GDRE WORKSHOP
Heavy Ions at Relativistic Energies

Open charm production in p+p and A+A collisions at 200 GeV with STAR at RHIC

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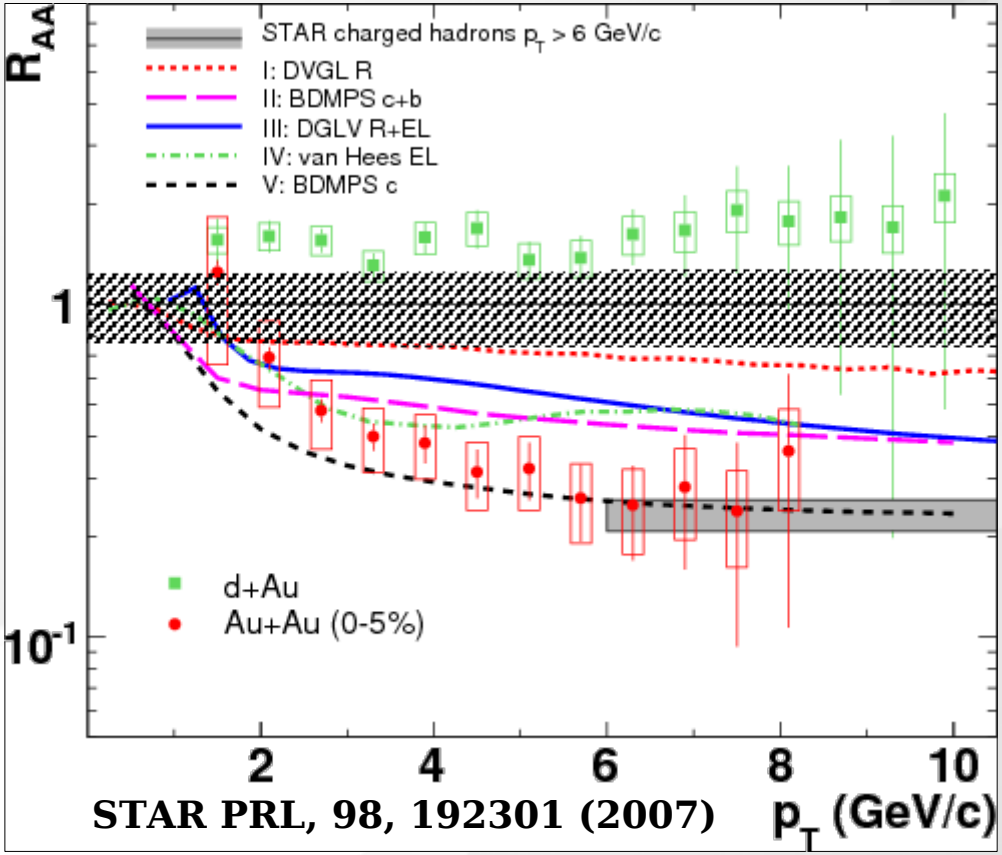
Motivation

Suppression in non photonic electron yields for B and D mesons decays in central AuAu collision

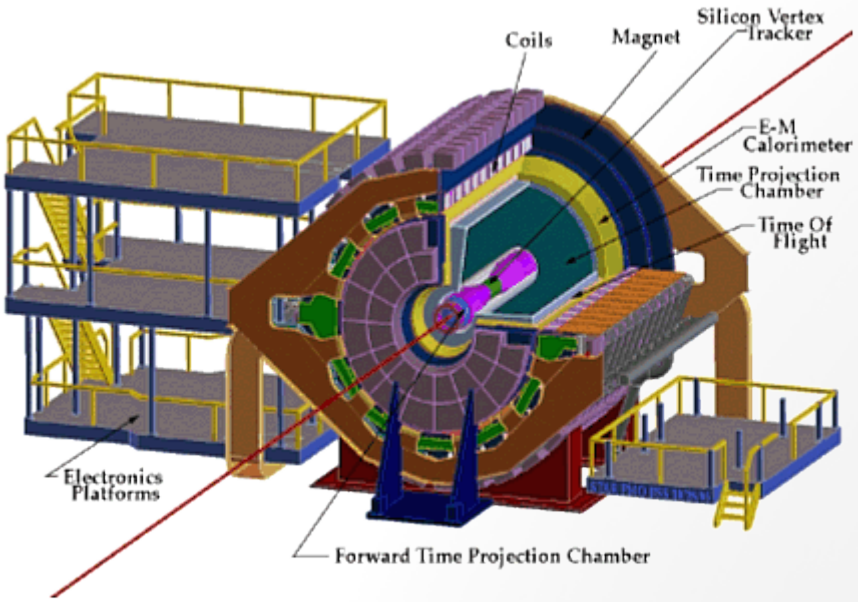
$$R_{AA} = \frac{Yield^{AA} / \langle N_{binary}^{AA} \rangle}{Yield^{pp}}$$

- **Similar** as observed for the **light quark hadrons**
- **Not expected** (dead cone-effect)
  D.Kharzeev et al. Phys Letter B. 519:1999
- **Theoretical Models** explaining the charm and bottom quark energy loss **are still inconclusive**



"A direct measurement of D mesons at high-p_T is required to understand energy loss of heavy quarks in detail." **STAR PRL, 98, 192301 (2007)**

The STAR Detector



Solenoidal Tracker at RHIC

Magnet

B = 0.5 T

TPC

Main tracking and PID device

$|\eta| < 1.5$

$\Delta p/p = 2-4\%$

$$\frac{\sigma_{dE/dx}}{dE/dx} = 8$$

Barrel EMC

Electron energy measurement

Lead scintillator (21 X_0)

$|\eta| < 1.5$

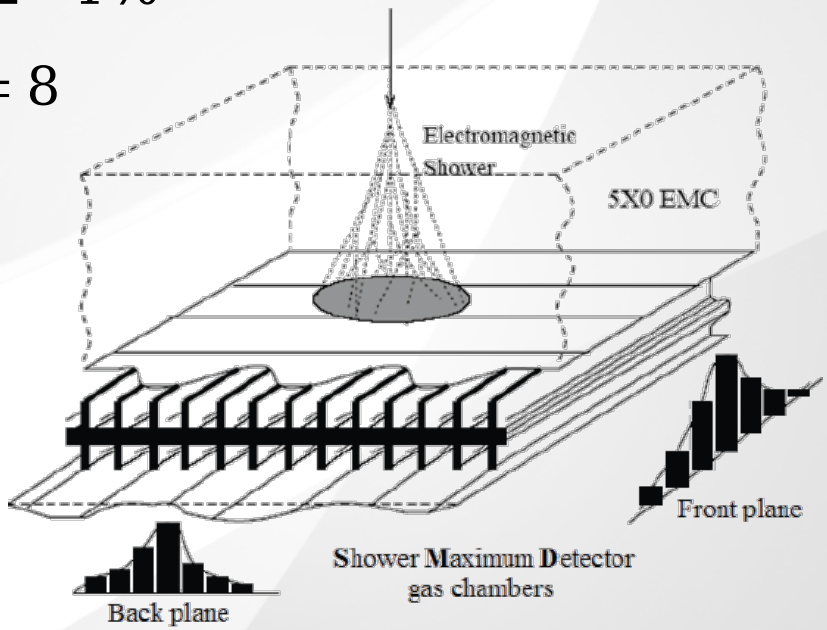
Shower Maximum Detector

Wire proportional detector with strip readout

Situated at 5 X_0

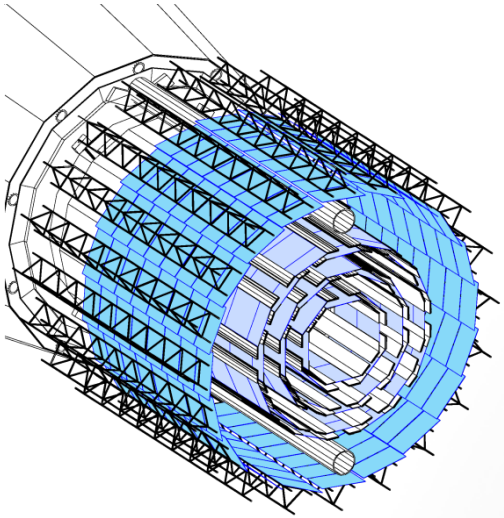
Resolution: $(\Delta\phi;\Delta\eta)=(0.007;0.007)$

