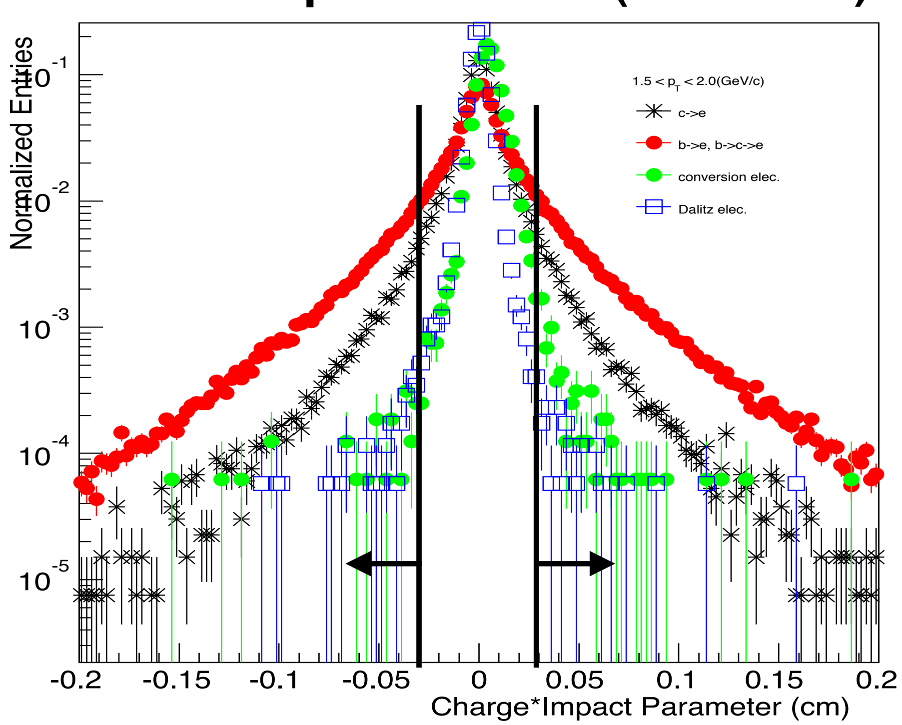


$1.3 < p_T < 1.5$ (GeV/c)

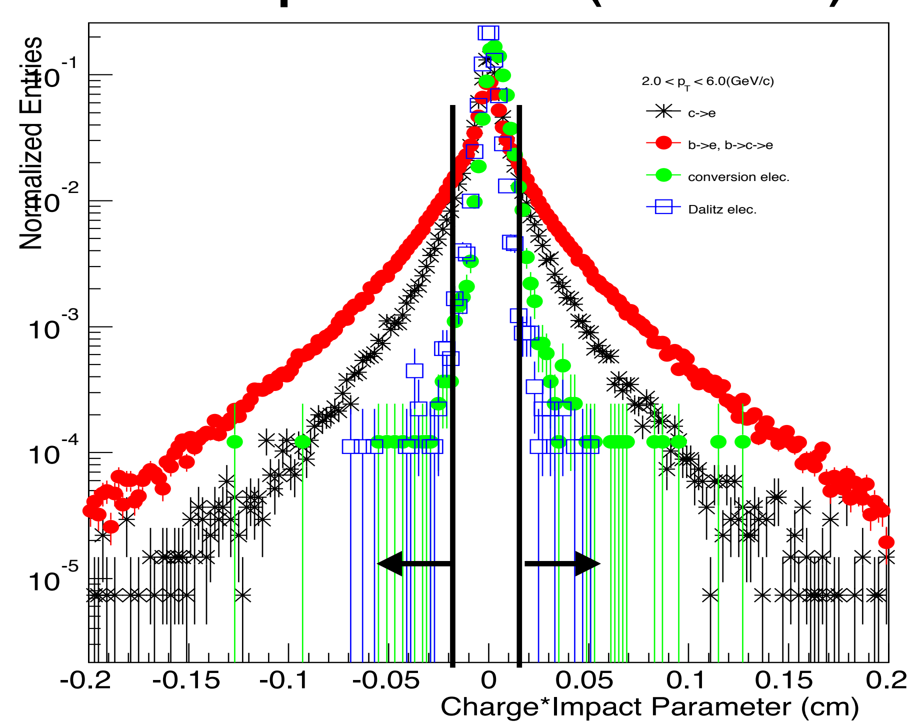


- c→e
- b→e (+b→c→e)
- Dalitz
- conversion

$1.5 < p_T < 2.0$ (GeV/c)



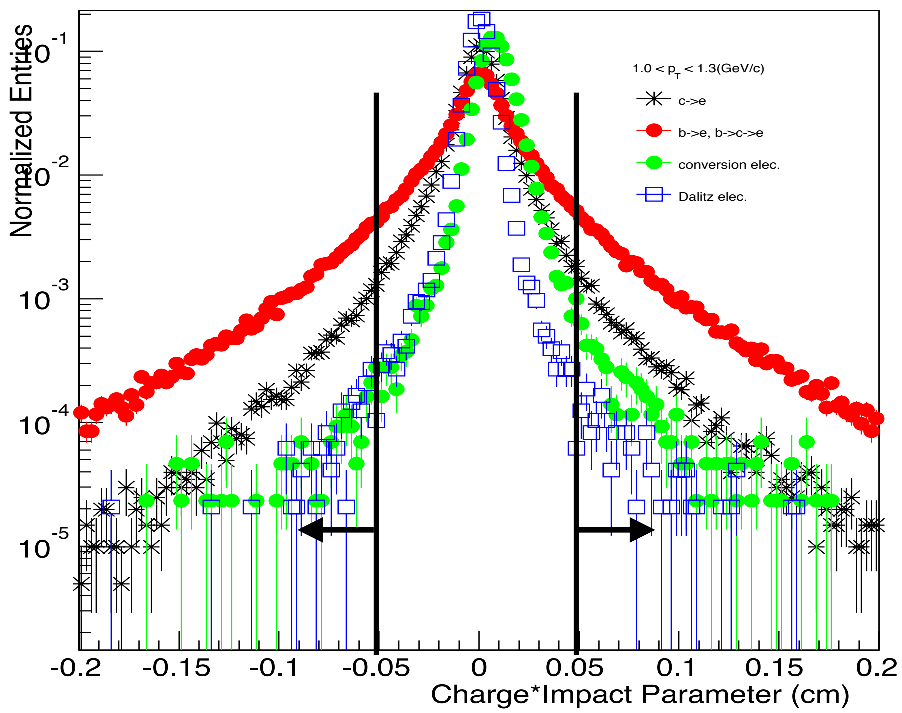
$2.0 < p_T < 6.0$ (GeV/c)



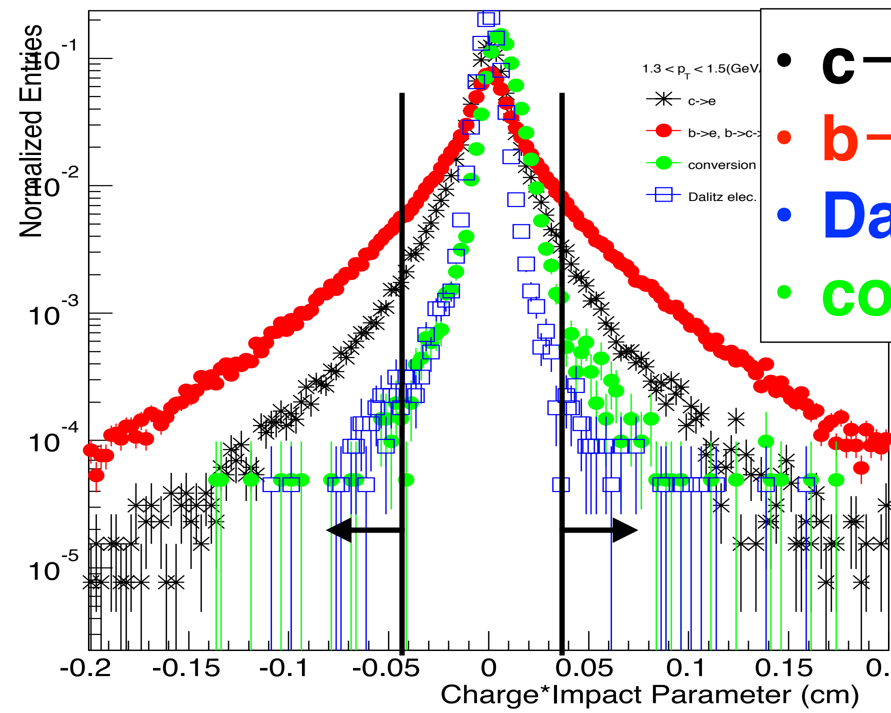
Each source is characterised by a distinctive impact parameter distribution for various p_T range

Impact Parameter Distributions for p_T

1.0 < p_T <1.3 (GeV/c)

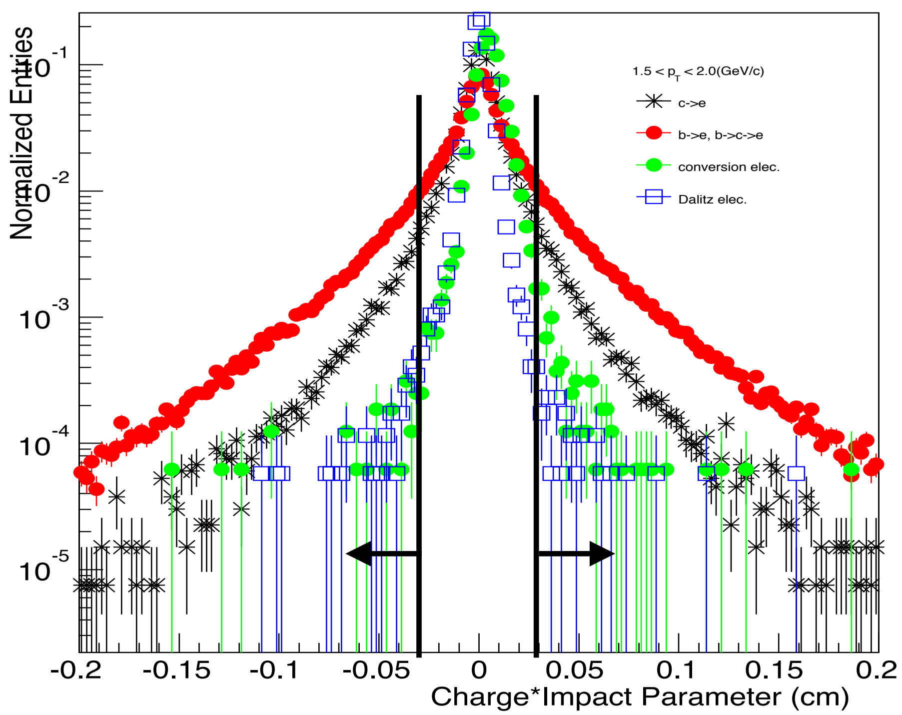


1.3 < p_T <1.5 (GeV/c)

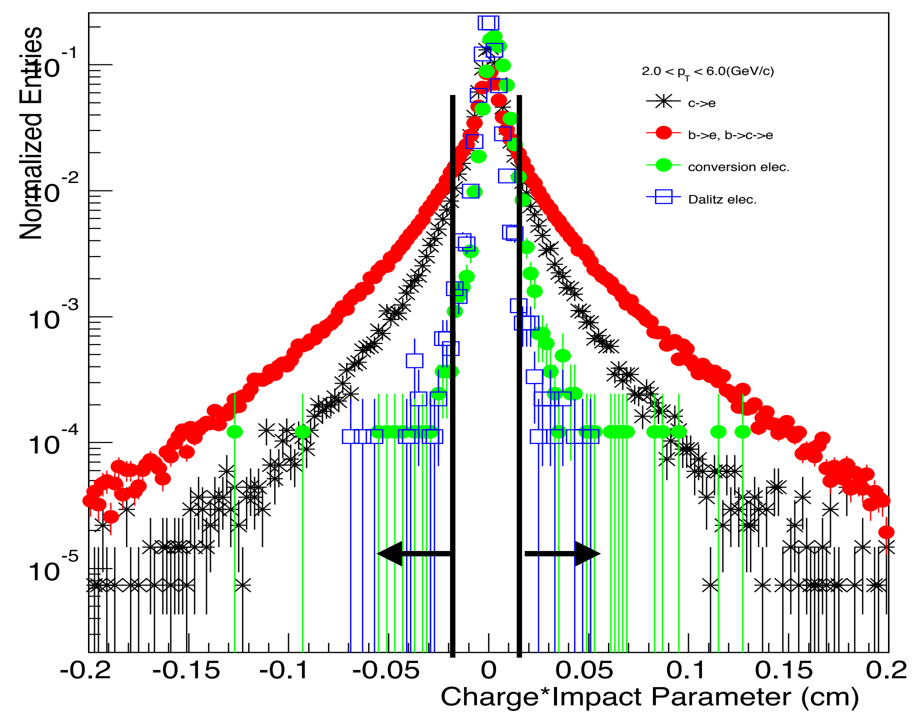


- c→e
- b→e (+b→c→e)
- Dalitz
- conversion

1.5 < p_T < 2.0 (GeV/c)