80% of the EM shower energy is being deposited in 2-3 strips



The STAR Detector

Silicon Tracking System



Silicon Strip Detector

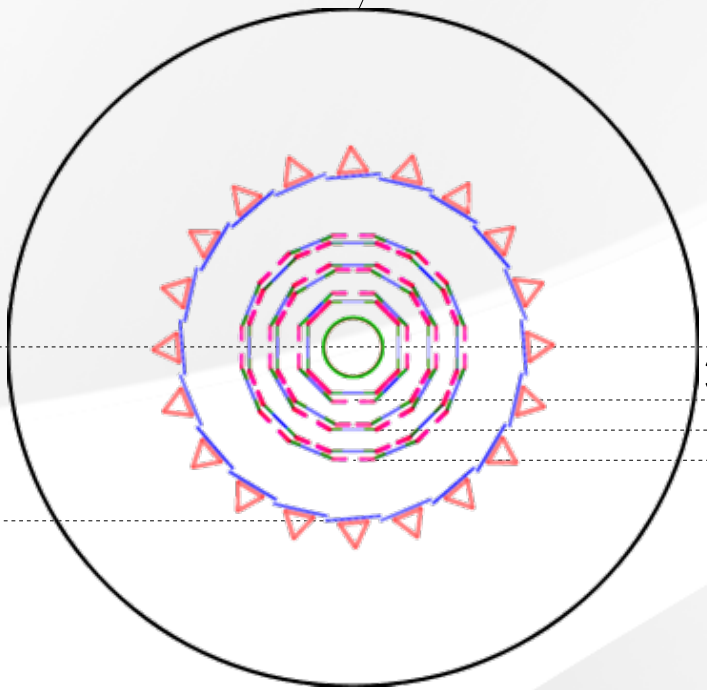
1% X_0

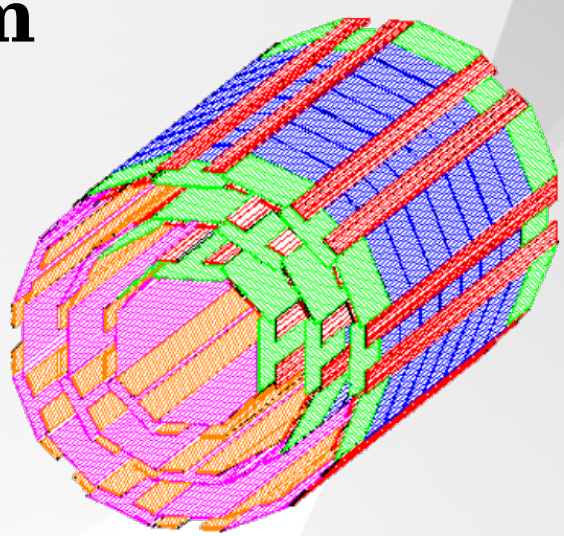
$\sigma_{r\phi}=30\,\mu m$

$\sigma_Z=800\,\mu m$

TPC

Inner Radius: 50 cm





Silicon Vertex Tracker

3 layers

1.5% X_0 each

$\sigma_{r\phi}=\sigma_Z=40\,\mu m$

23 cm

6.85 cm

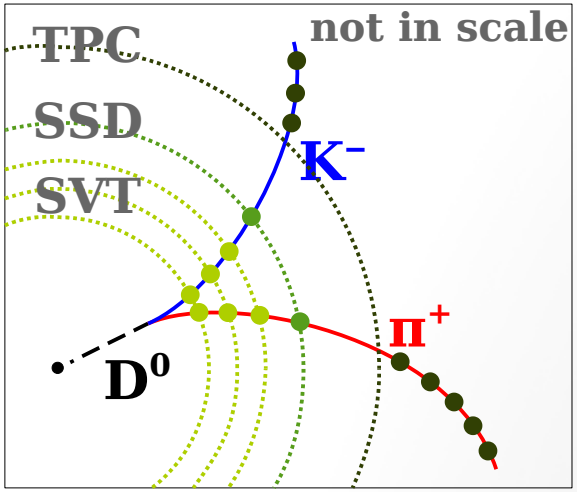
10.8 cm

14.7 cm

Reconstruction of the D^0 decay

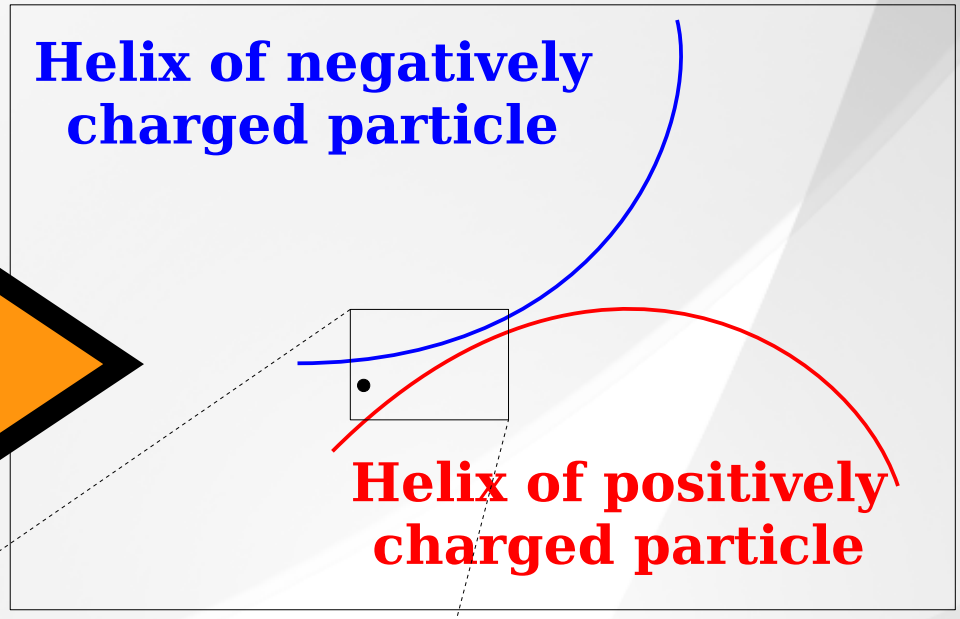
$D^0 \rightarrow K^-\pi^+$ BR: 3.89%

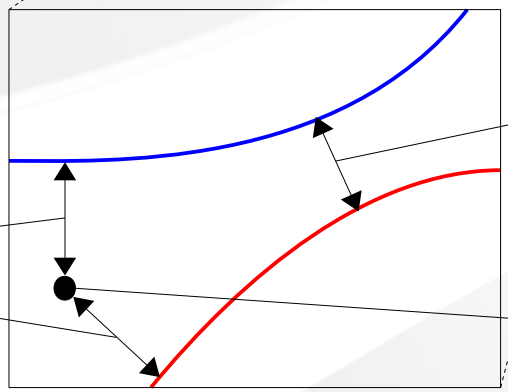
$c\tau = 123\ \mu m$



D^0 decay

Reconstructed Tracks





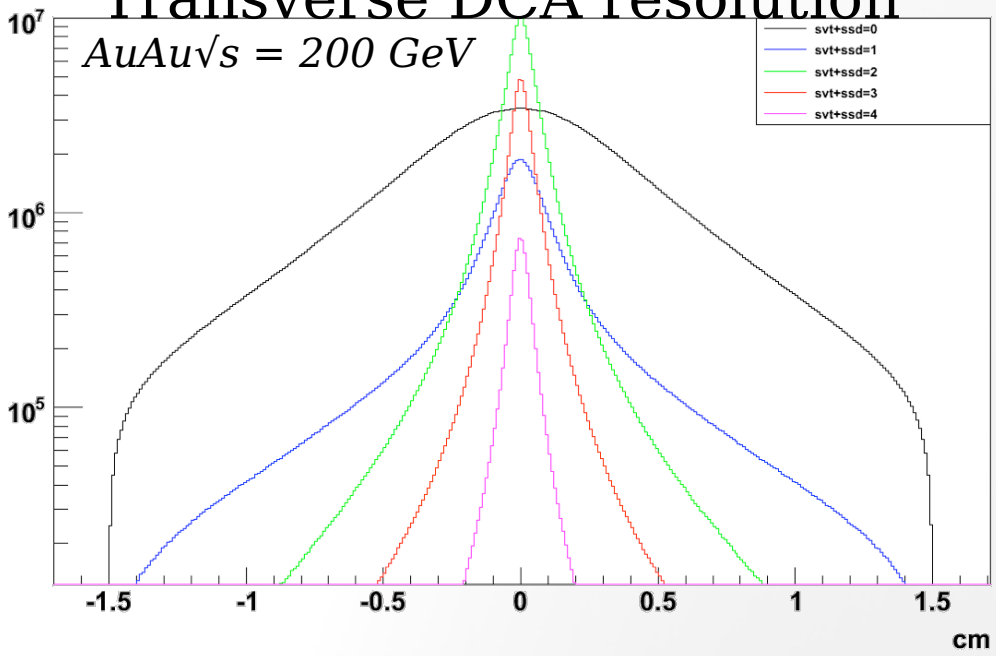
Distance of Closest Approach between tracks

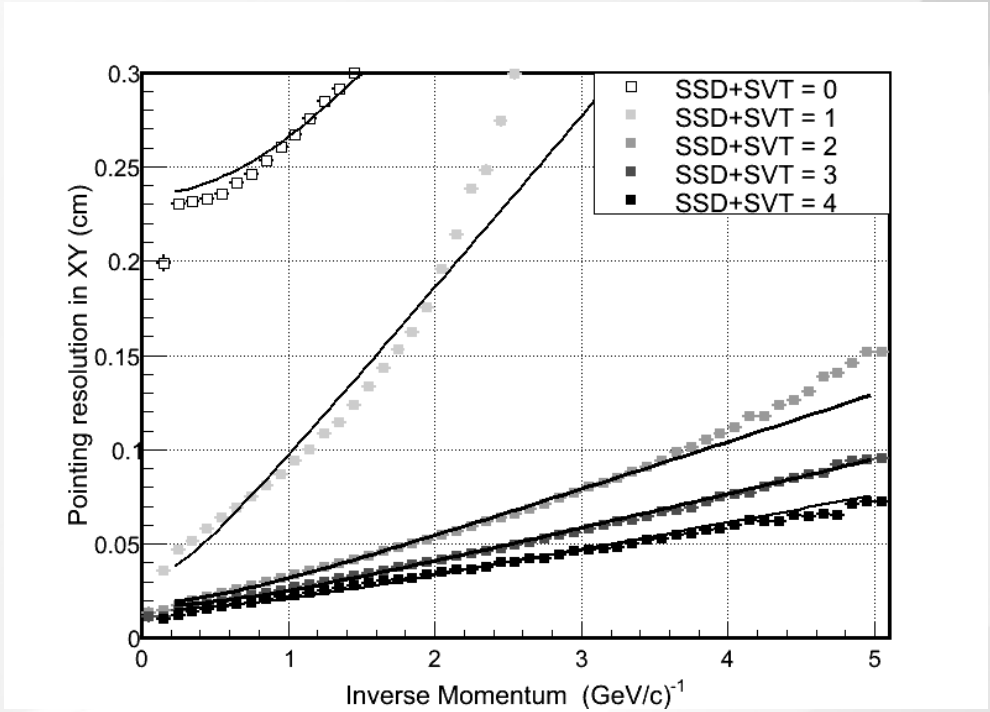
Distance of Closest Approach (DCA) to PV

Primary Vertex

Reconstruction of the D^0 decay

DCA resolution



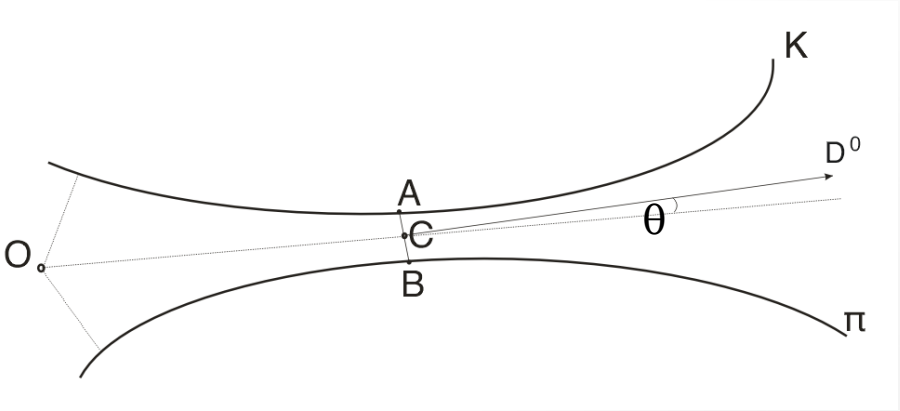


DCA resolution improves with the number of hits in SVT and SSD detectors!

<u>At p = 1 GeV/c the DCA resolution improves by a factor of 10</u>

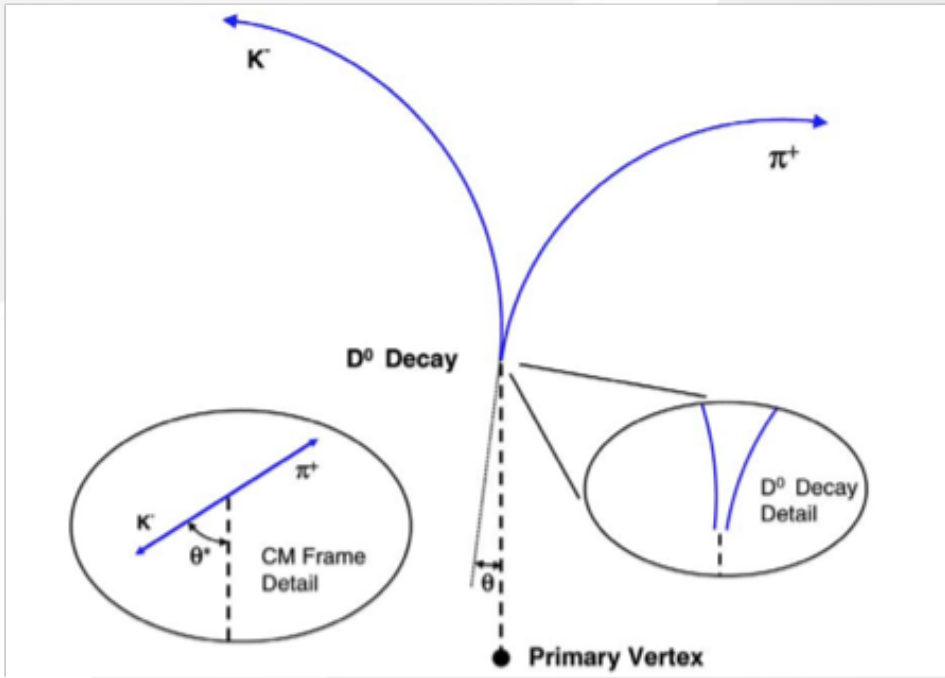
Reconstruction of the D^0 decay

μVertexing

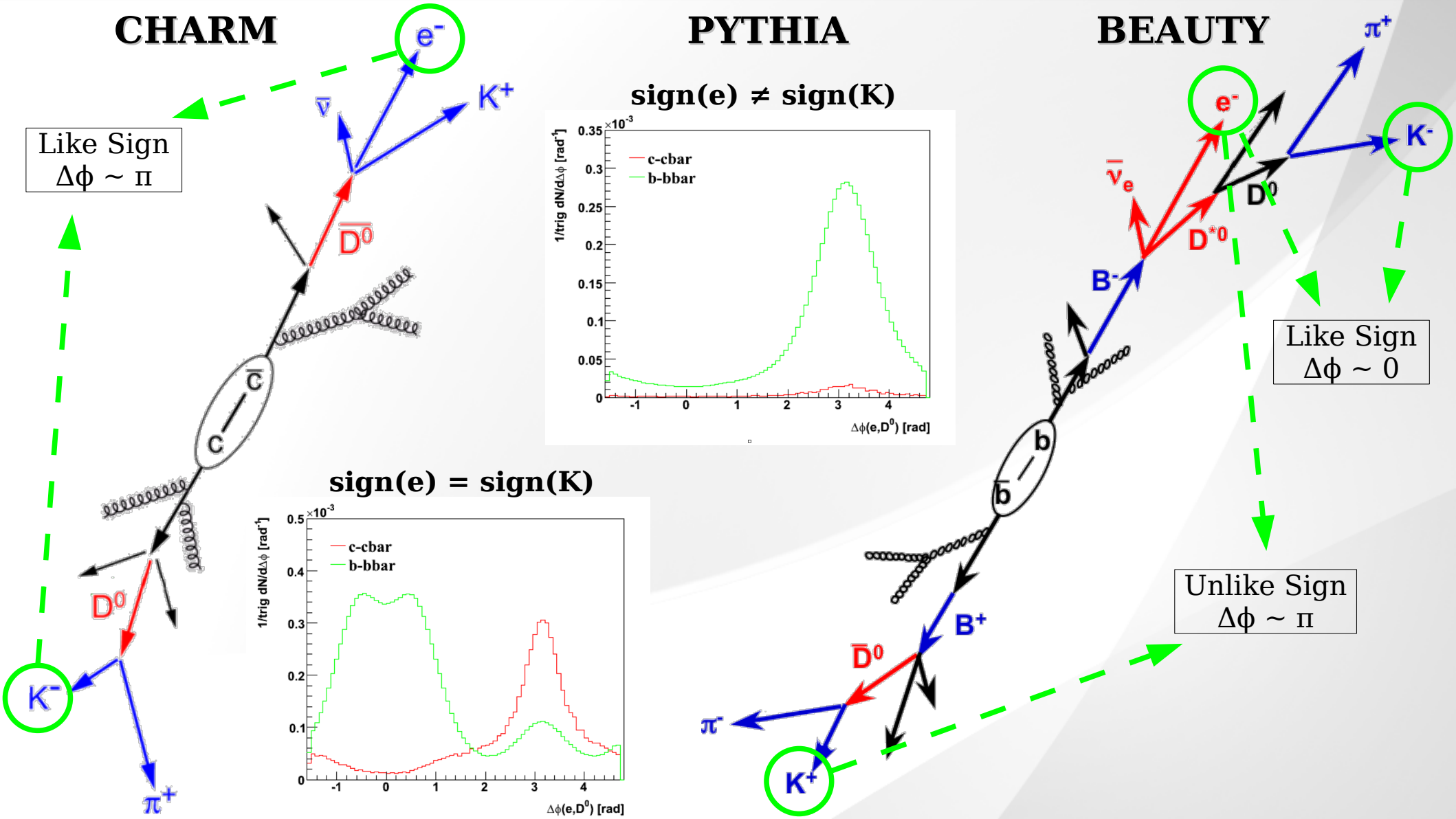


θ^* – *angle between K and direction of D0 in the rest frame of the parent*

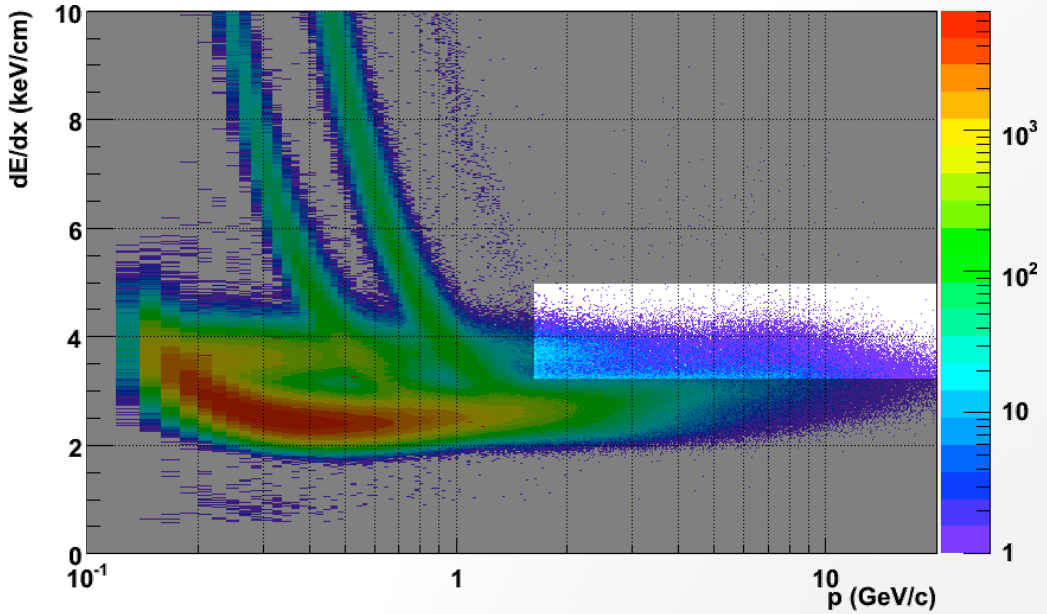
O – Primary vertex
C – Possible D0 decay point
$|AB|$ – DCA between tracks
$|OC|$ – Decay length
θ – pointing angle



Charm and beauty contributions



Trigger particle selection



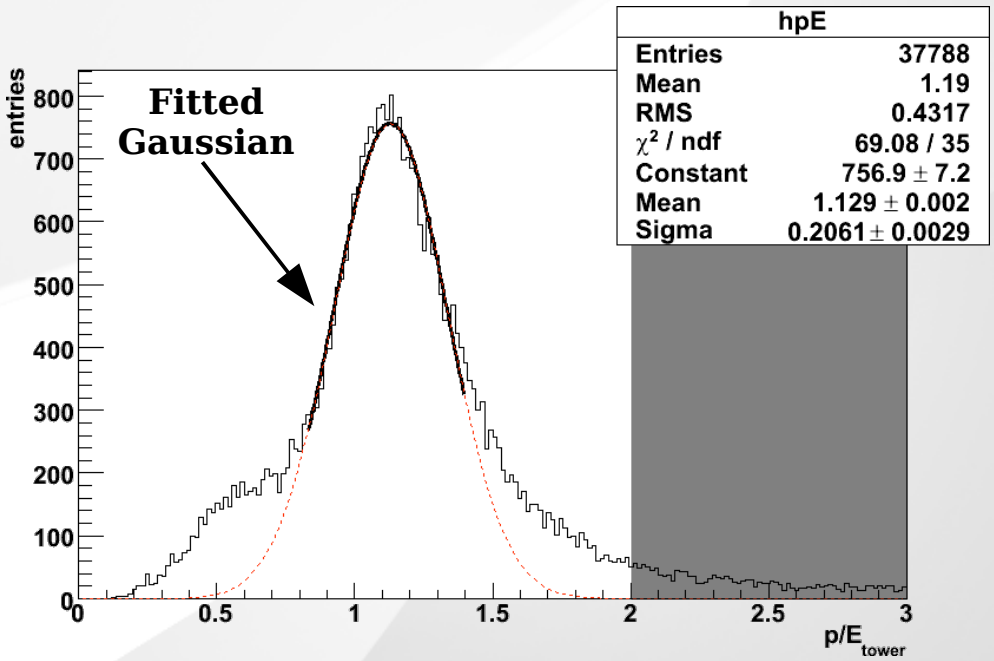
PID cuts [TPC]

- Electrons band:
  dE/dx ∈ (3.5; 5.0) [keV/cm]
- Away from overlapping region
  p > 1.5 [GeV/c]

PID cuts [EMC]

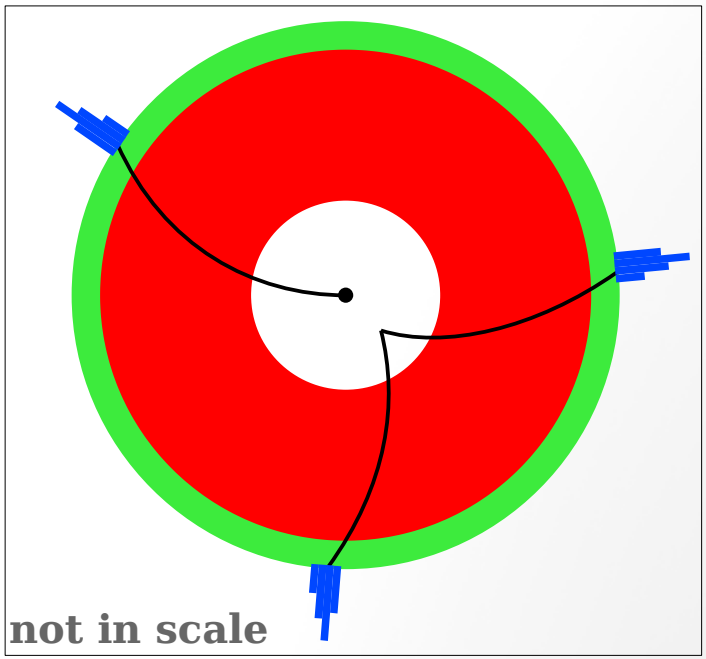
- p/*E* ∈ *(0; 2) [keV/cm]*
  p – momentum from TPC
  E – energy of the shower

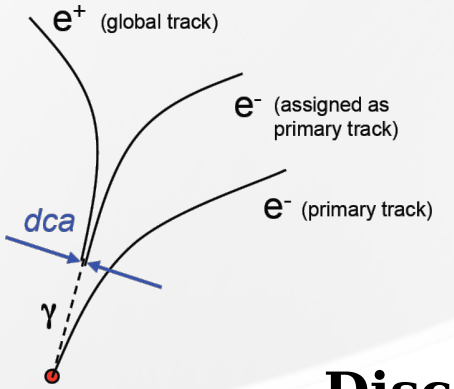
<u>Should have a peak ~ 1 for electrons</u>