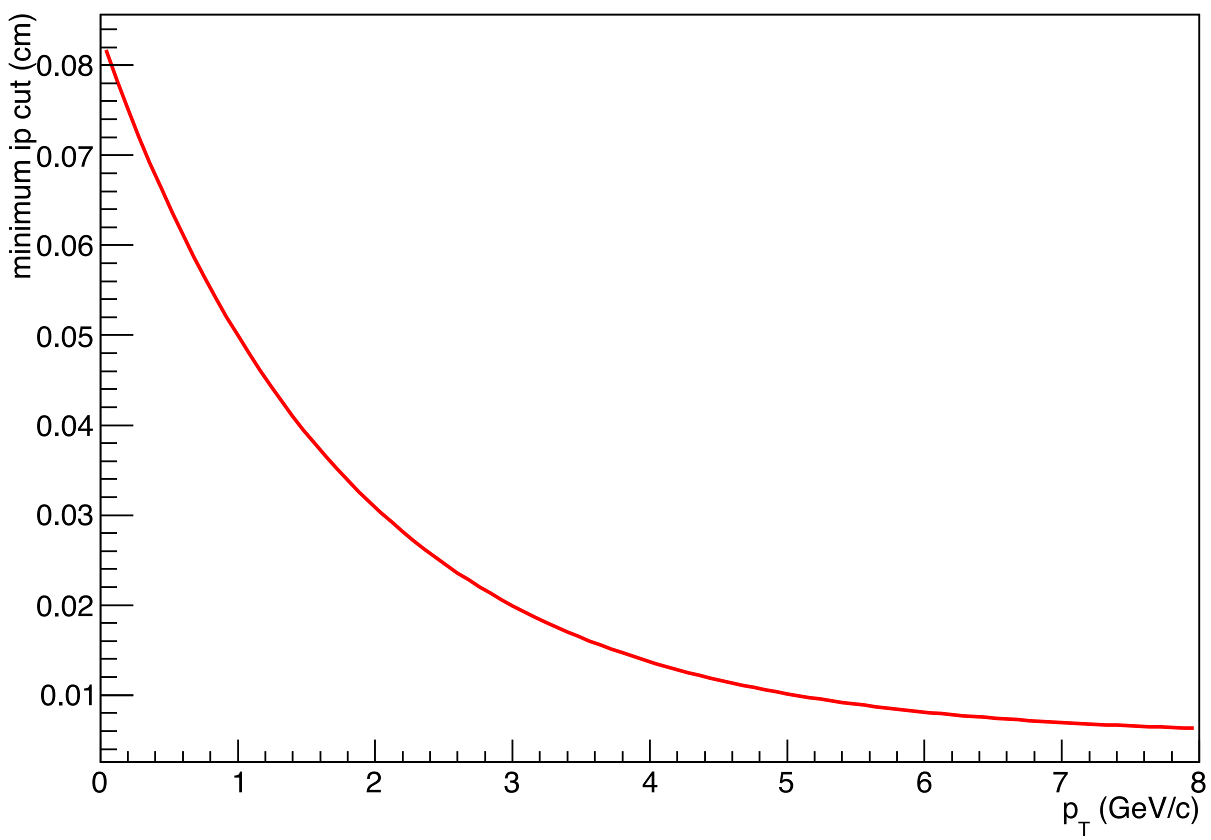
2.0 < p_T < 6.0 (GeV/c)



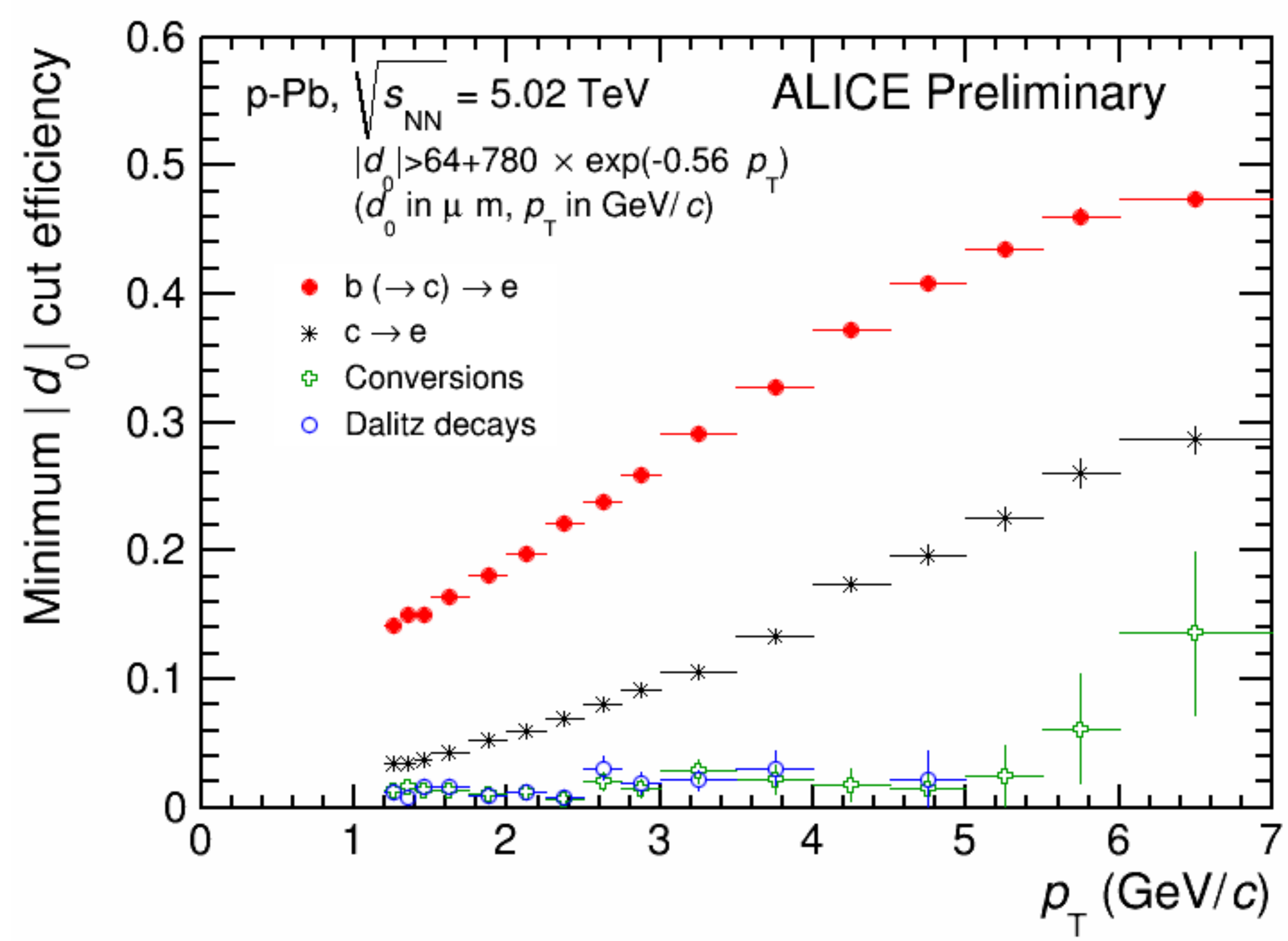
Impact parameter distributions are p_T dependent

p_T Dependent Minimum Impact Parameter Cut

- p_T dependent impact parameter cut



- Impact parameter cut efficiency



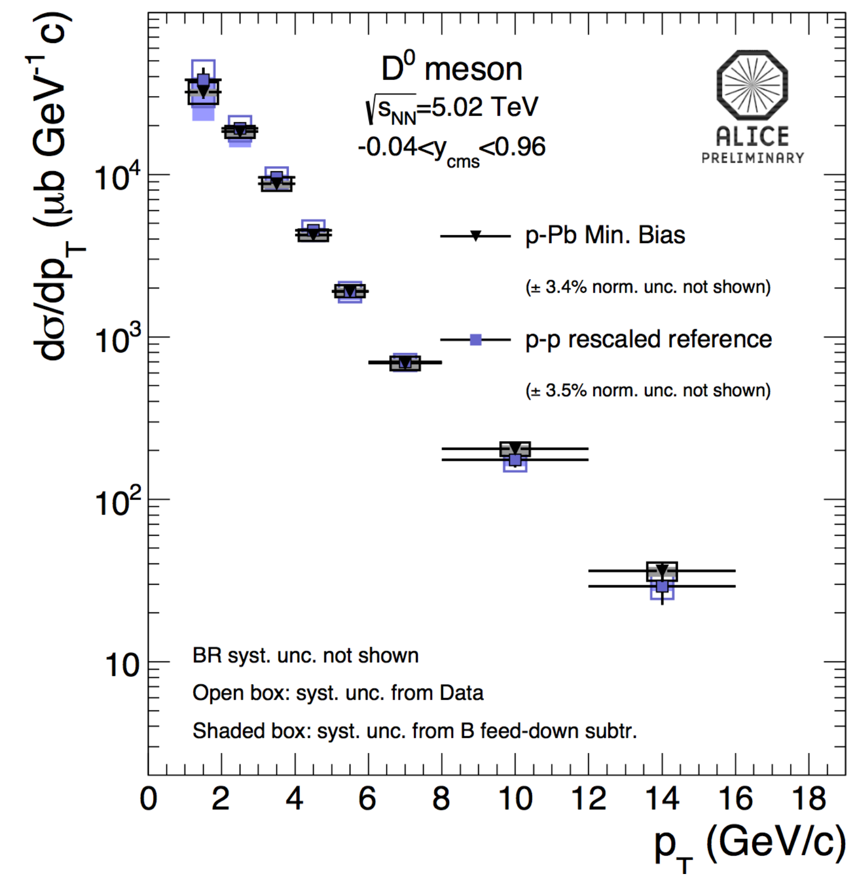
- Minimum impact parameter cut optimised by Monte Carlo

Estimation of Electron Backgrounds

Backgrounds are estimated by weighting relevant electron source yields in MC simulations (PYTHIA, DPMJET) using ALICE measured spectra

- Electrons from **charm-hadron decays** via the D-meson cross section measured with ALICE

ALICE measured ↘ $D^0 \rightarrow e$ ↙ PYTHIA decay kinematics

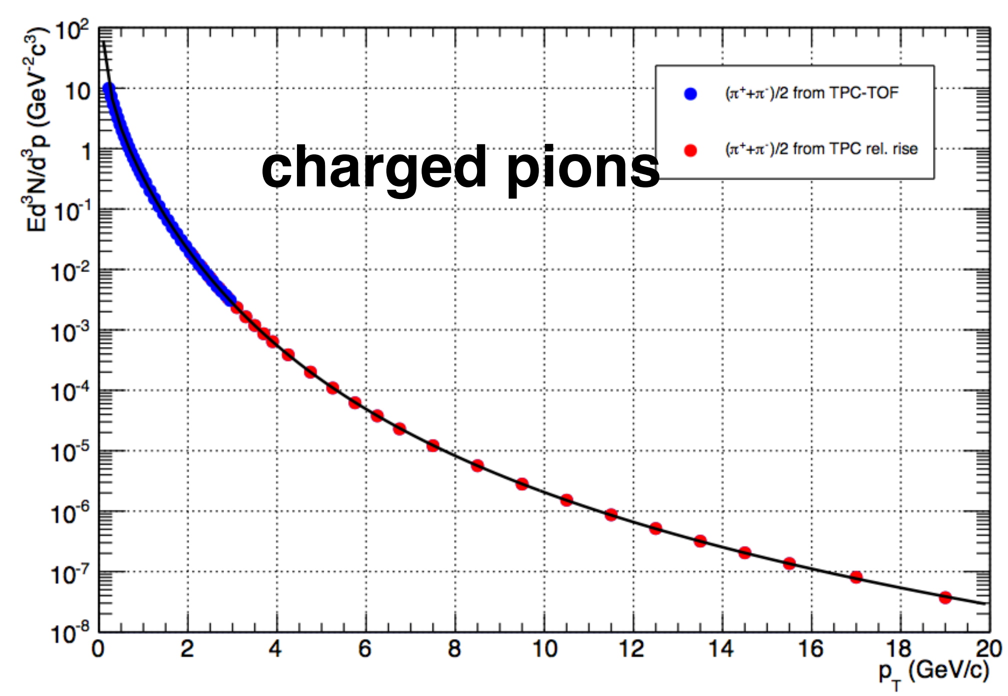


- The contributions of **light meson decays** :

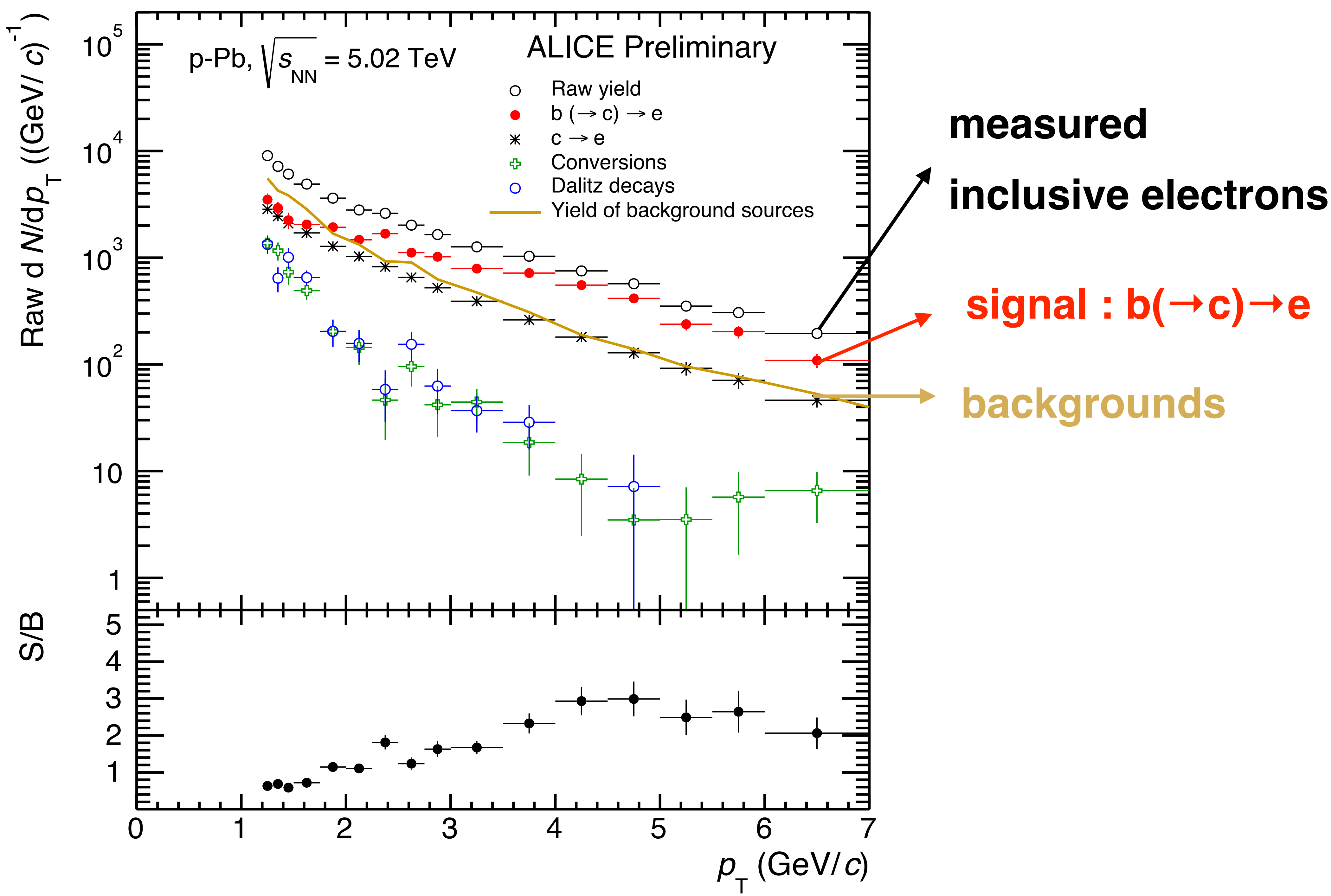
Pion Dalitz decay ($\pi^0 \rightarrow e^+e^-\gamma$)