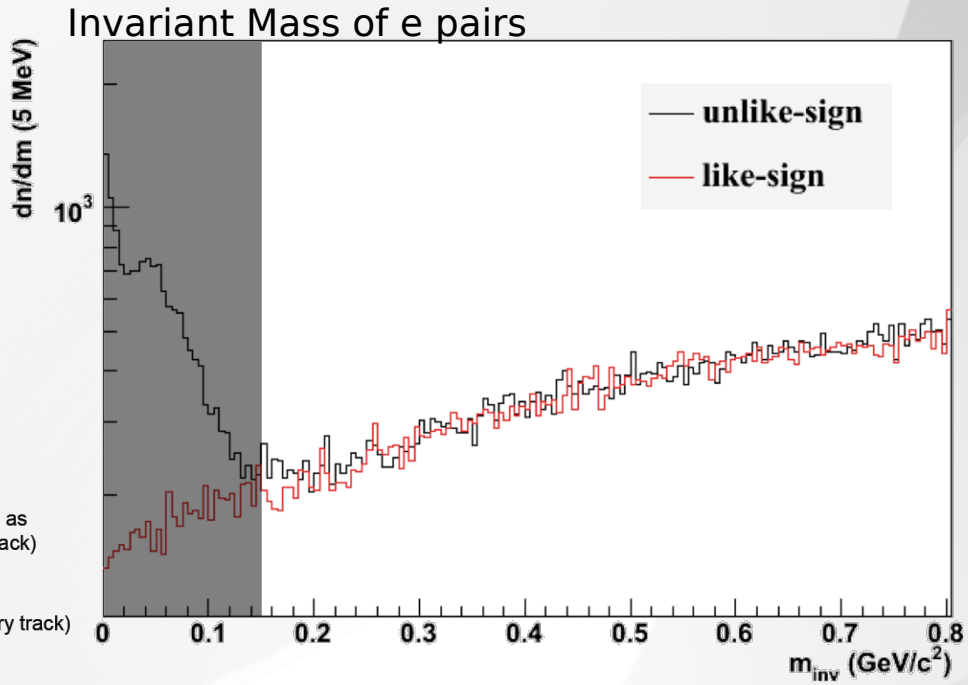


Trigger particle selection

Extrapolate **TPC** tracks on the **BEMC** surface and check for nearby **towers** within a distance







Sources of Contamination:

- Photon Conversion (material)
- neutral meson decays (π^0, η)

Discrimination Method:

- Calculate the invariant mass of every e^+e^- and e^+e^+/e^-e^-
- Superimposing the plots indicates the cut at 150 MeV/c^2

Analysis Methodology

p+p 2006

Event Cuts

Vertex-Z ∈ (-30; 30) [cm]

Trigger electron E_t > 5.4 [GeV]

Au+Au 2007

Event Cuts

Vertex-Z ∈ (-20; 20) [cm]

Trigger electron E_t > 4.2 [GeV]

Track Cuts

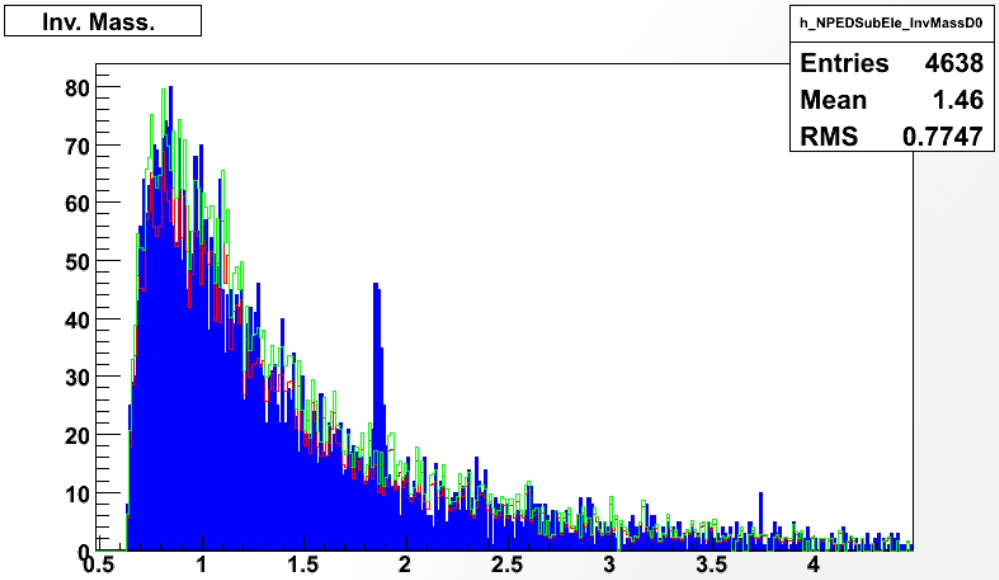
DCA to Primary Vertex < 1.5 [cm]

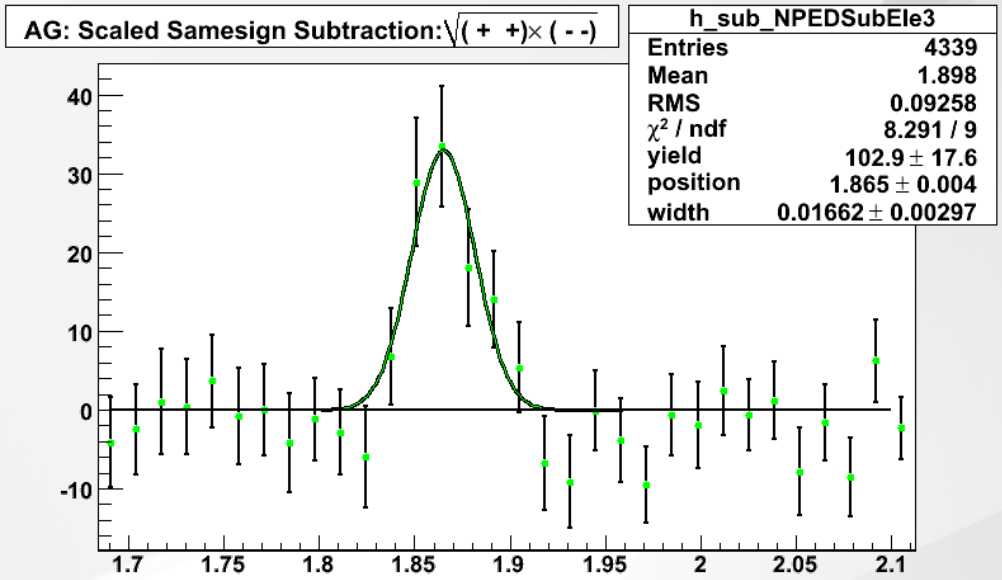
TPC hits > 25 (of 45 possible)

|η| < 1.0

p+p 2006 Results

Monte Carlo (PYTHIA+GEANT)





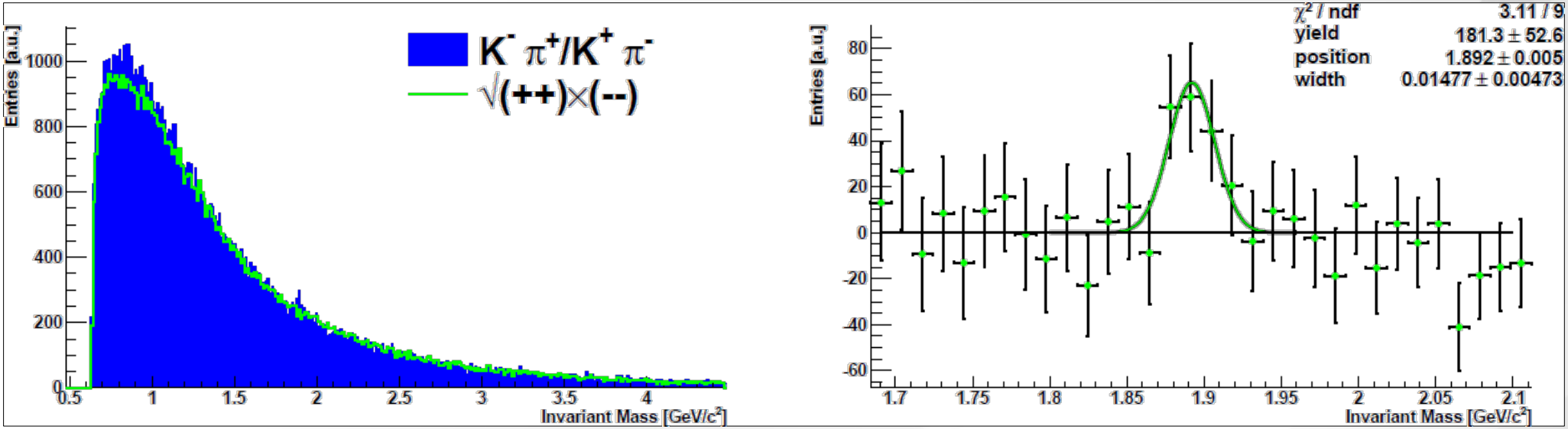
Fit results

Peak position m = 1865 ± 4 MeV/c^2

Width of the signal σ_m = 17 ± 3 MeV/c^2

p+p 2006 Results

Data: no Δφ(e-D0) cut



Fit results

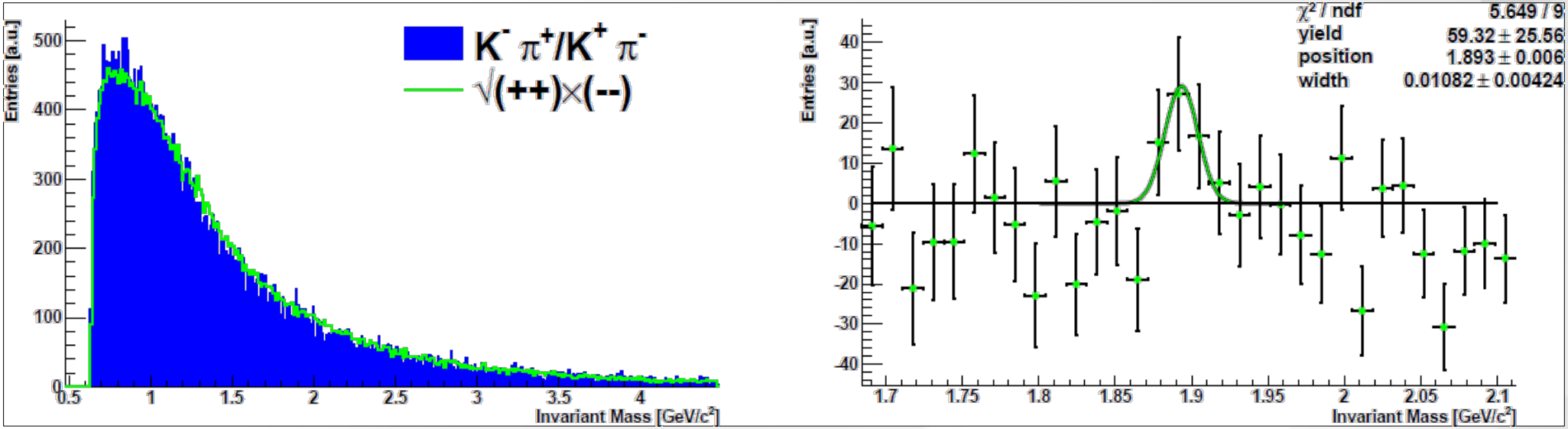
Peak position m = 1892±5 MeV/c^2

Width of the signal σ_m = 14.7±4.7 MeV/c^2

Signal significance ~4.85

p+p 2006 Results

Data: Δφ(e-D0) = 0 ± 1.2



Fit results

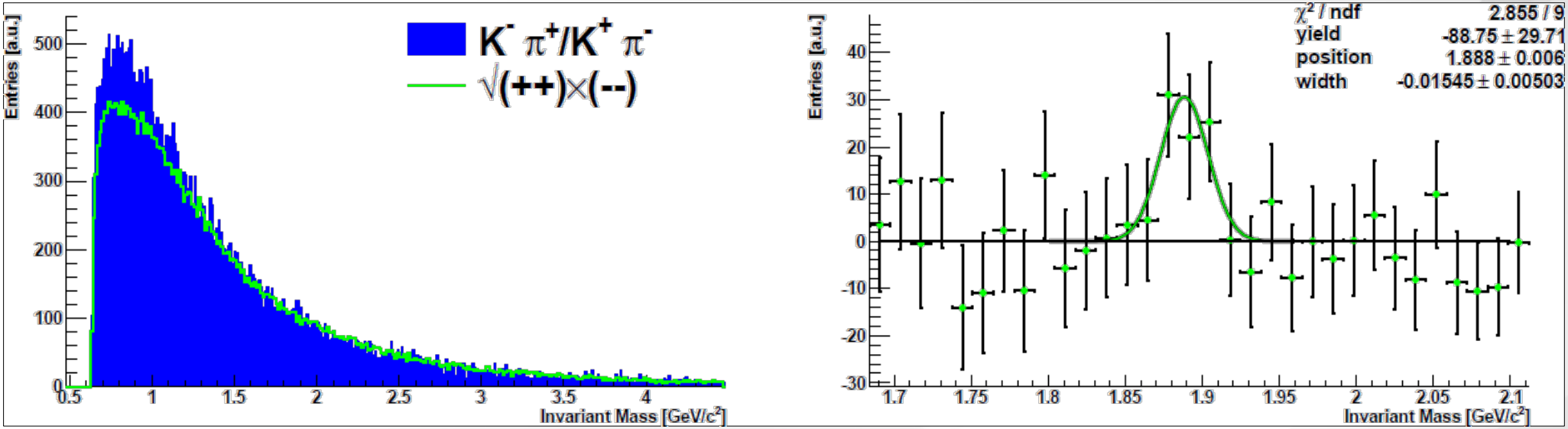
Peak position m = 1893±6 MeV/c^2

Width of the signal σ_m = 10.8±4.2 MeV/c^2

Signal significance ~2.5

p+p 2006 Results

Data: Δφ(e-D0) = π ± 1.2



Fit results

Peak position m = 1888±6 MeV/c^2

Width of the signal σ_m = 16.0±5.0 MeV/c^2

Signal significance ~3.04

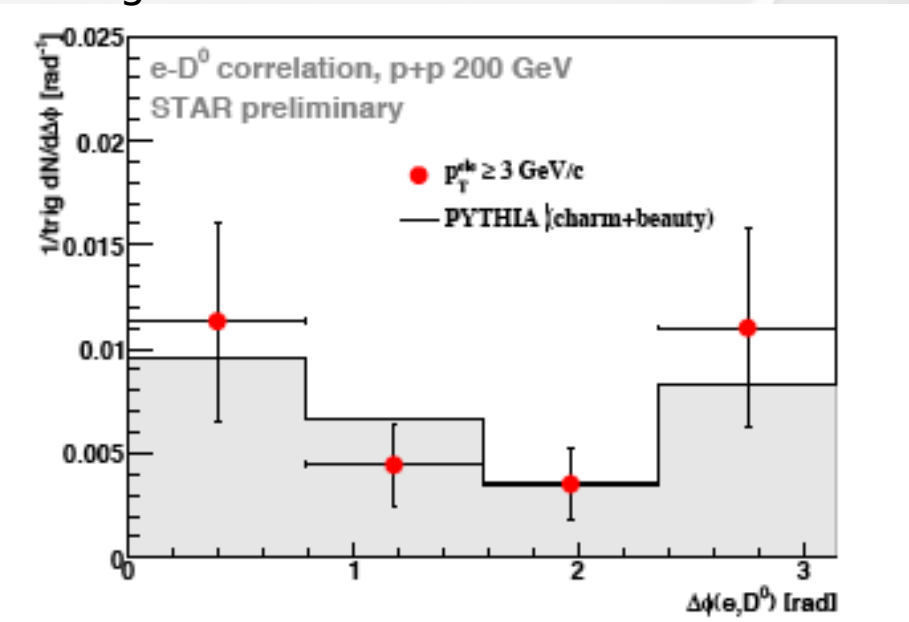
p+p 2006 Results

Comparison

Δφ(e-D0) = 0 ± 1.2
Peak position m = 1893±6 MeV/c^2
Width of the signal σ_m = 10.8±4.2 MeV/c^2
Signal significance ~2.5

Δφ(e-D0) = π ± 1.2
Peak position m = 1888±6 MeV/c^2
Width of the signal σ_m = 16.0±5.0 MeV/c^2
Signal significance ~3.04

Charm and beauty yields
in agreement with PYTHIA simulations



J. Phys. G35, 104117 (2008)

p+p 2006 Results

Publication on pp2006 – will be submitted in few days

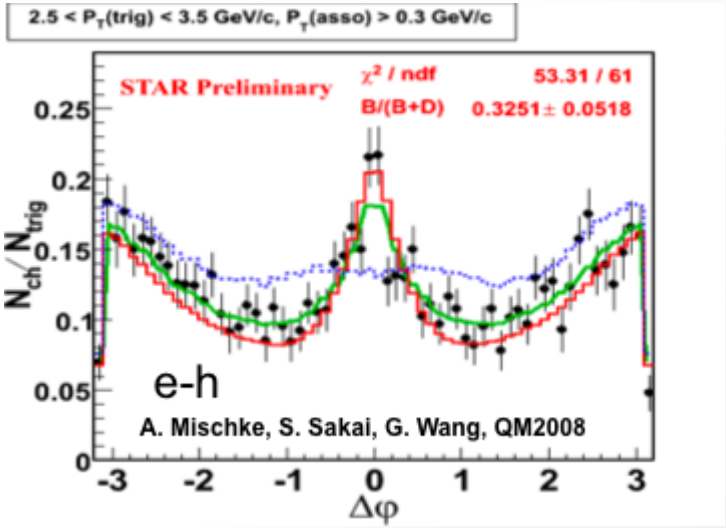
Measurement of the Bottom contribution to non-photonic electron production in $p+p$ collisions at $\sqrt{s}$=200 GeV

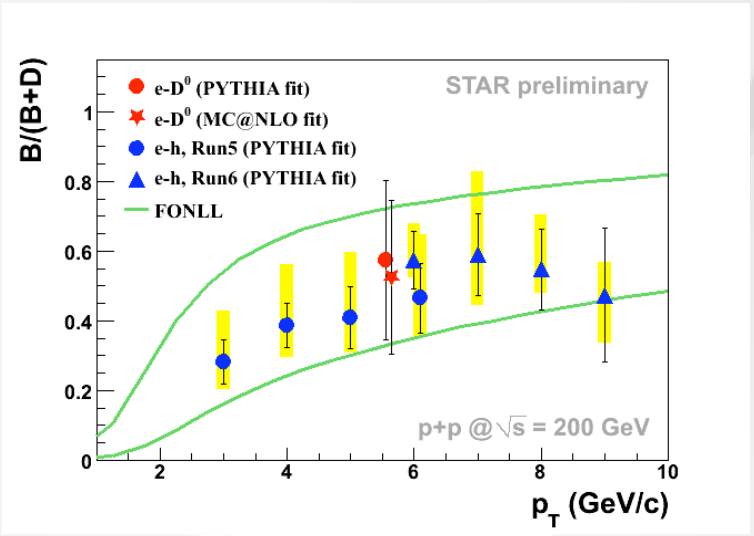
M. M. Aggarwal,[31] Z. Ahammed,[22] A. V. Alakhverdyants,[18] I. Alekseev ,[16] J. Alford,[19] B. D. Anderson,[19] DanielAnson,[29] D. Arkhipkin,[3] G. S. Averichev,[18] J. Balewski,[23] L. S. Barnby,[2] S. Baumgart,[53] D. R. Beavis,[3] R. Bellwied,[51] M. J. Betancourt,[23] R. R. Betts,[8] A. Bhasin,[17] A. K. Bhati,[31] H. Bichsel,[50] J. Bielcik,[10] J. Bielcikova,[11] B. Biritz,[6] L. C. Bland,[3] B. E. Bonner,[37] J. Bouchet,[19] E. Braidot,[28] A. V. Brandin,[26] A. Bridgeman,[1] E. Bruna,[53] S. Bueltmann,[30] I. Bunzarov,[18] T. P. Burton,[3] X. Z. Cai,[41] H. Caines,[53] M. Calderón de la Barca Sánchez,[5] O. Catu,[53] D. Cebra,[5] R. Cendejas,[6] M. C. Cervantes,[43] Z. Chajecki,[29] P. Chaloupka,[11] S. Chattopadhyay,[48] H. F. Chen,[39] J. H. Chen,[41] J. Y. Chen,[52] J. Cheng,[45] M. Cherney,[9] A. Chikanian,[53] K. E. Choi,[35] W. Christie,[3] P. Chung,[11] R. F. Clarke,[43] M. J. M. Codrington,[43] R. Corliss,[23] J. G. Cramer,[50] H. J. Crawford,[4] D. Das,[5] S. Dash,[13] A. Davila Leyva,[44] L. C. De Silva,[51] R. R. Debbe,[3] T. G. Dedovich,[18] A. A. Derevschikov,[33] R. Derradi de Souza,[7] L. Didenko,[3] P. Djawotho,[43] S. M. Dogra,[17] X. Dong,[22] J. L. Drachenberg,[43] J. E. Draper,[5] J. C. Dunlop,[3] M. R. Dutta Mazumdar,[48] L. G. Efimov,[18] E. Elhalhuli,[2] M. Elnimr,[51] J. Engelage,[4] G. Eppley,[37] B. Erazmus,[42] M. Estienne,[42] L. Eun,[32] O. Evdokimov,[8] P. Fachini,[3] R. Fatemi,[20] J. Fedorisin,[18] R. G. Fersch,[20] P. Filip,[18] E. Finch,[53] V. Fine,[3] Y. Fisyak,[3] C. A. Gagliardi,[43] D. R. Gangadharan,[6] M. S. Ganti,[48] E. J. Garcia-Solis,[8] A. Geromitsos,[42] F. Geurts,[37] V. Ghazikhanian,[6] P. Ghosh,[48] Y. N. Gorbunov,[9] A. Gordon,[3] O. Grebenyuk,[22] D. Grosnick,[47] S. M. Guertin,[6] A. Gupta,[17] W. Guryn,[3] B. Haag,[5] A. Hamed,[43] L-X. Han,[41] J. W. Harris,[53] J. P. Hays-Wehle,[23] M. Heinz,[53] S. Heppelmann,[32] A. Hirsch,[34] E. Hjort,[22] A. M. Hoffman,[23] G. W. Hoffmann,[44] D. J. Hofman,[8] B. Huang,[39] H. Z. Huang,[6] T. J. Humanic,[29] L. Huo,[43] G. Igo,[6] P. Jacobs,[22] W. W. Jacobs,[15] C. Jena,[13] F. Jin,[41] C. L. Jones,[23]