Conversion electrons: $\pi^0 \rightarrow \gamma\gamma$(BR~98%), $\gamma + X \rightarrow e^+e^-$

- Based on measured in ALICE light meson spectra, estimate light meson decay electron backgrounds with PYTHIA decay kinematics

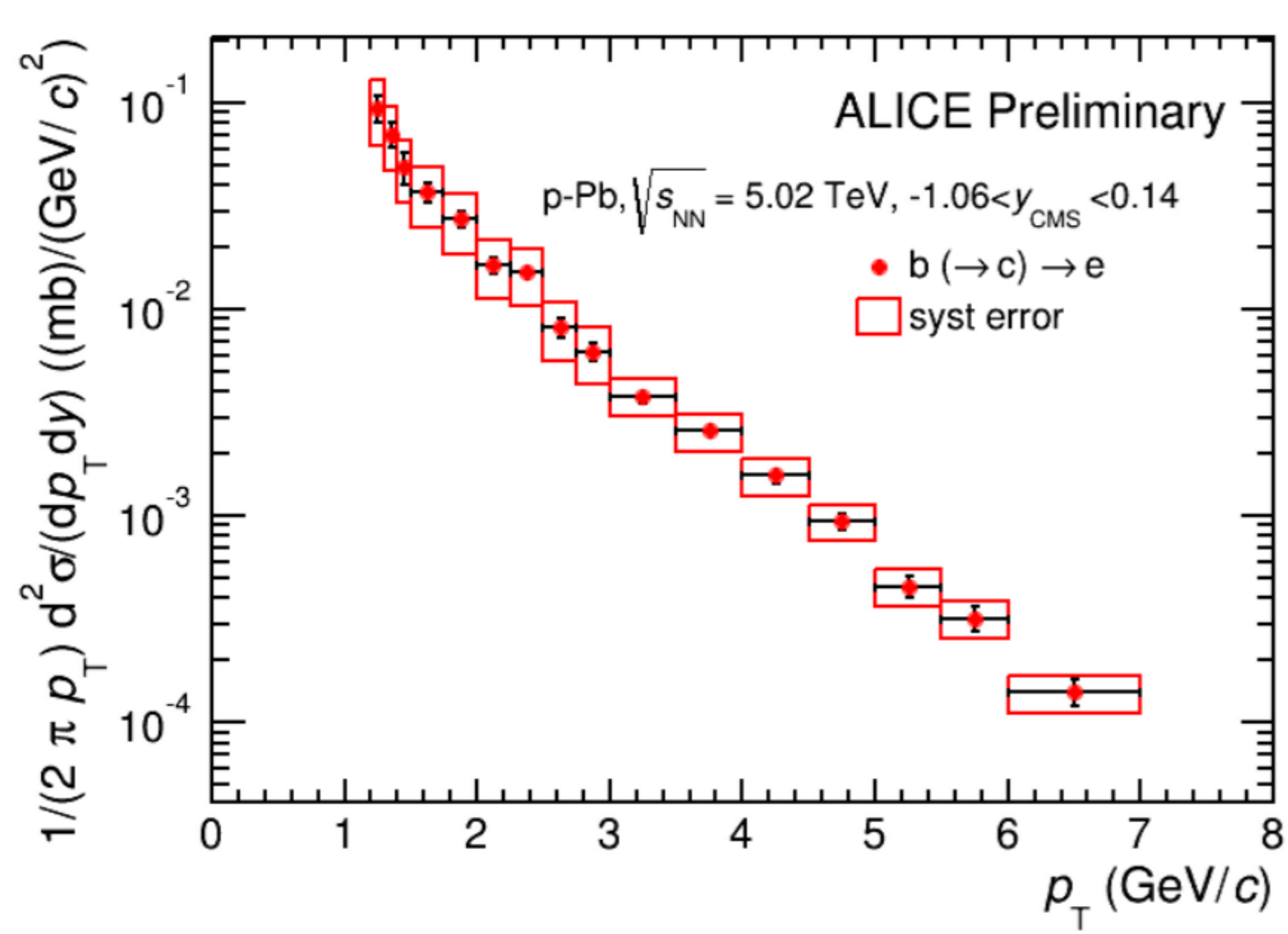


Raw Yield after Impact Parameter Cut Applied



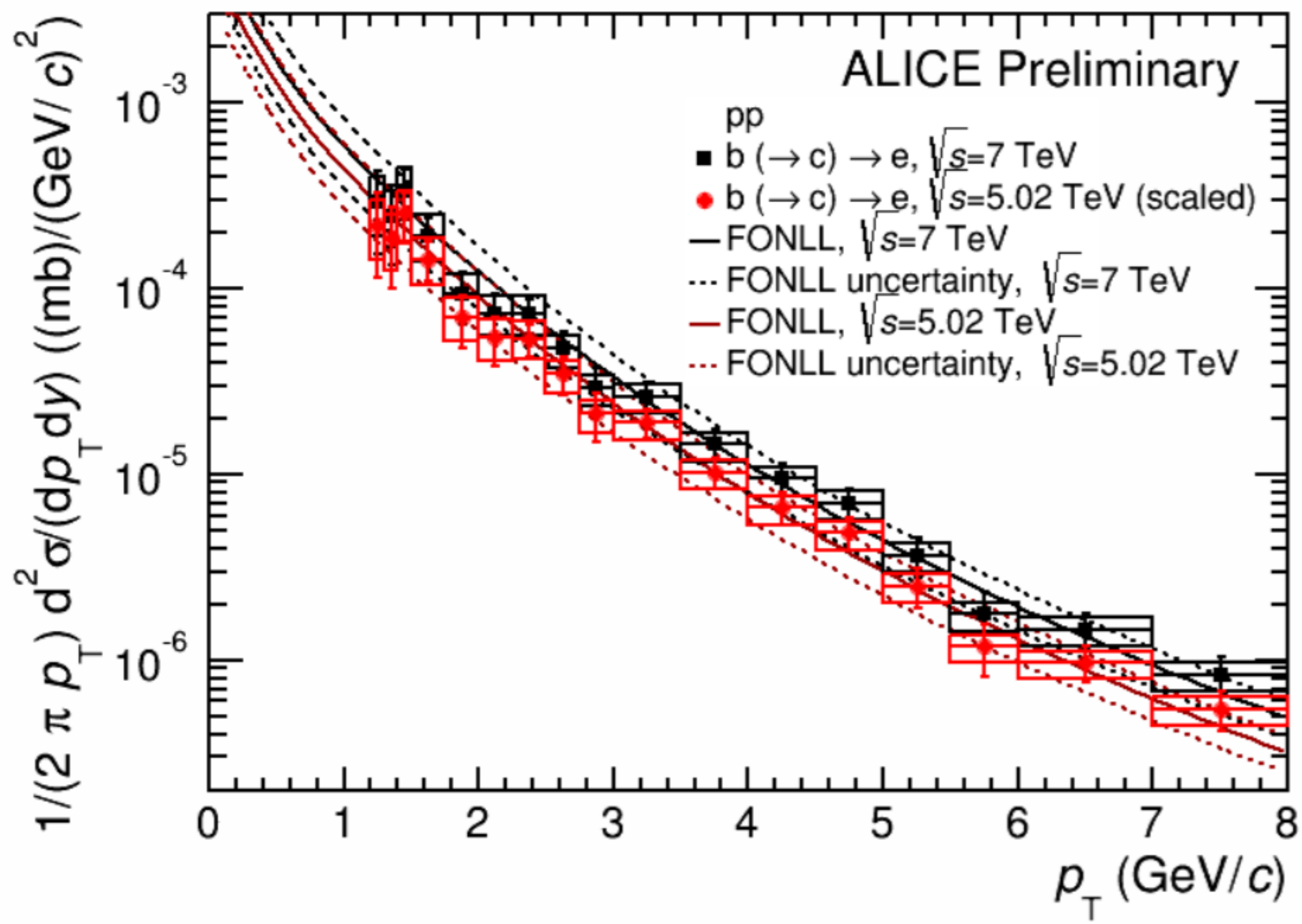
Correct for efficiency and acceptance→p_T spectrum

b→e Transverse Momentum Distributions in p-Pb Collisions



p_T range (GeV/c)	1.2-7
Error source	Systematic uncertainty [%]
Tracking	$\pm$ 7
Particle identification	$^{+11}_{-11}(^{+12}_{-11})$ for p_T <6 GeV/c (> 6)
charge & η dependence	$\pm$ 4
Minimum d_0 cut	$\pm 10(\pm 25)$ for p_T >3 GeV/c (< 3)
Light hadron decay background	$\pm$ 10
Charm hadron decay background	$\approx^{+20}_{-15}(<^{+10}_{-8})$ for p_T =1.2 GeV/c (> 2)
Total	$\approx^{+37}_{-34}(<^{+32}_{-31}, <^{+21}_{-20})$ for p_T =1.2 GeV/c (2< p_T <3, 3< p_T < 7)

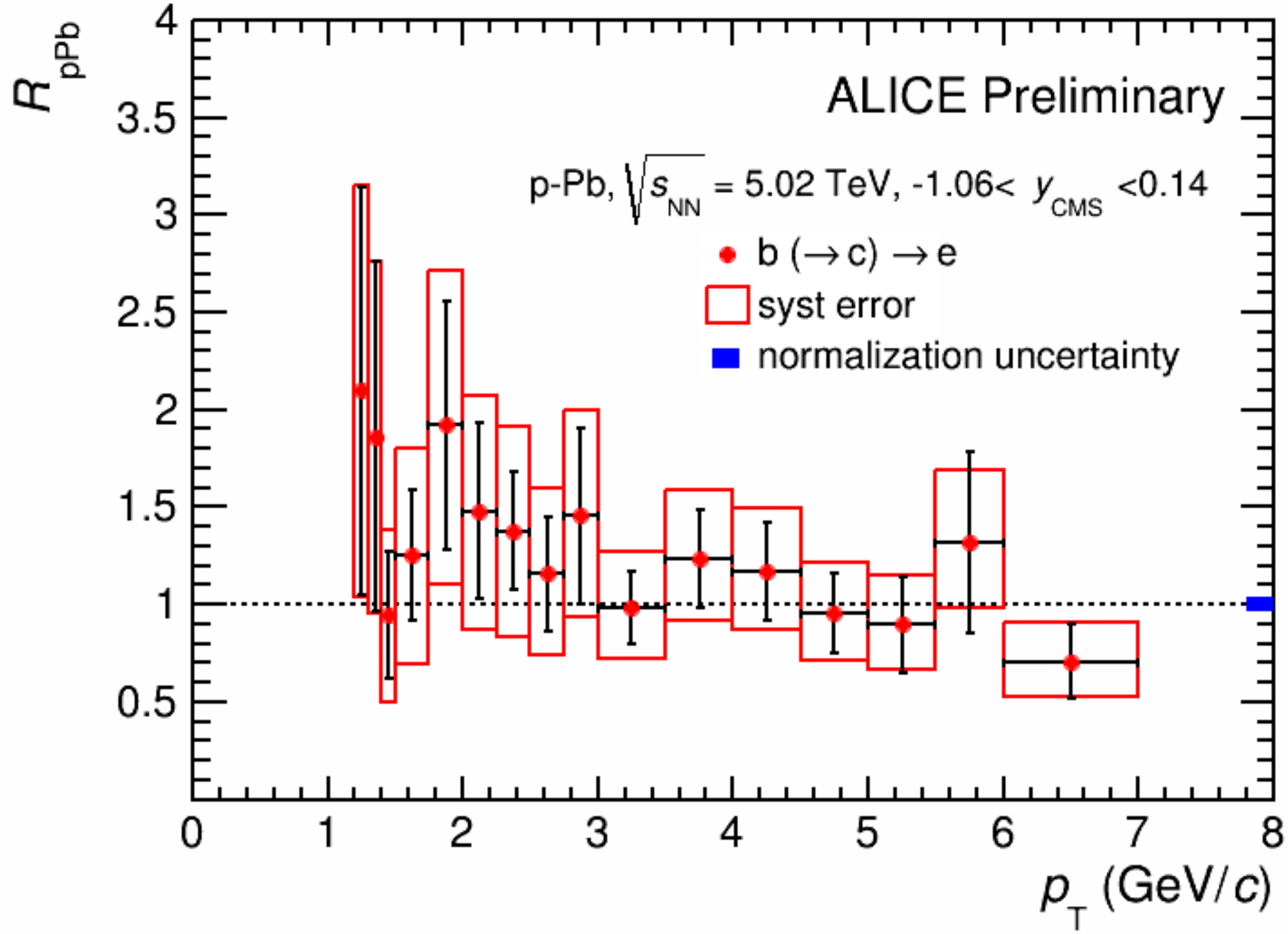
pp Reference



- **Extrapolation of the measured cross section from pp collisions at 7 TeV to 5.02 TeV based on the √s dependence of FONLL calculation**

> - Cross section of beauty decay electrons in pp collisions at √s = 7 TeV is consistent with FONLL pQCD calculations.
> - FONLL scaling uncertainty is included.