Ongoing analysis for pp2009 data.
Grater Statistics – 900M (Min Bias)

p+p 2006 Results

Heavy flavor contribution to non-photonic electrons





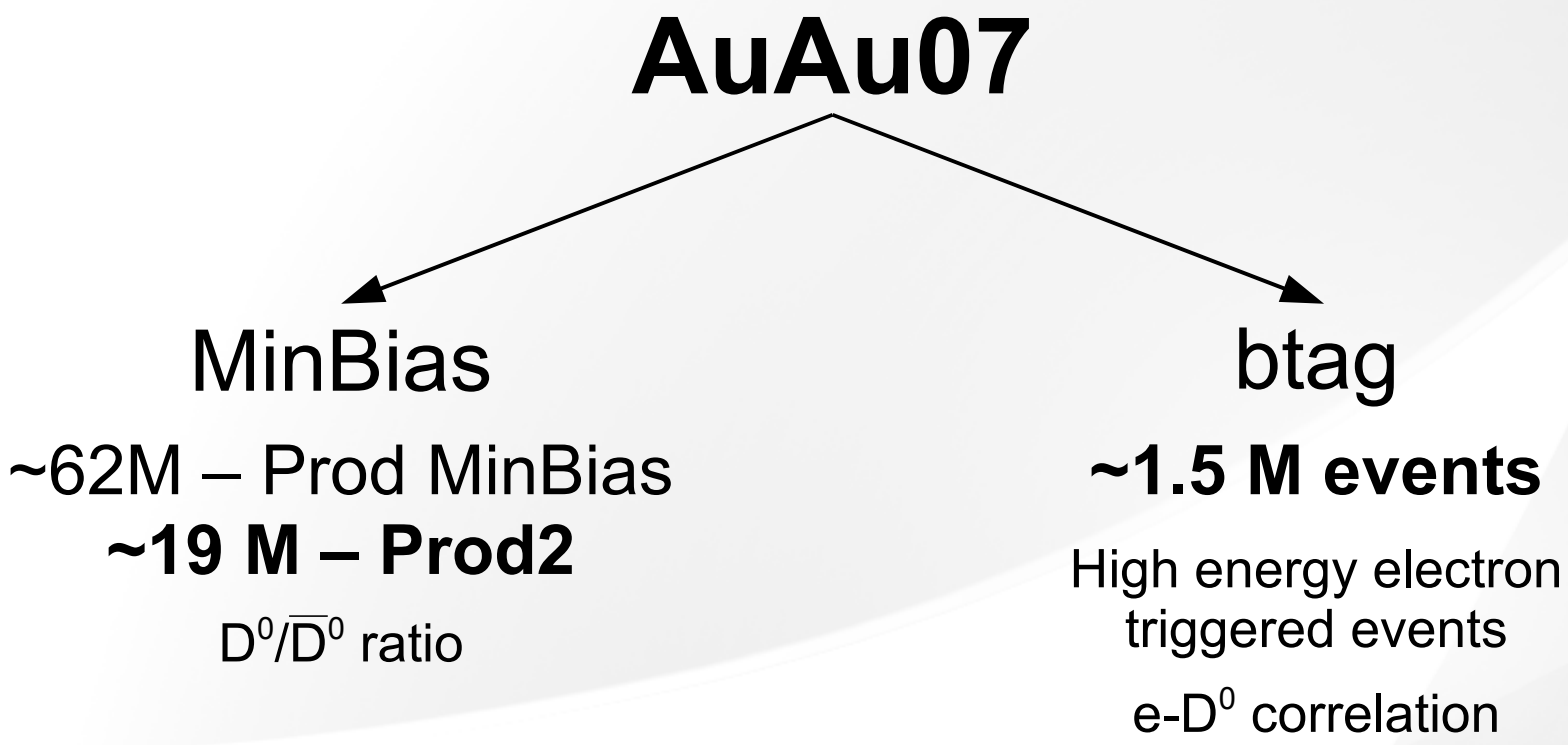
B much heavier than D
↓
Sub leading electrons
get a larger kick from B
↓
Near side e-h correlation
is broadened

Conclusion from e-h and e-D correlations:

<u>B contribution to non photonic electrons is ~50% at p_T ~ 5 GeV/c</u>

J. Phys. G35, 104117 (2008)

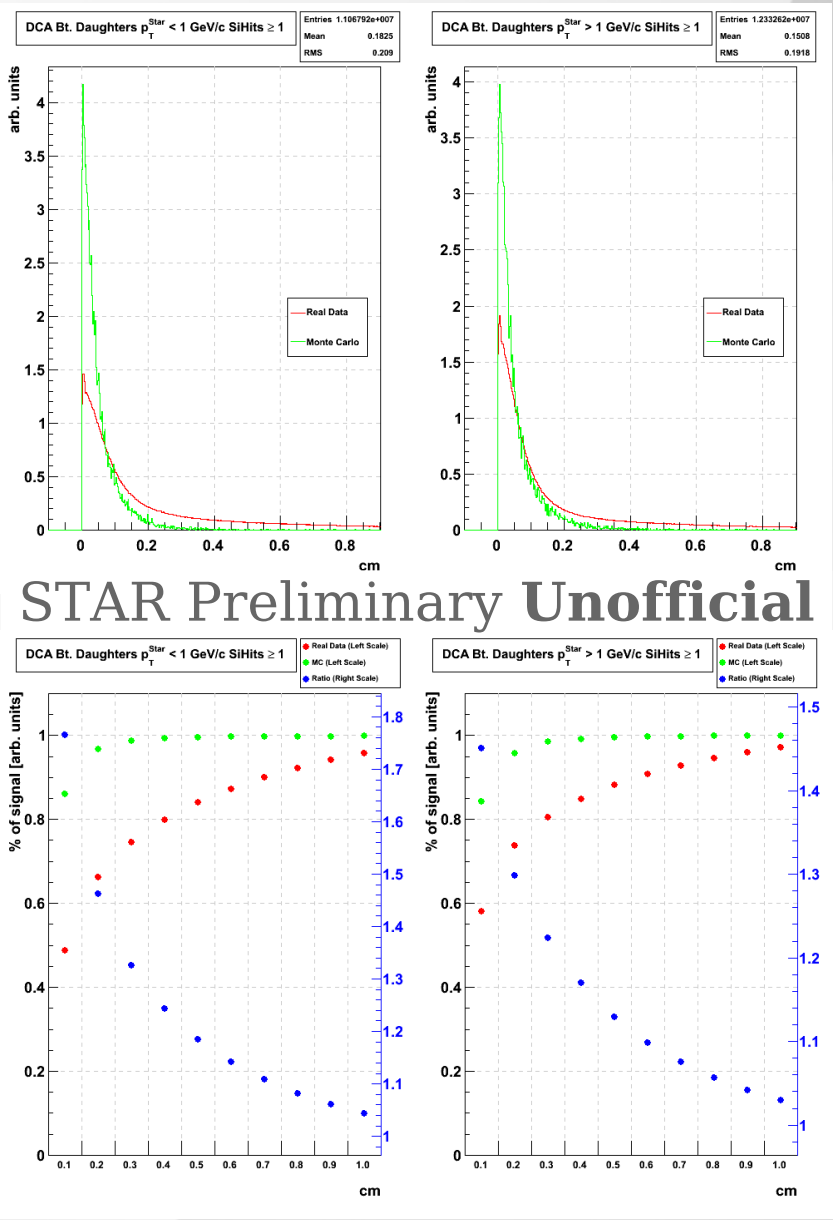
Au+Au 2007


AuAu07
MinBias
~62M – Prod MinBias
~19 M – Prod2
$D^0/\overline{D}^0$ ratio
btag
~1.5 M events
High energy electron triggered events
e-D^0 correlation

Cuts Study

Already studied

- Decay Length
- DCA Btwn. Tracks
- DCA D0 to PV
- DCA Tracks to PV
- Cos(θ*)



<u>More are on the way</u>

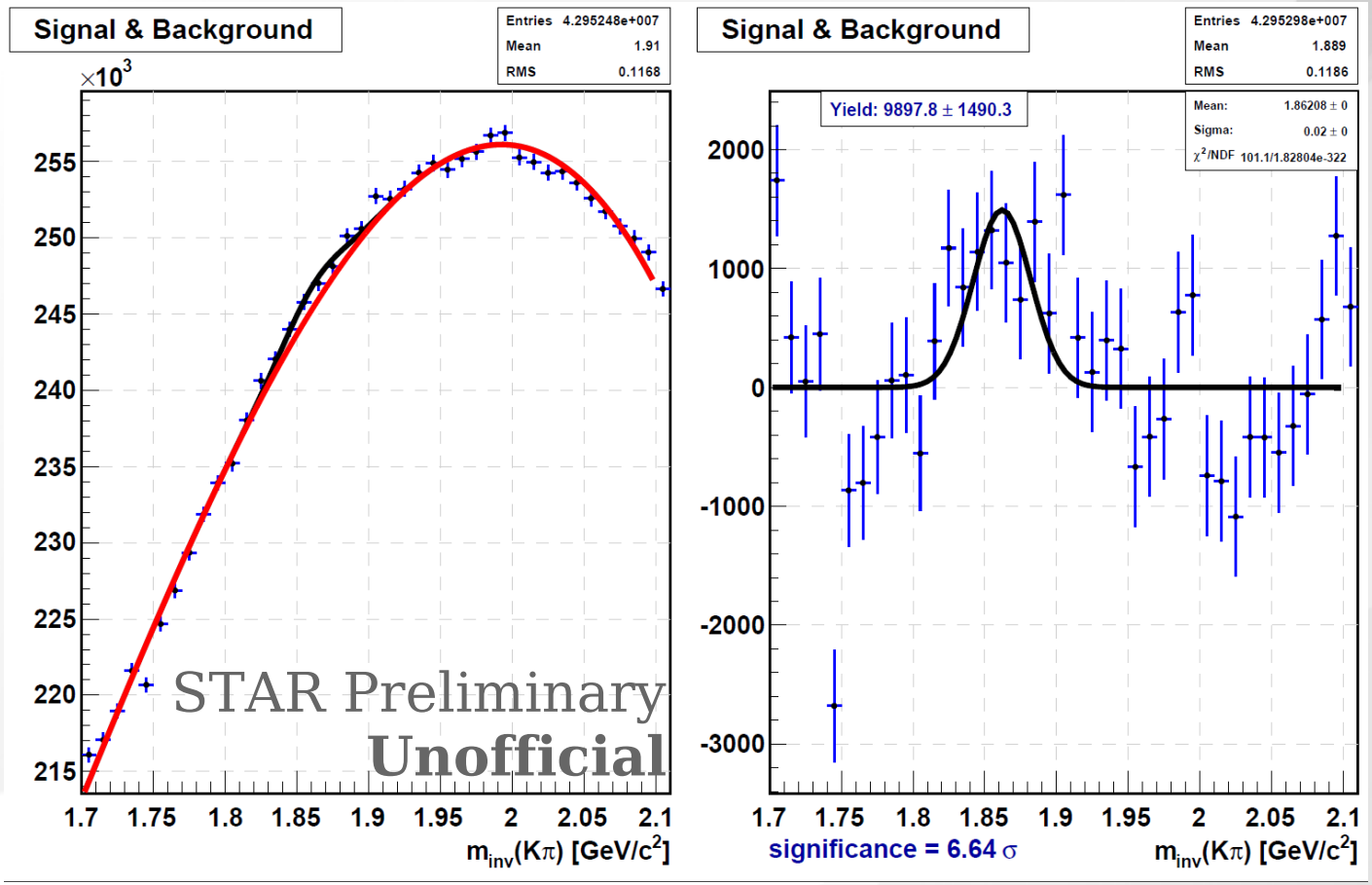
Au+Au 2007 btag

Cutset

- SVT + SSD ≥ 1
- DCA btwn. tracks ≤ 0.06 cm
- DCA D0 to PV ≤ 0.1 cm
- Decay length ≤ 0.2 cm
- $\cos(\theta^*_K) \leq 0.6$
- $p_T(K,\pi) \geq 0.8$ GeV/c

One of 114 cutsets
(and counting)

no Δφ(e-D0) cut



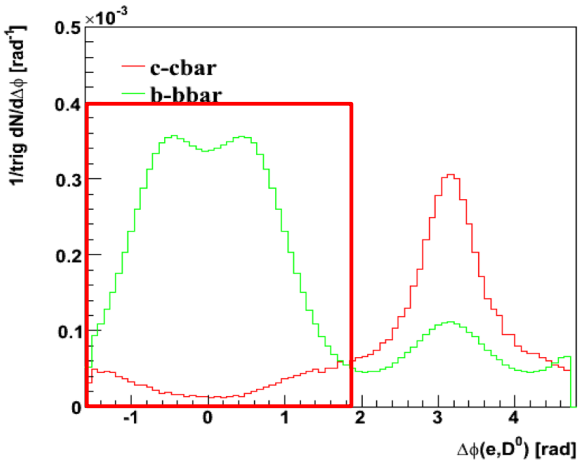
Statistics
94k events

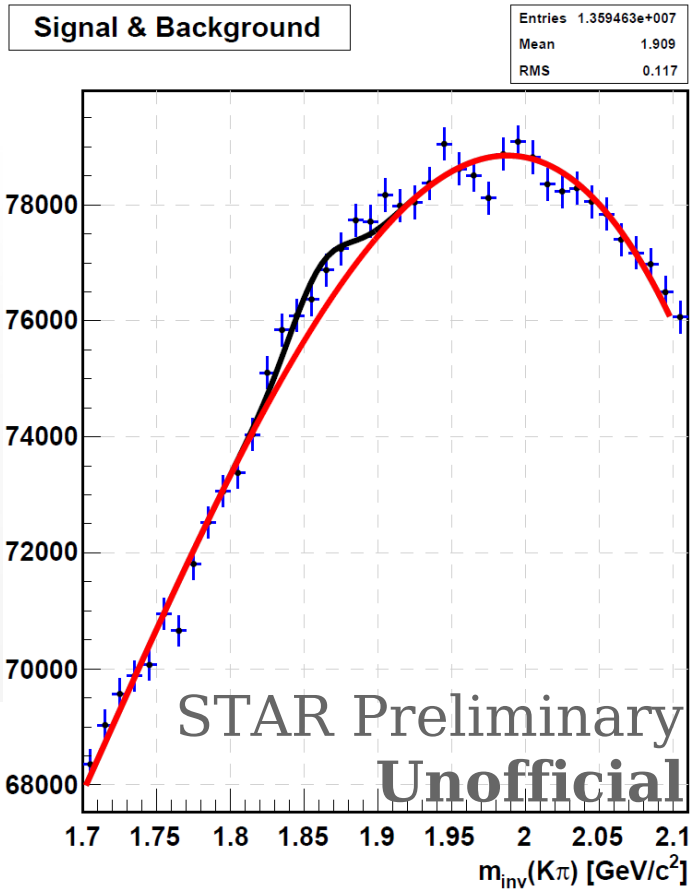
Significance
∫signal/√∫(S+B) [mass ± 2·σ]