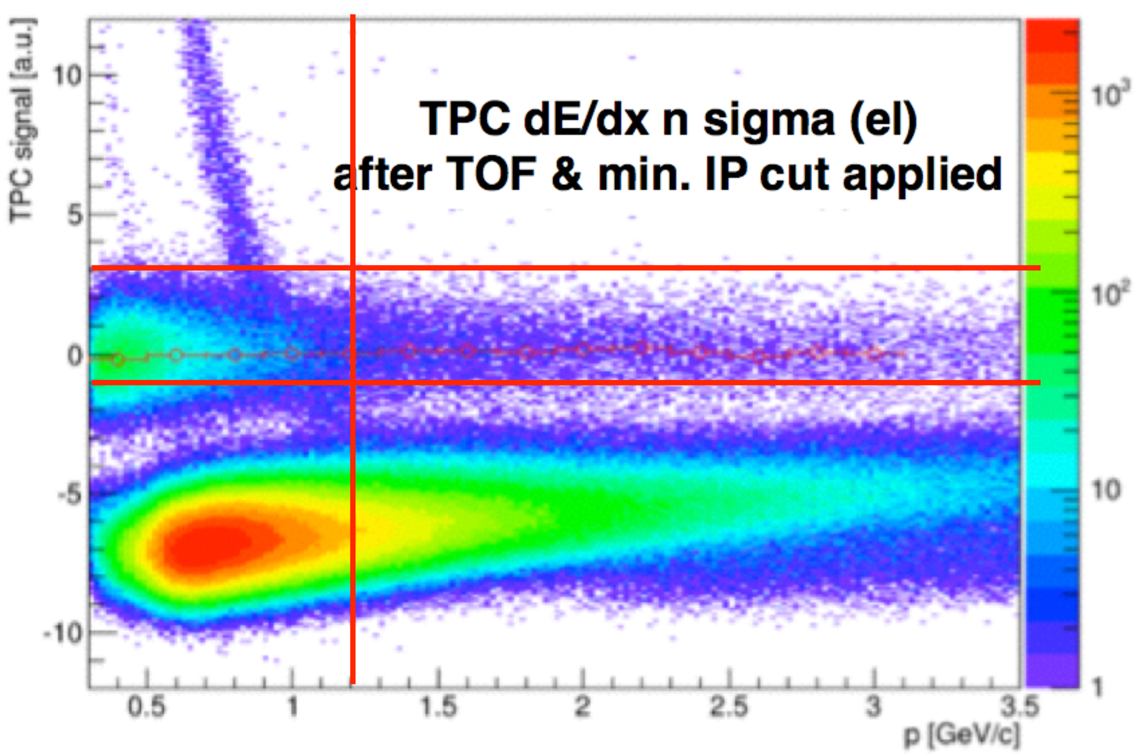
Beauty Decay Electron R_{pPb}



- R_{pPb} of electrons from beauty-hadron decays is consistent with unity in given p_T range
- Cold nuclear matter effect is not seen with current uncertainty

Summary & Outlook

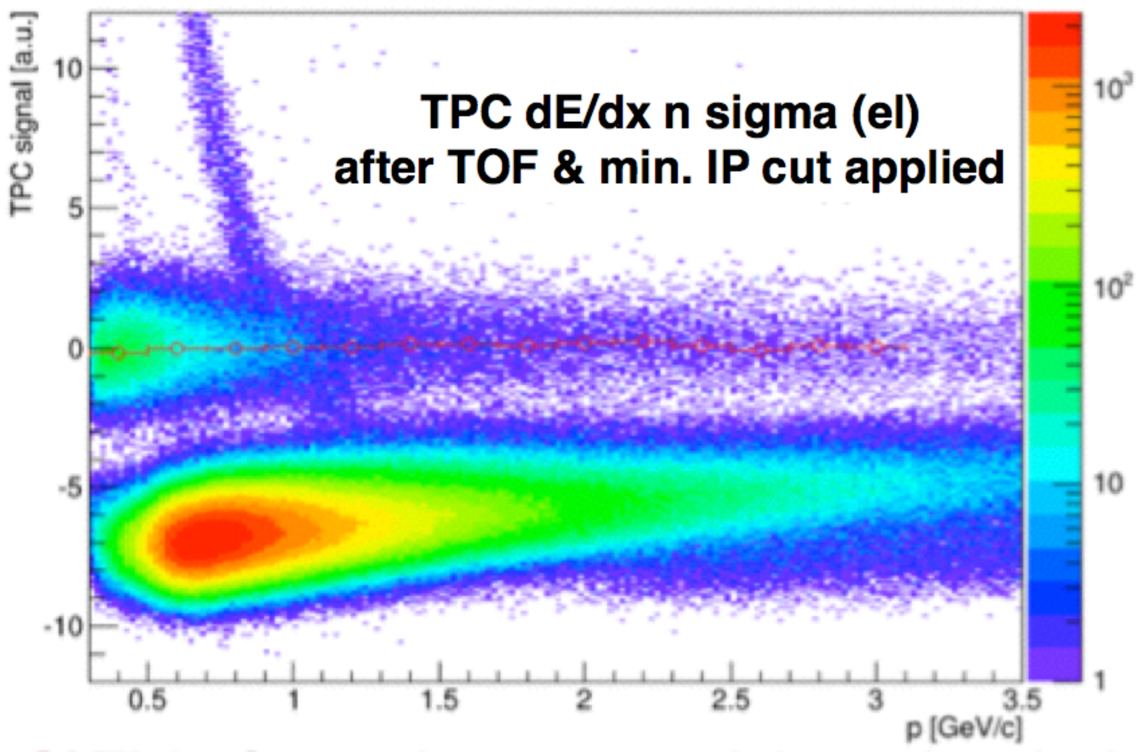
- Beauty production was studied via the measurement of electrons from beauty-hadron decays.
- R_{pPb} of electrons from beauty-hadron decays is compatible with unity within uncertainties between 1.2 GeV/c < p_T < 7 GeV/c.
- At low p_T(below 1.2 GeV/c), there is some remaining contamination, mostly proton.

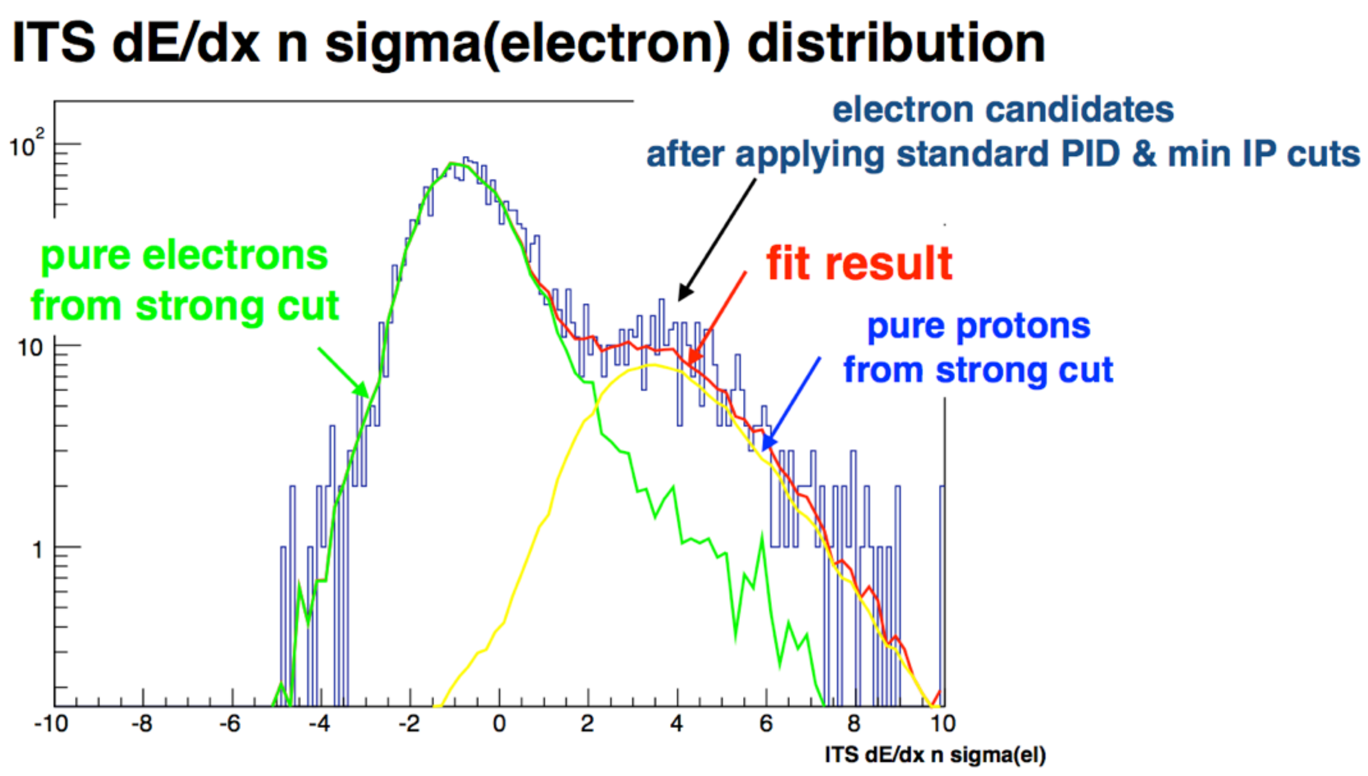


Summary & Outlook

- Beauty production was studied via the measurement of electrons from beauty-hadron decays.
- R_{pPb} of electrons from beauty-hadron decays is compatible with unity within uncertainties between 1.2 GeV/c < p_T < 7 GeV/c.
- At low p_T(below 1.2 GeV/c), there is some remaining contamination, mostly proton.

Using the ITS dE/dx, we estimate the proton contamination.

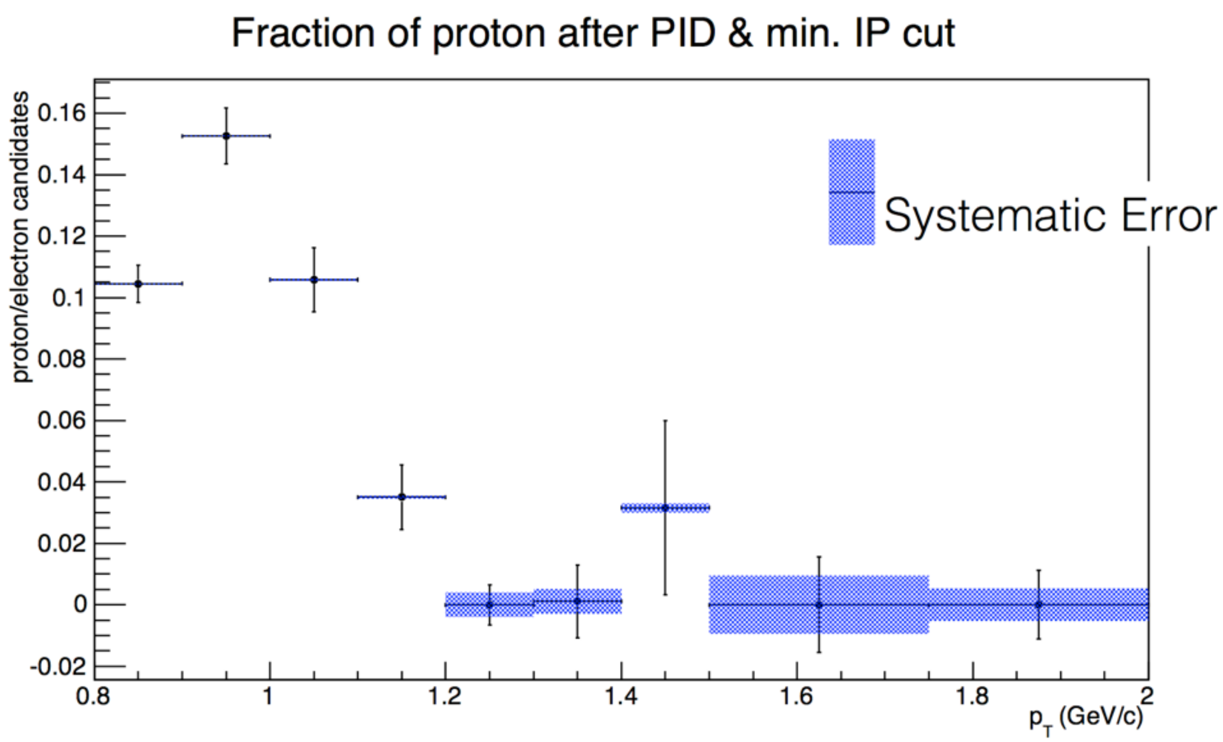


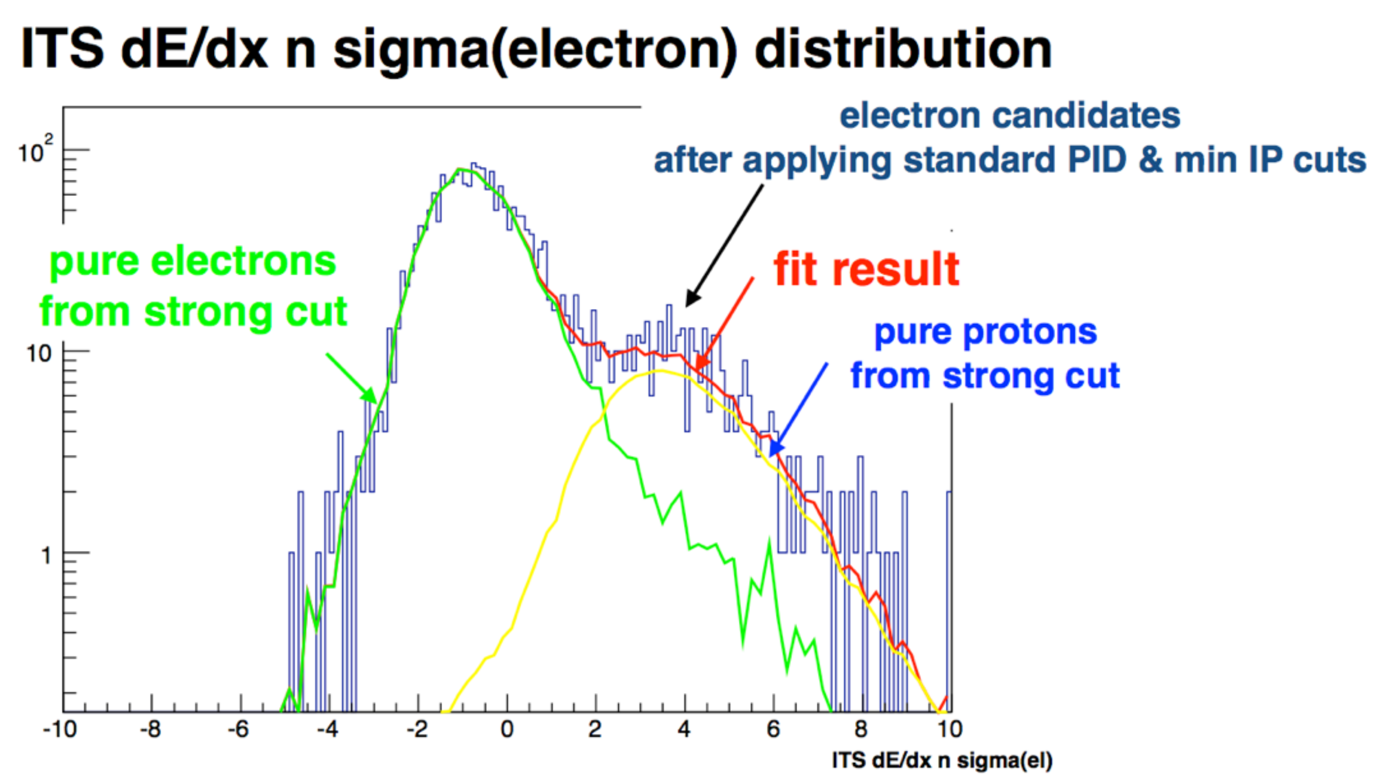


Summary & Outlook

- Beauty production was studied via the measurement of electrons from beauty-hadron decays.
- R_{pPb} of electrons from beauty-hadron decays is compatible with unity within uncertainties between 1.2 GeV/c < p_T < 7 GeV/c.
- At low p(below 1.2 GeV/c), there is some remaining contamination, mostly proton.

Subtract the estimated proton contamination.





Summary & Outlook

- Beauty production was studied via the measurement of electrons from beauty-hadron decays.
- R_{pPb} of electrons from beauty-hadron decays is compatible with unity within uncertainties between 1.2 GeV/c < p_T < 7 GeV/c.
- At low p_T(below 1.2 GeV/c), there is some remaining contamination, mostly proton.

  → Solved!

  → extend p_T reach down to 1 GeV/c

- Fine Tuning of the systematics → publish paper!!

Back Up

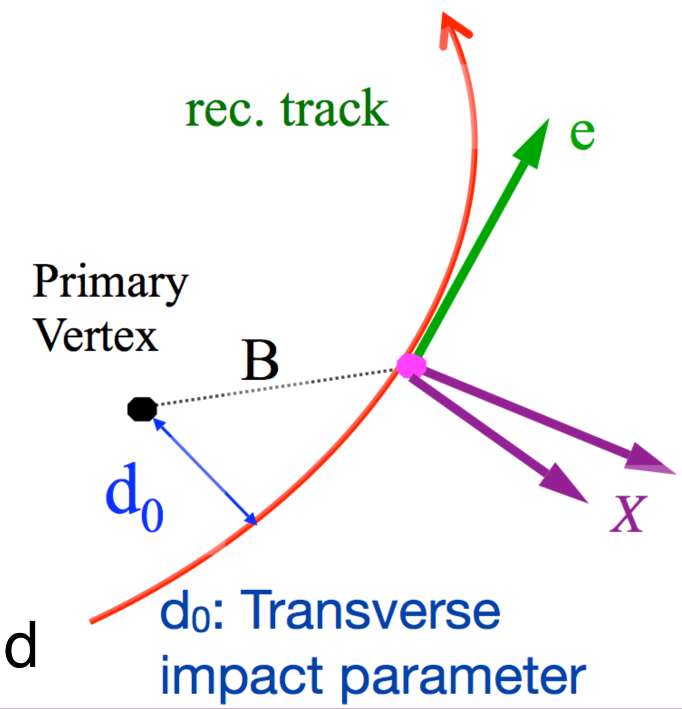
Analysis Approach for Electrons from B Hadron Decay

1. Charged particle tracks selected fulfilling **track quality** and **eID cuts** (composed by electrons from photon conversion, Dalitz, charm hadron decays, beauty hadron decays)

★**Impact Parameter : Track's transverse distance closest approach to the primary vertex**

★Beauty hadron has **cτ ≃ 500 μm** and **hard momentum spectrum,** which leads to **larger impact parameter** of decay electrons than those from background.

➡ Electron tracks from beauty hadron decays features **broader IP distribution** compared to that from background

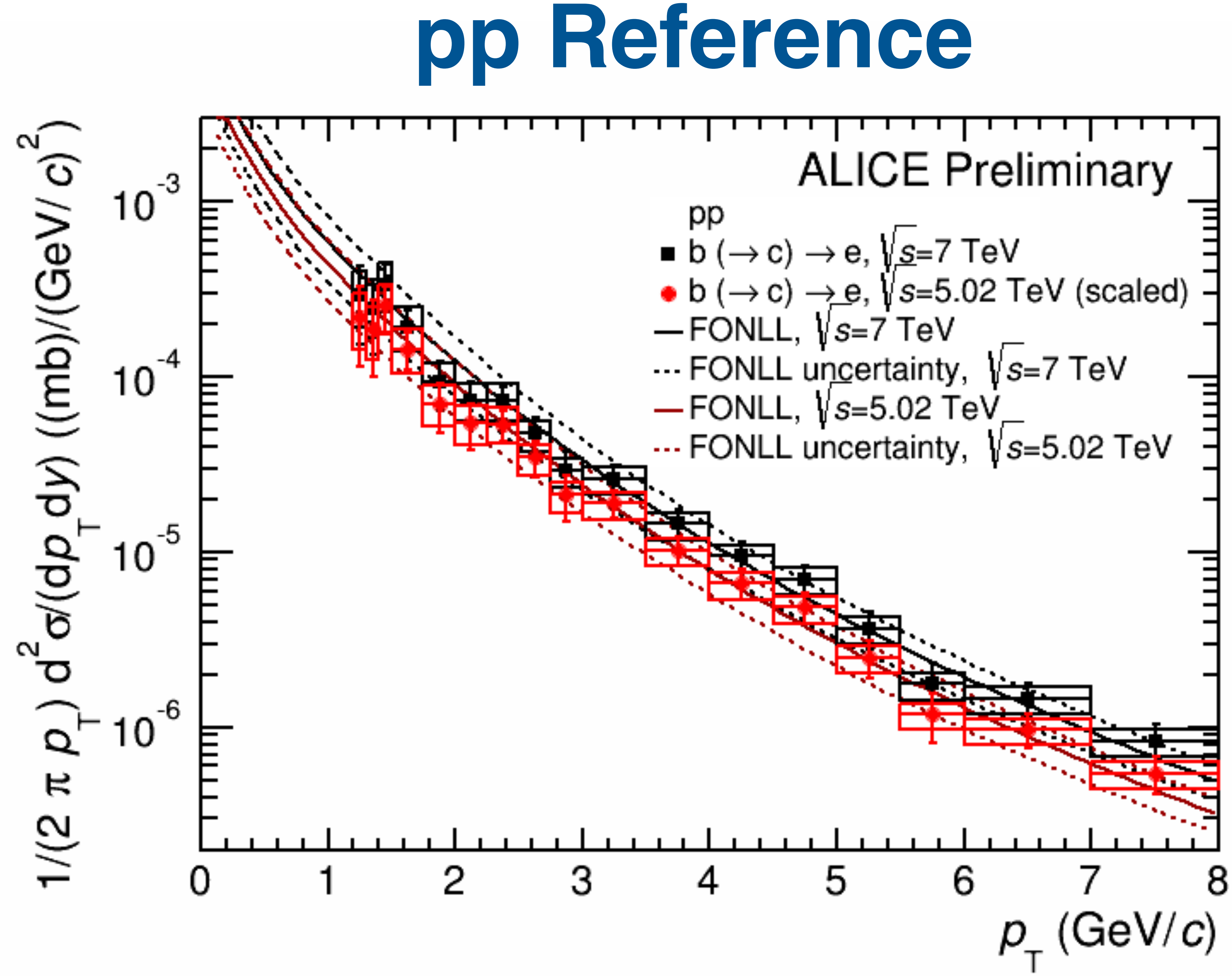


2. Minimum impact parameter cut to increase S/B ratio

3. Subtract remaining background(non-heavy flavour electrons & charm hadron decay electrons) based on ALICE measurement

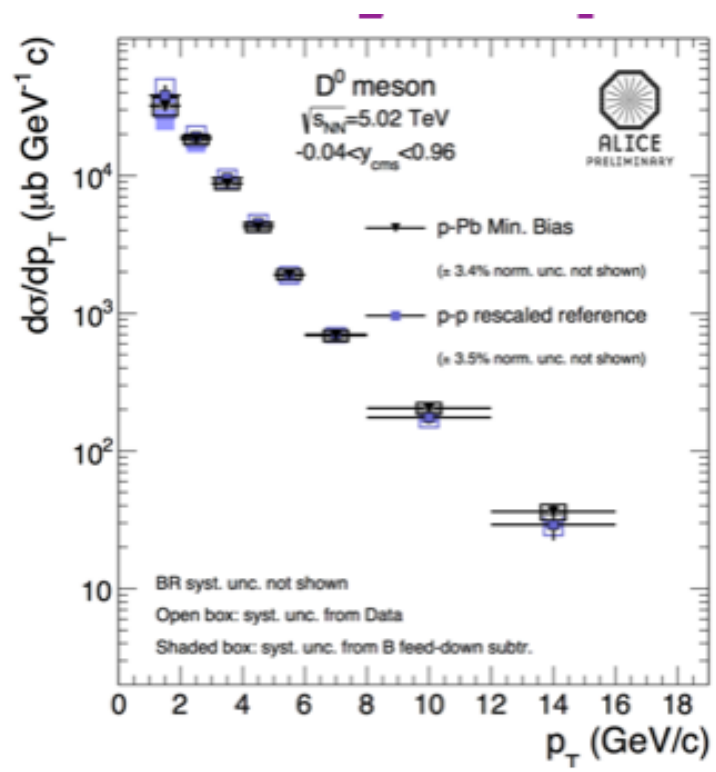
4. Correct subtracted electron spectra for acceptance and efficiency

pp Reference



- Cross section of beauty decay electrons in pp collisions at $\sqrt{s}$ = 7 TeV is consistent with FONLL pQCD calculations.
- Extrapolation of the data from pp collisions at 7 TeV to 5.02 TeV based on the $\sqrt{s}$ dependence of FONLL calculation
- FONLL scaling uncertainty is included

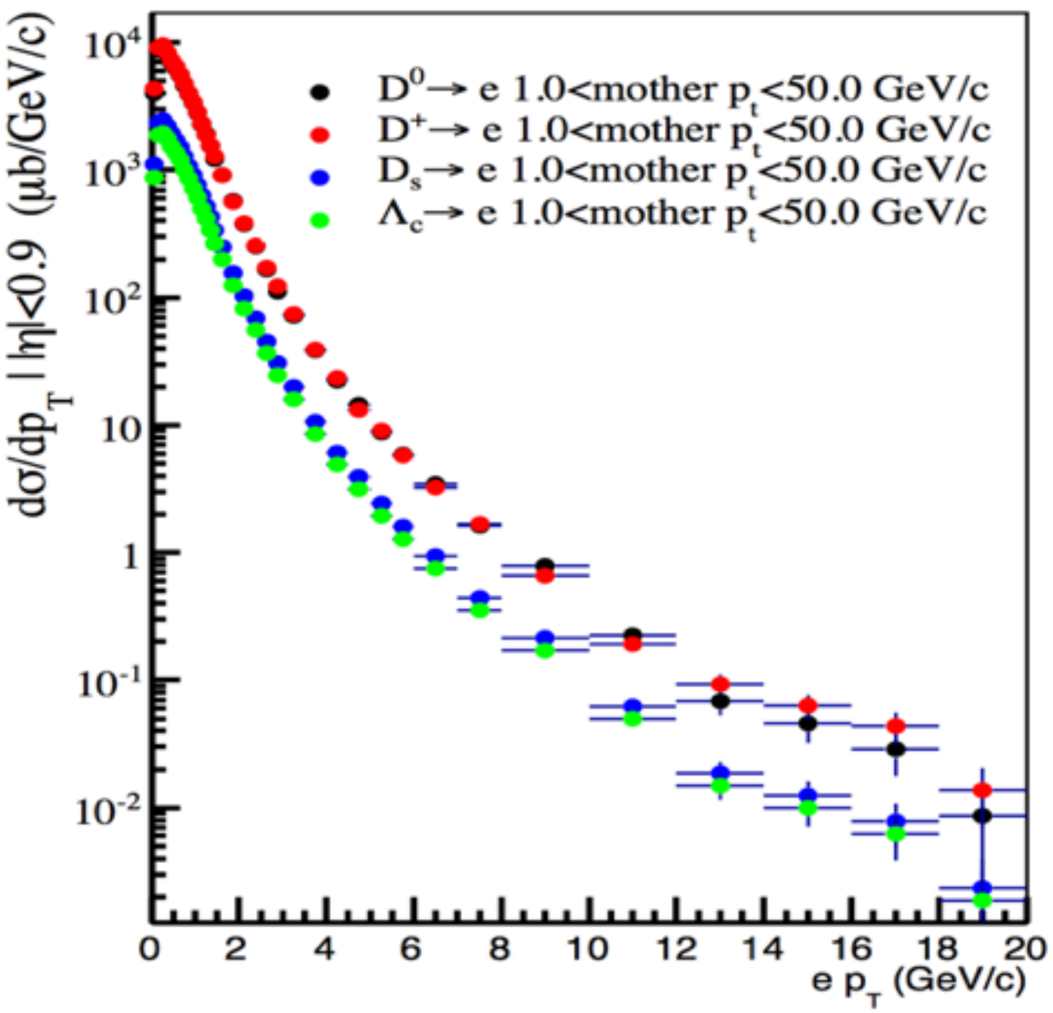
- **We have measured D meson p_T spectra for pPb so that we can estimate decayed electron p_T spectra based on certain decay kinematics model**

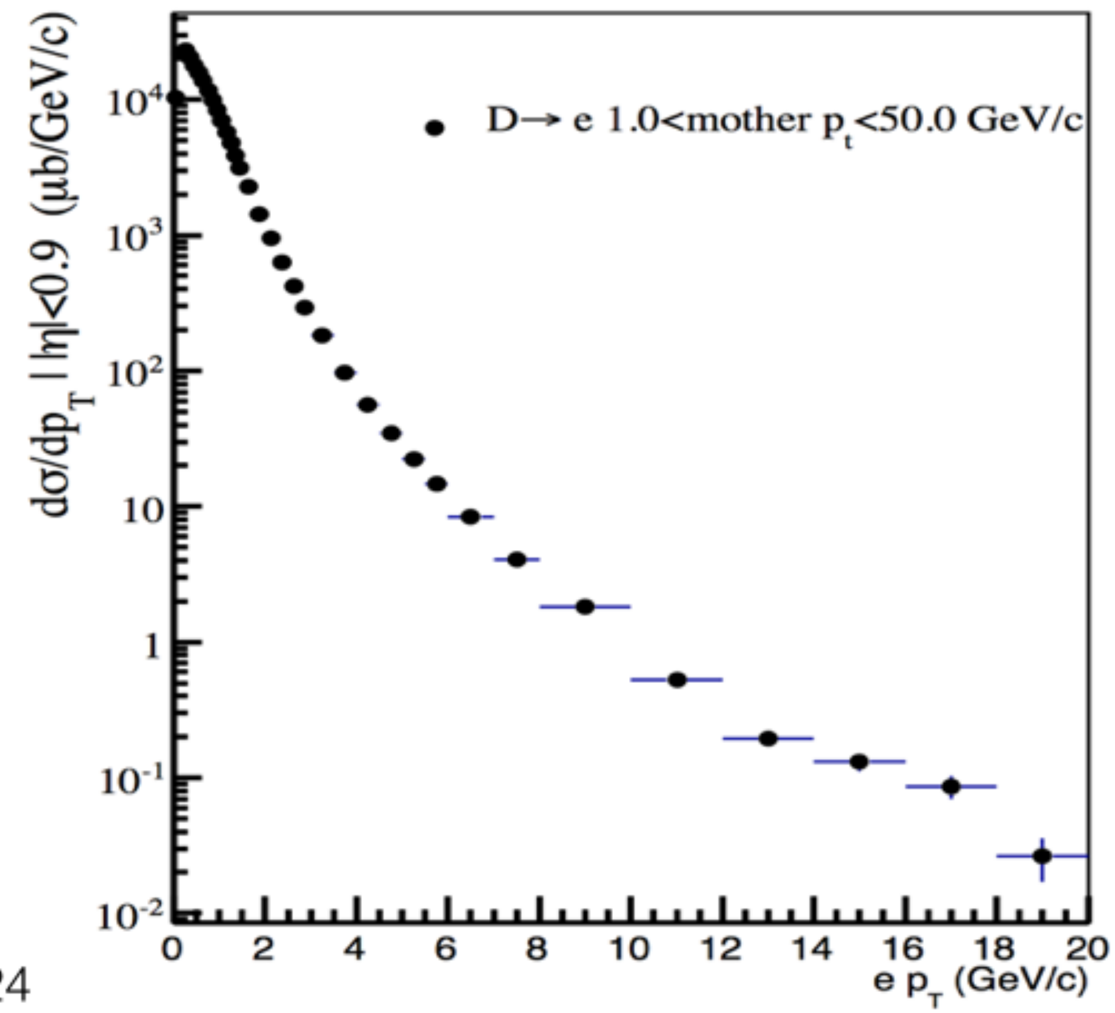


ALICE measured

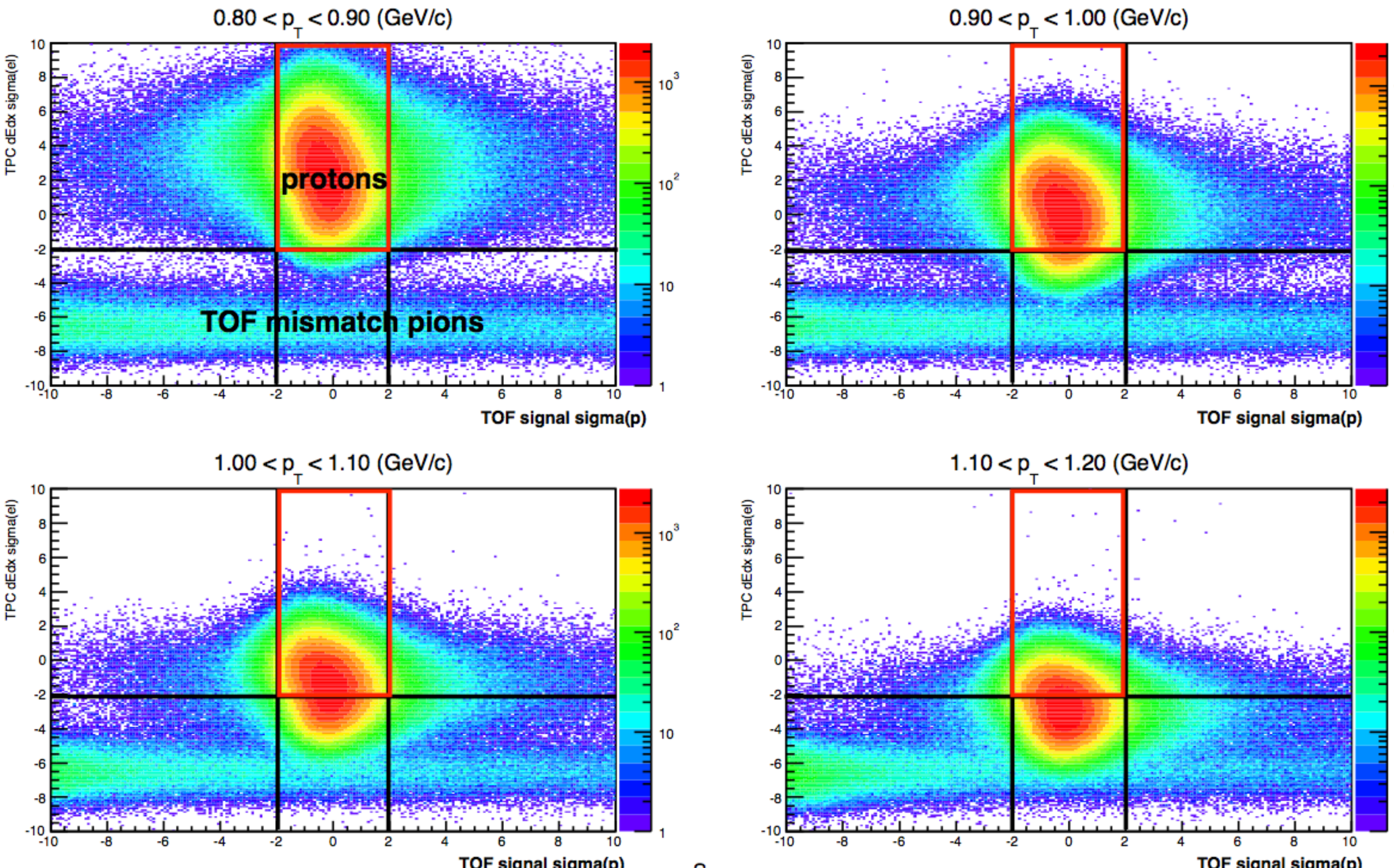
PYTHIA decay kinematics

$D^0 \rightarrow e$

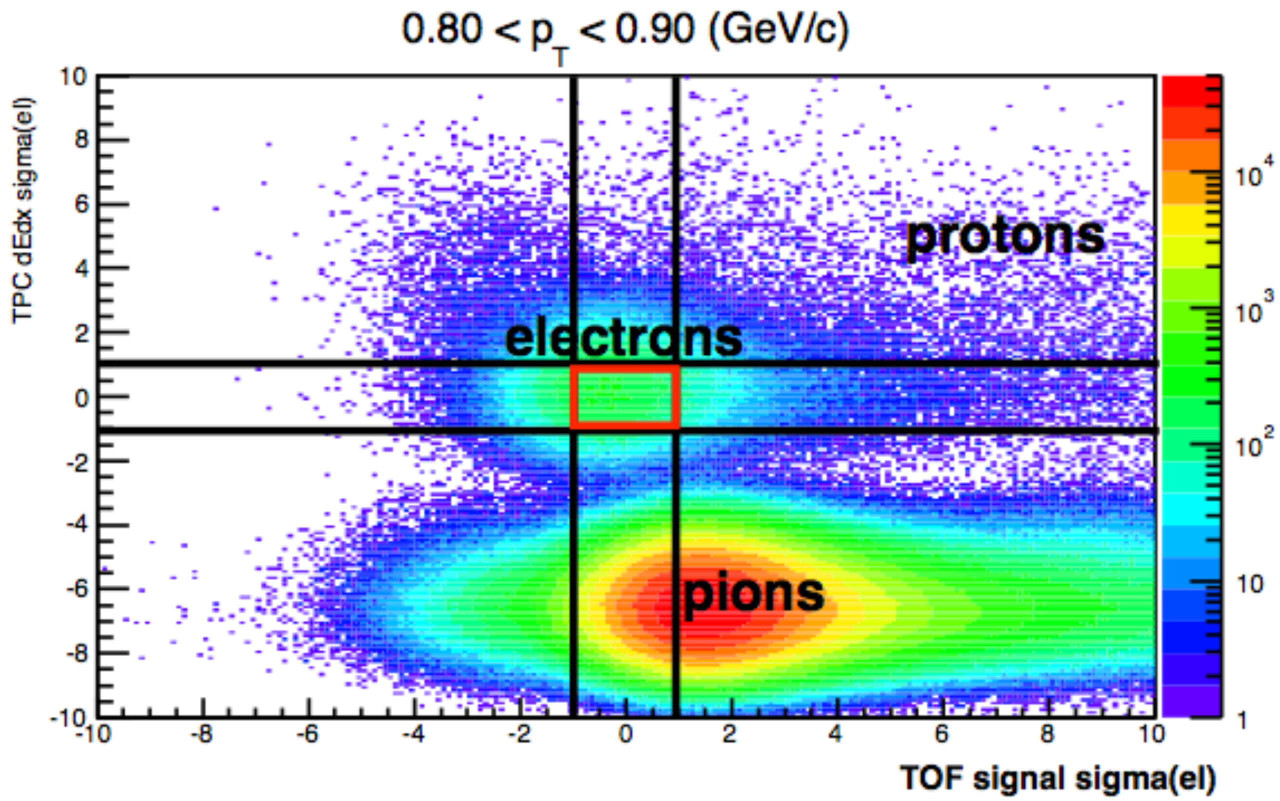


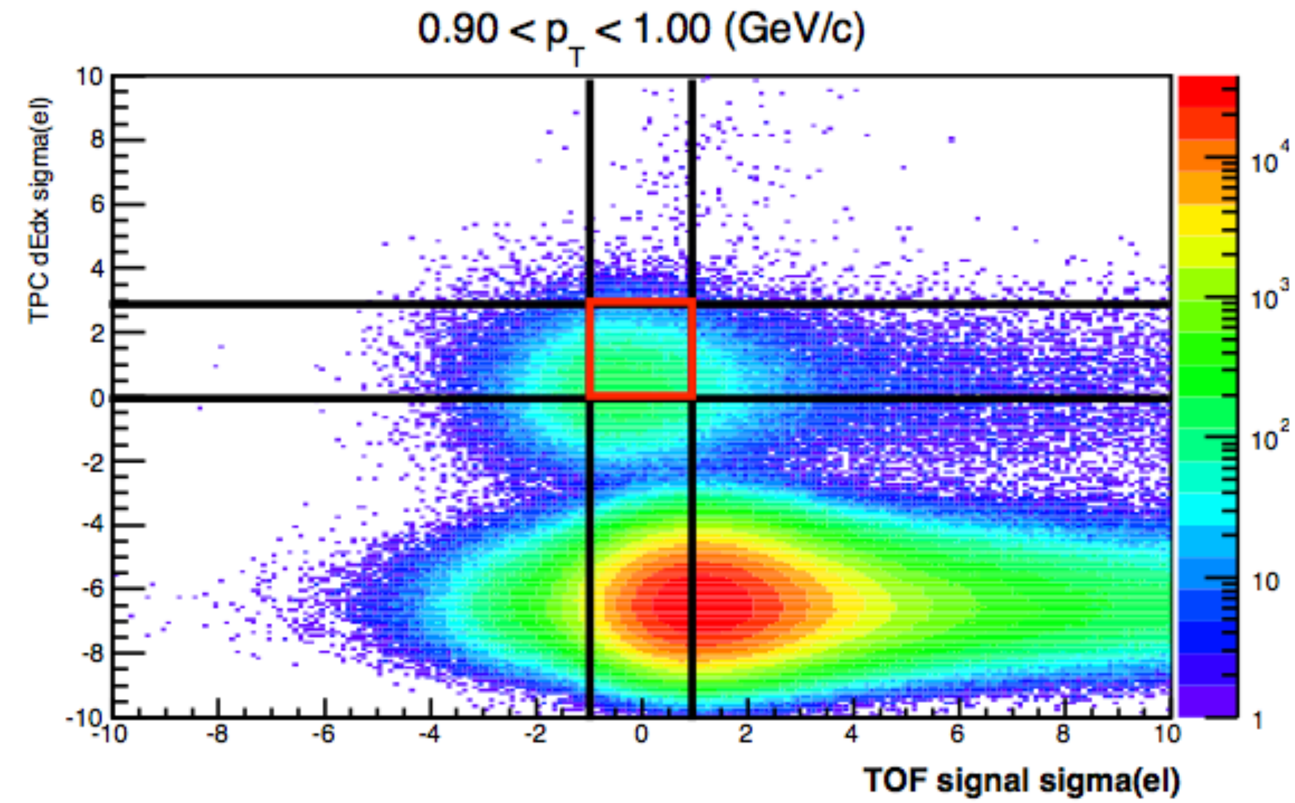


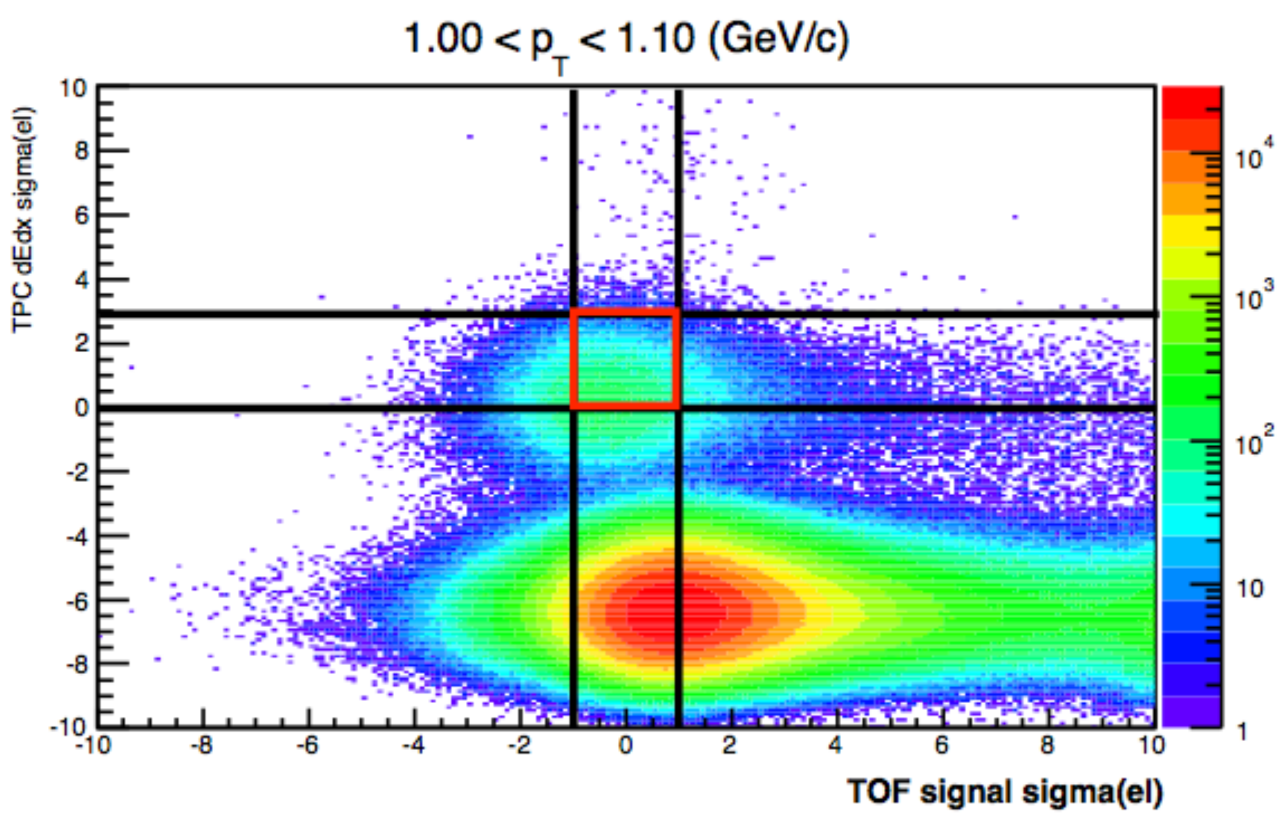
Pure proton selection :
with TPC dE/dx n sigma(el) & TOF signal sigma(p)

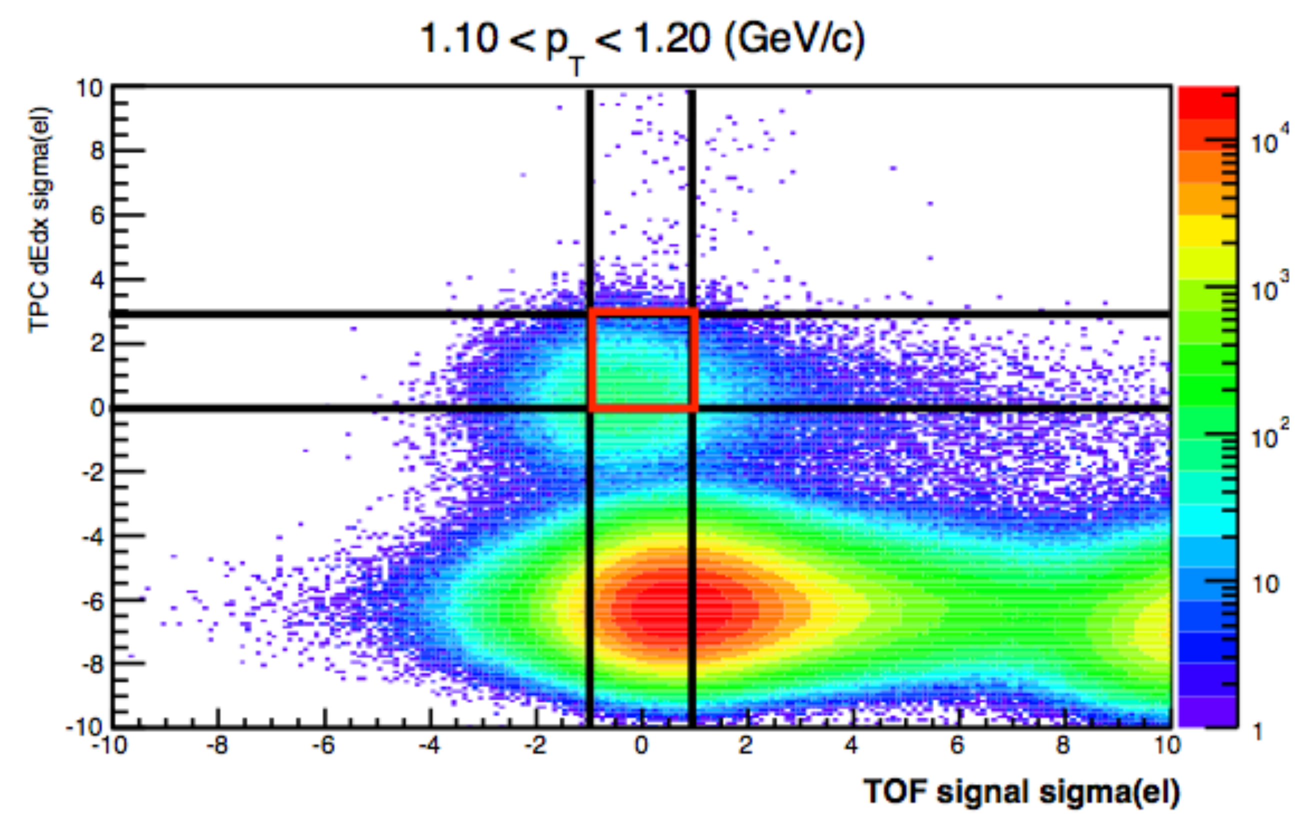


Pure electron selection :
with TPC dE/dx n sigma(el) & TOF signal sigma(el)

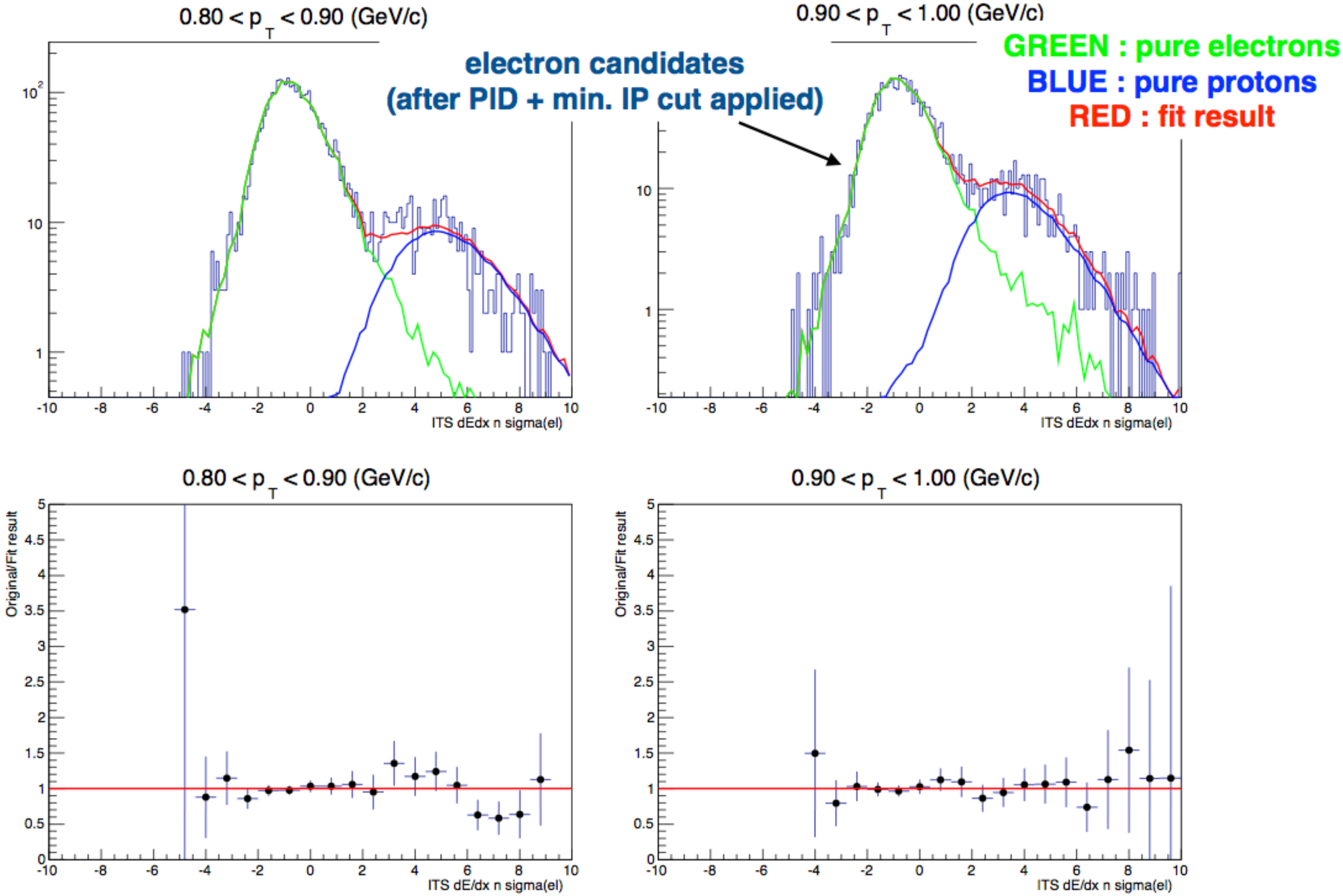






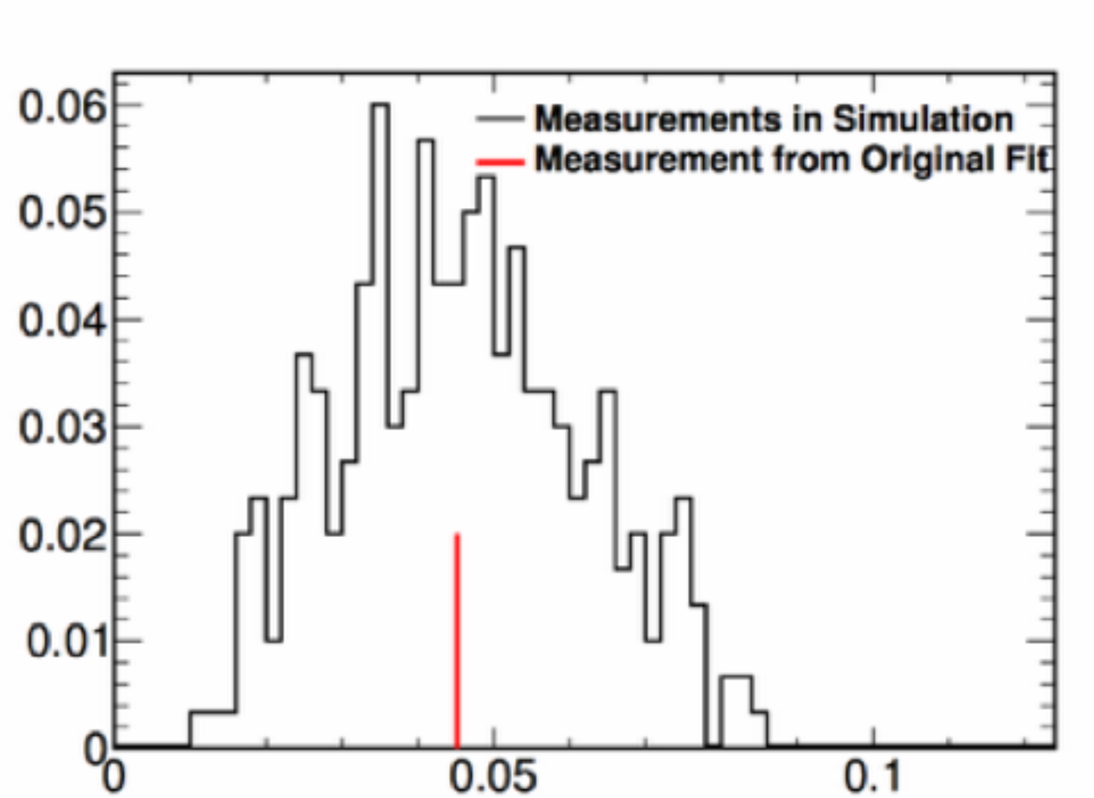


Fit Results : with Data template



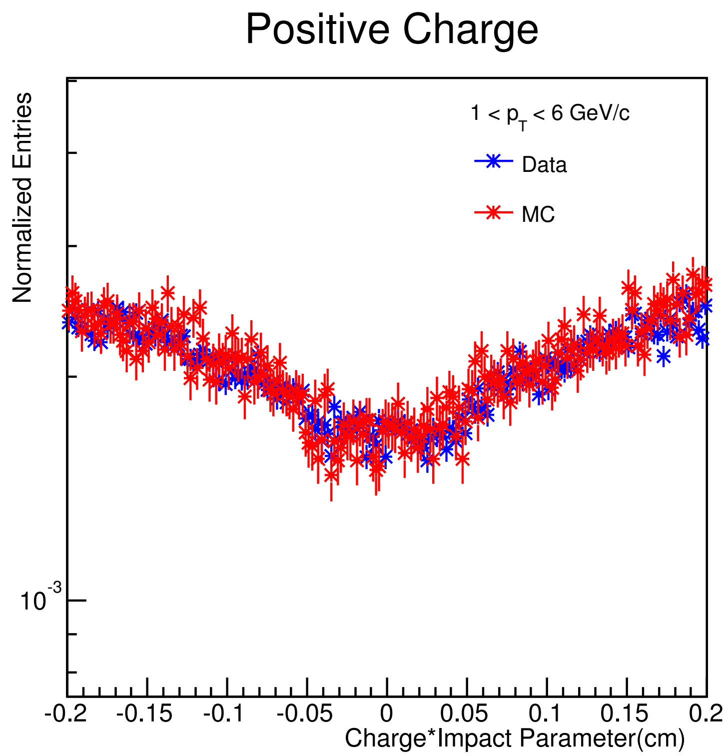
Error estimation for fraction of proton (toy model)

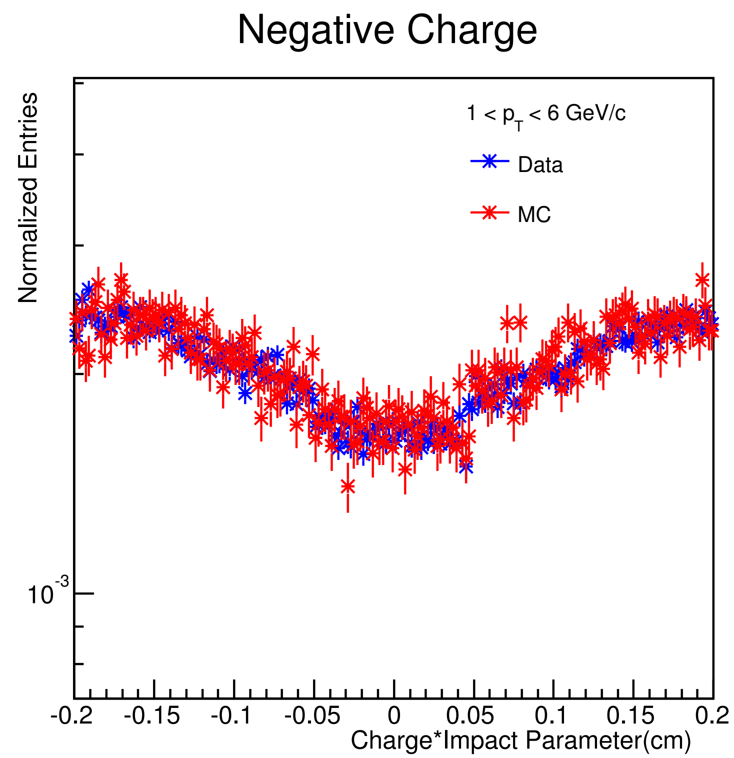
- Using the resulting fit function, create sample distribution with random generator.
- Fit new sample distribution with original fit functions → Different fit results are produced.
- Repeating this procedure many times, the result is a distribution of the measuring parameter.
- This distribution yields the complete information about the statistical errors as well as the bias due to the fit

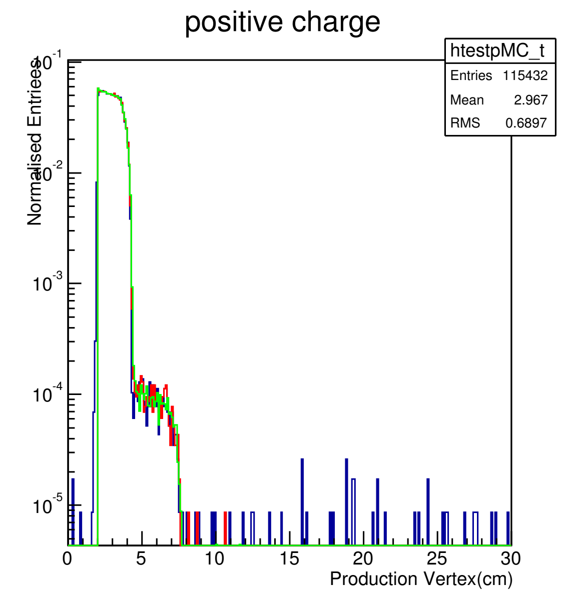


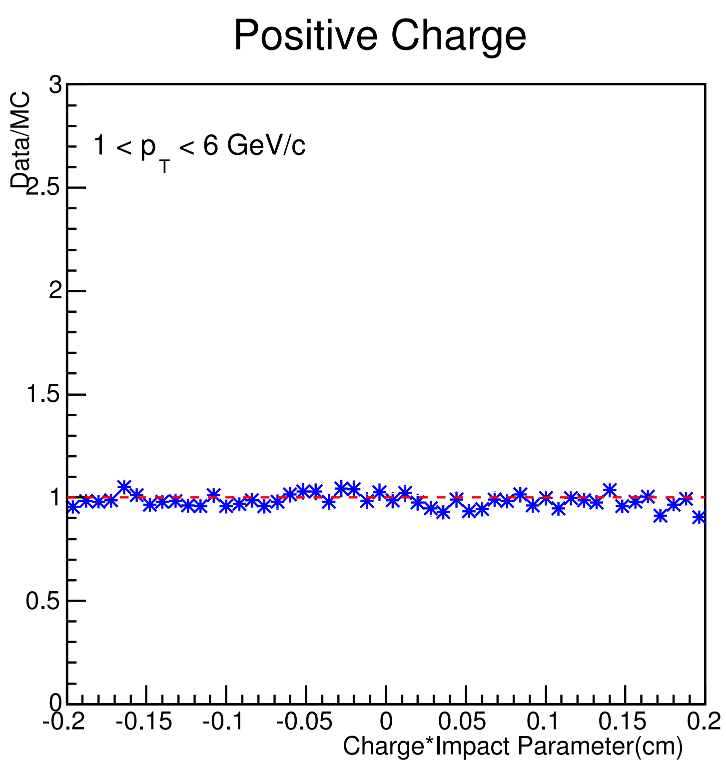
➡ statistical error : standard deviation of resulting distribution.

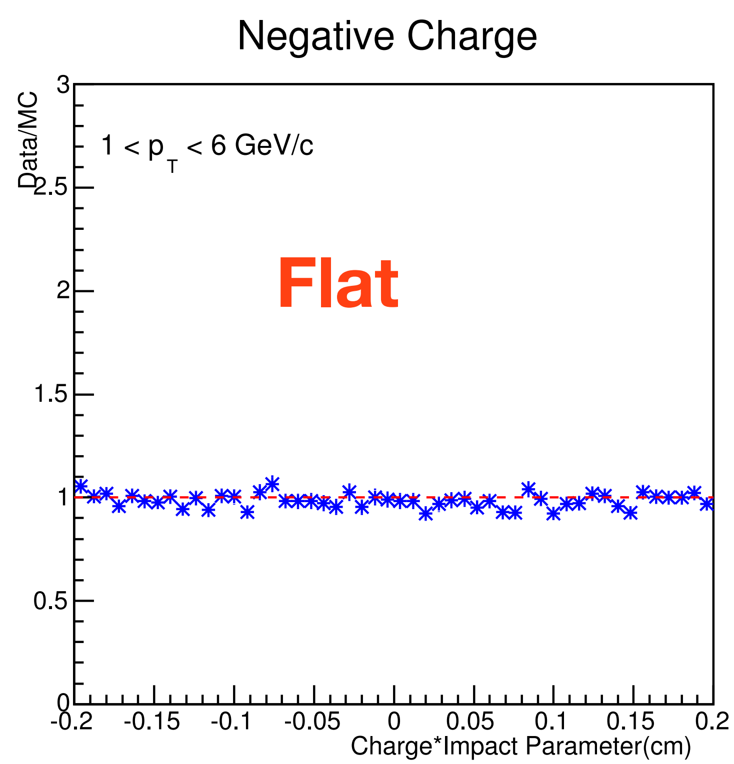
➡ systematic error : difference between originally measured data and mean of resulting distribution.



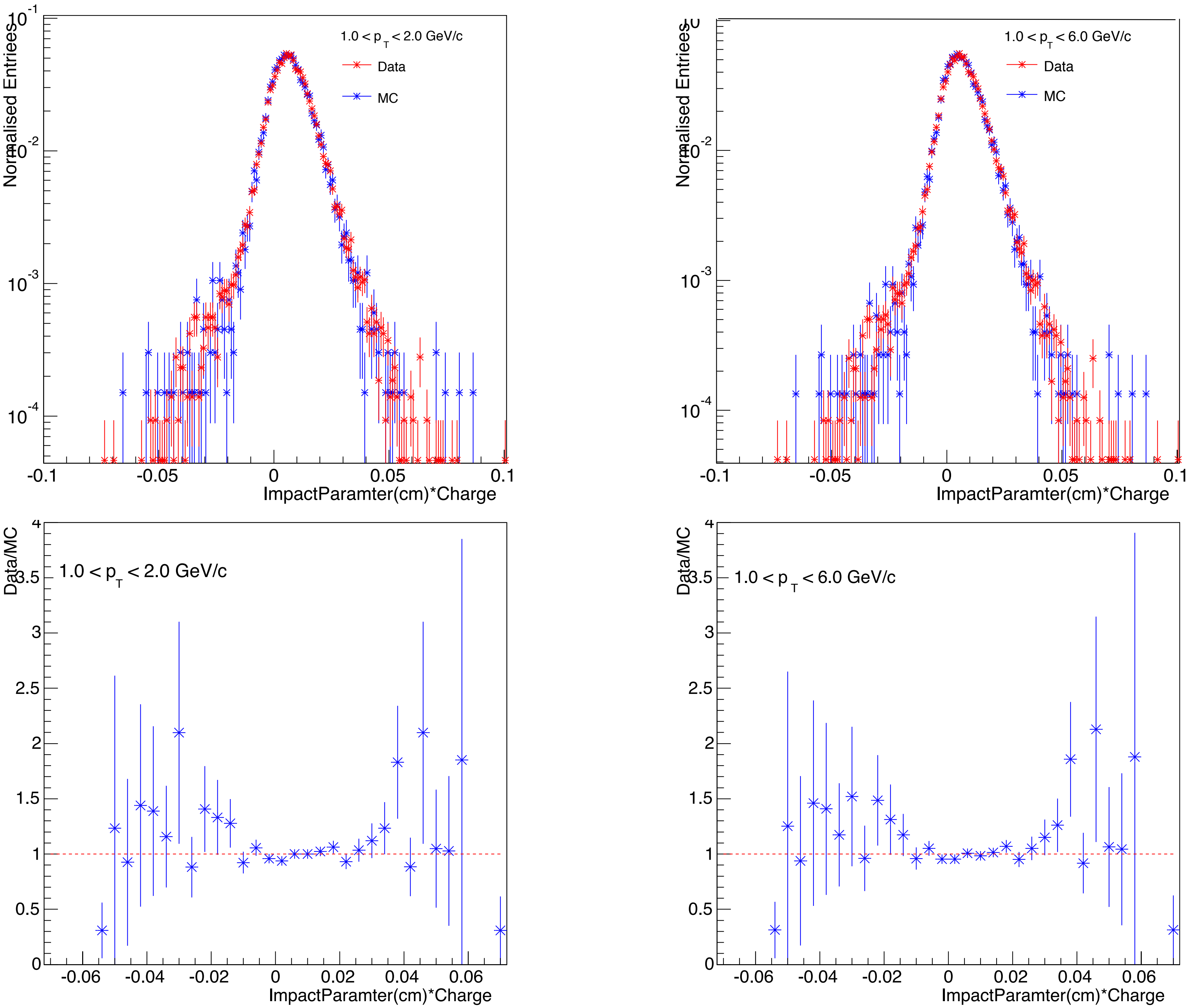




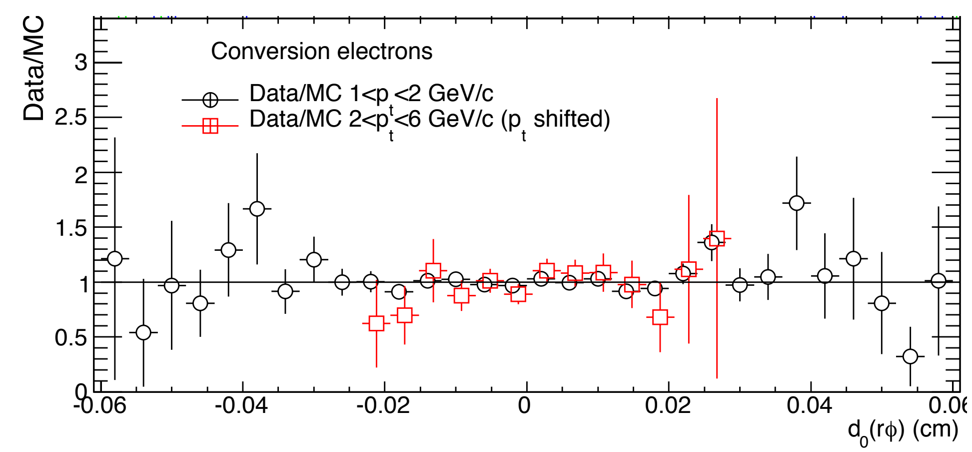




Fine for pions from K0s decays


1.0 < p_T < 2.0 GeV/c
Data
MC
Normalised Entries
ImpactParamter(cm)*Charge
1.0 < p_T < 6.0 GeV/c
Data/MC

pp at 7 TeV


Conversion electrons
Data/MC 1<p_t<2 GeV/c
Data/MC 2<p_t<6 GeV/c (p_t shifted)
Data/MC
d_0(rϕ) (cm)