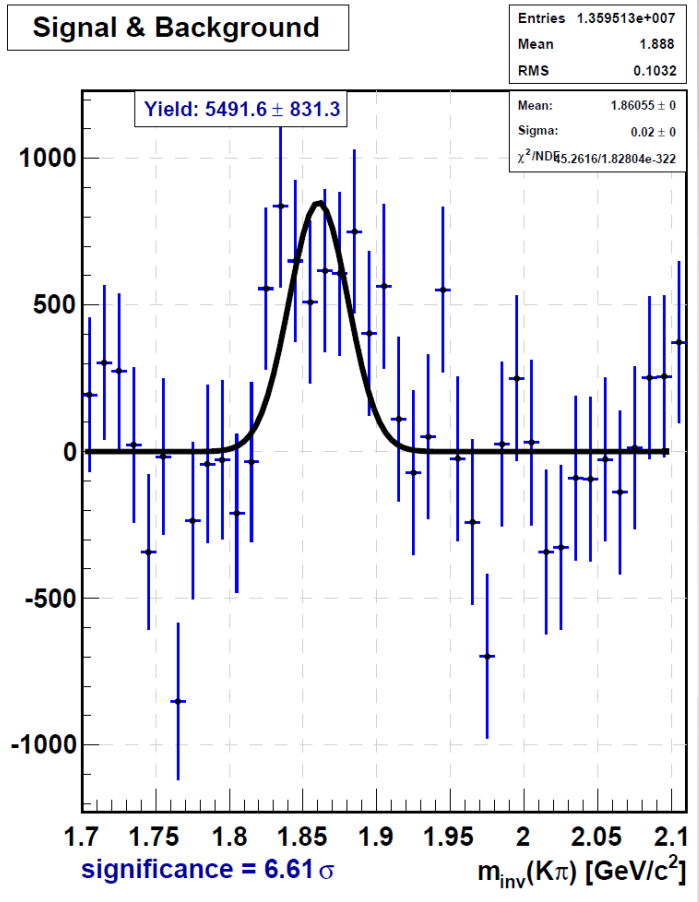
Au+Au 2007 btag

$\Delta\varphi(\text{e-D0}) = 0 \pm 1.2$

$\text{sign(e)} = \text{sign(K)}$



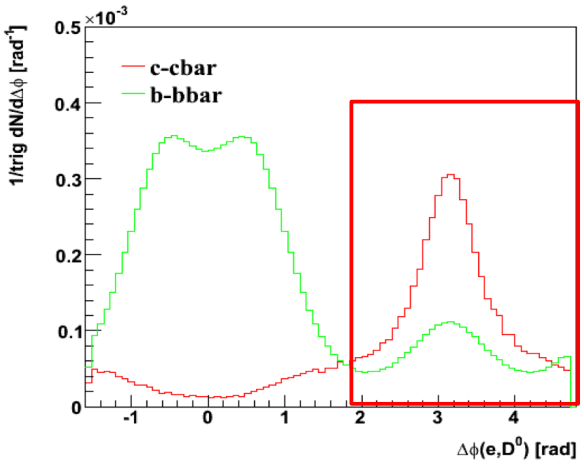


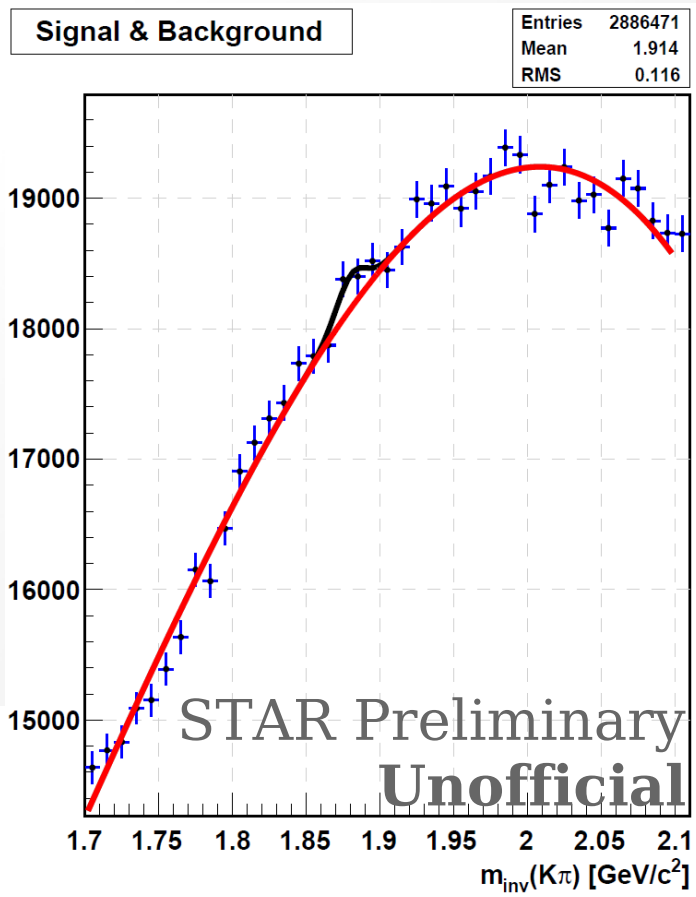


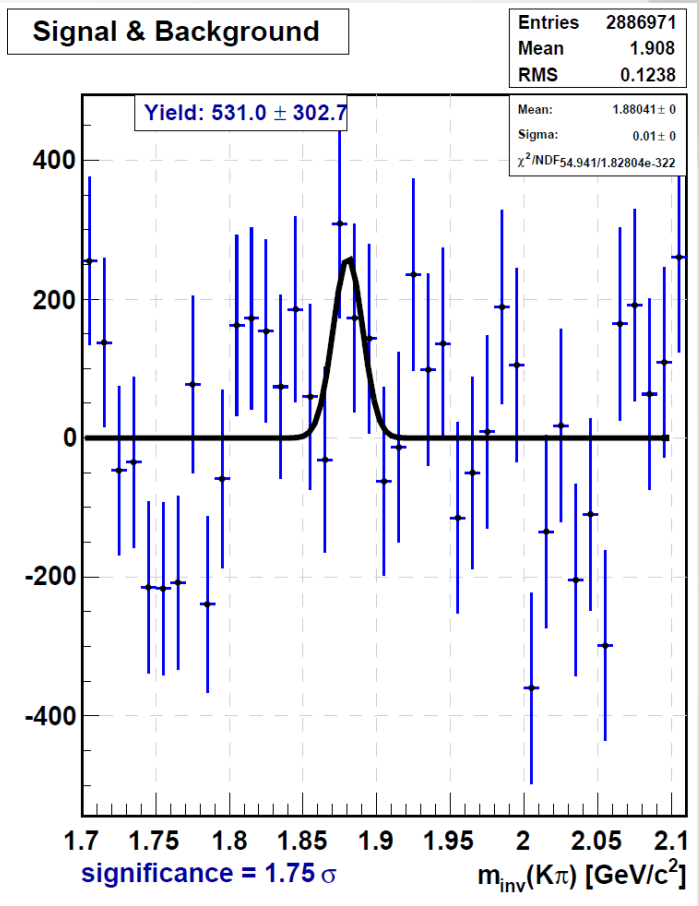
Au+Au 2007 btag

$\Delta\varphi(e\text{-}D0) = \pi \pm 1.2$

$\text{sign}(e) = \text{sign}(K)$

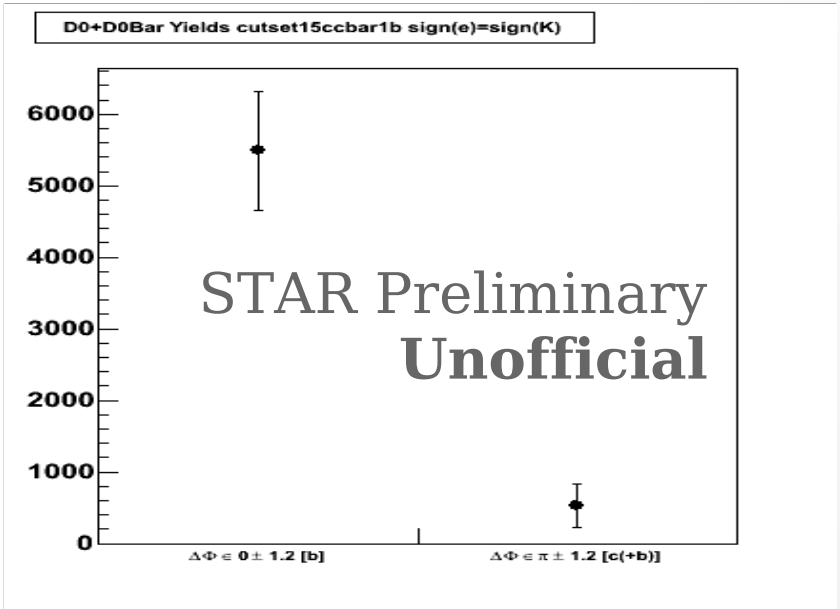






Au+Au 2007 vs p+p 2006

Au+Au 2007



Δφ(e-D0) = 0 ± 1.2

Peak position m = 1860 ± 8 MeV/c^2

Width of the signal σ_m = 20 ± 0.8 MeV/c^2

Signal significance ~6.61

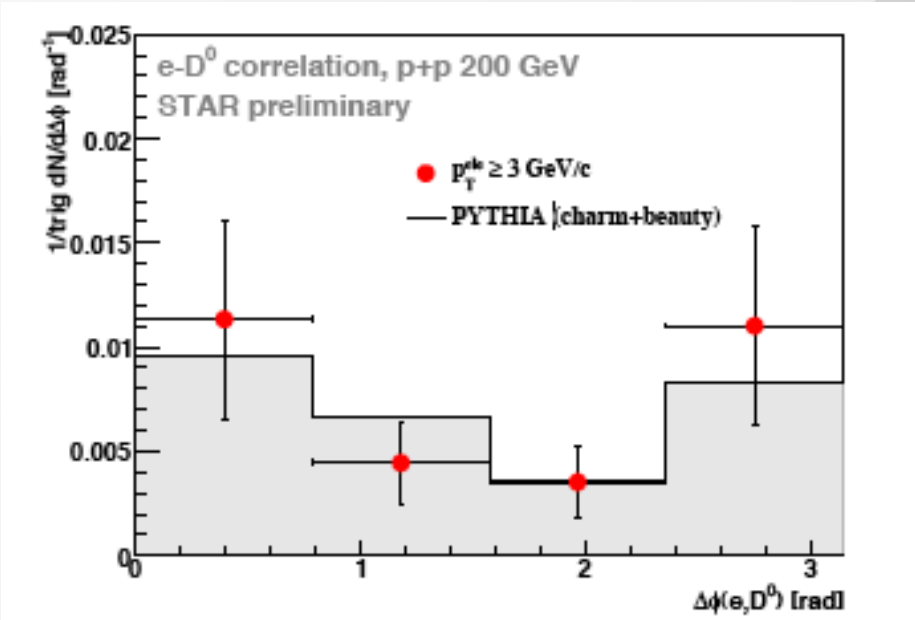
Δφ(e-D0) = π ± 1.2

Peak position m = 1880 ± 5 MeV/c^2

Width of the signal σ_m = 10 ± 8 MeV/c^2

Signal significance ~1.75

p+p 2006



Δφ(e-D0) = 0 ± 1.2

Peak position m = 1893±6 MeV/c^2

Width of the signal σ_m = 10.8±4.2 MeV/c^2

Signal significance ~2.5

Δφ(e-D0) = π ± 1.2

Peak position m = 1888±6 MeV/c^2

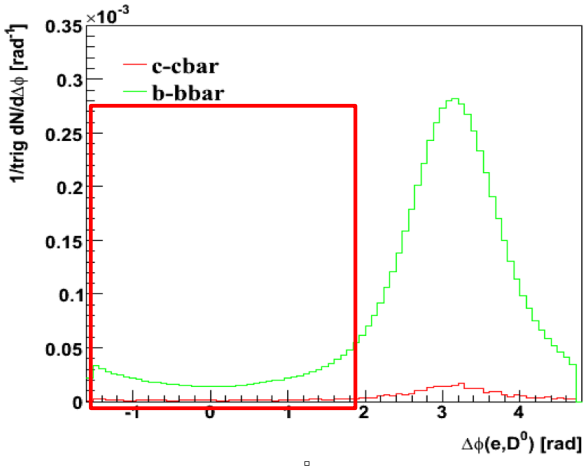
Width of the signal σ_m = 16.0±5.0 MeV/c^2

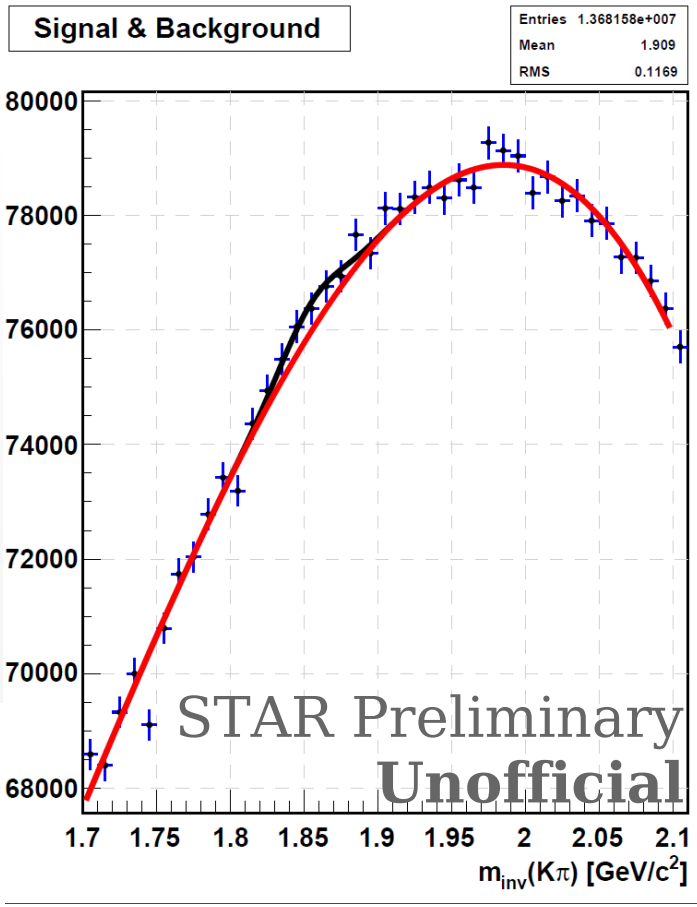
Signal significance ~3.04

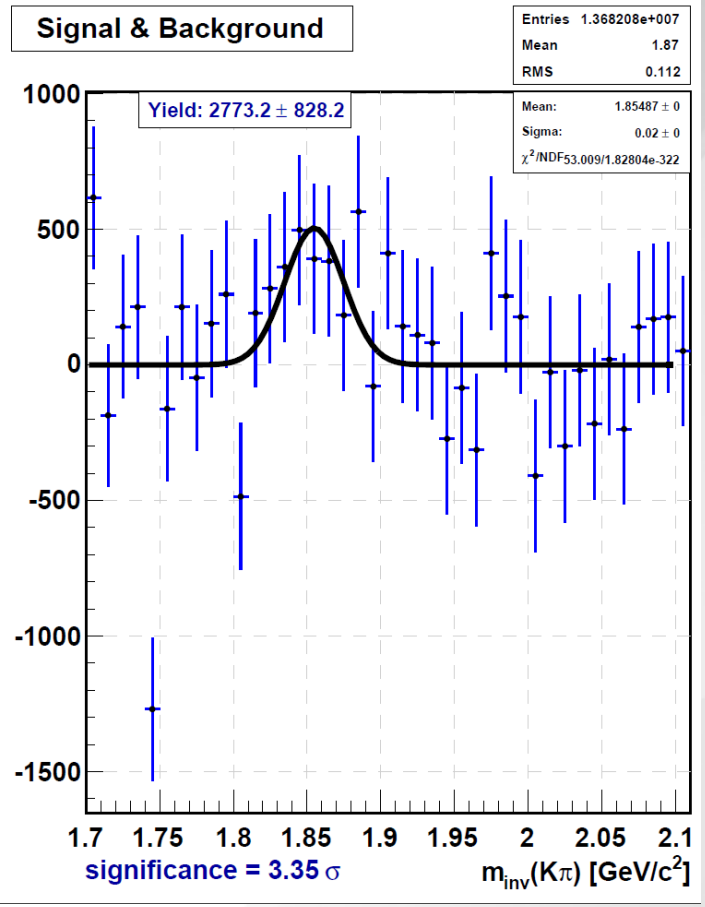
Au+Au 2007 btag

$\Delta\varphi(\text{e-D0}) = 0 \pm 1.2$

$\text{sign(e)} \neq \text{sign(K)}$



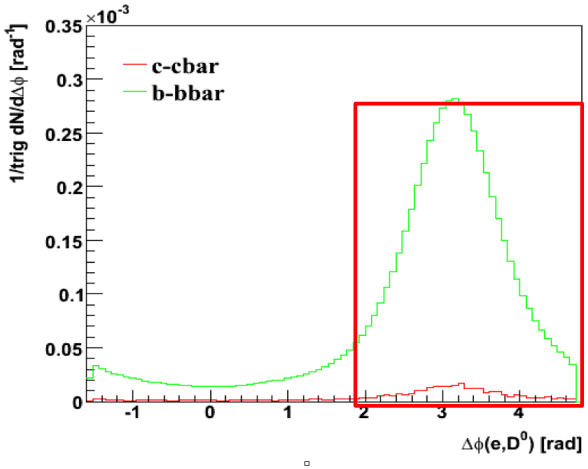


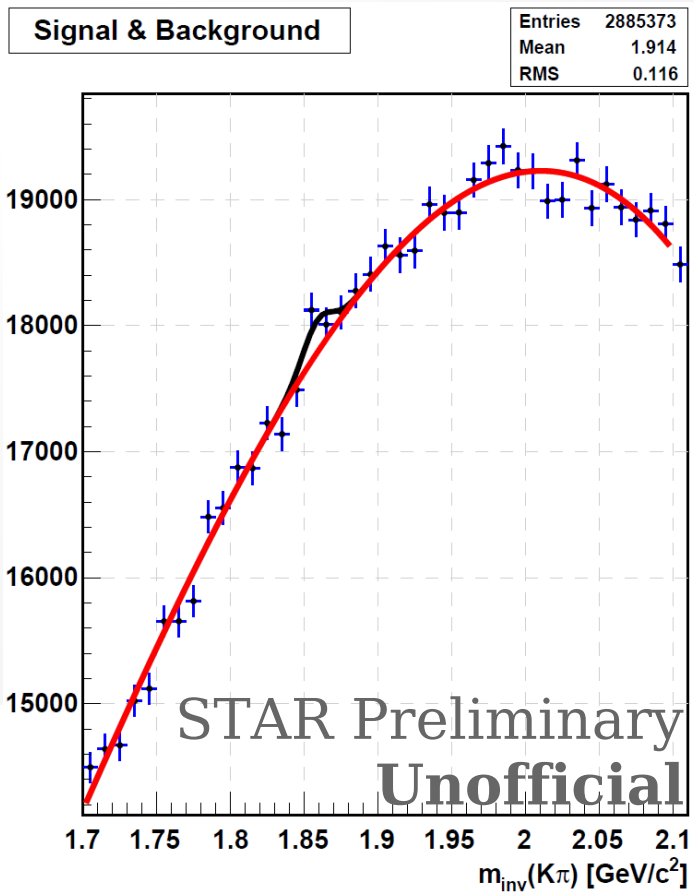


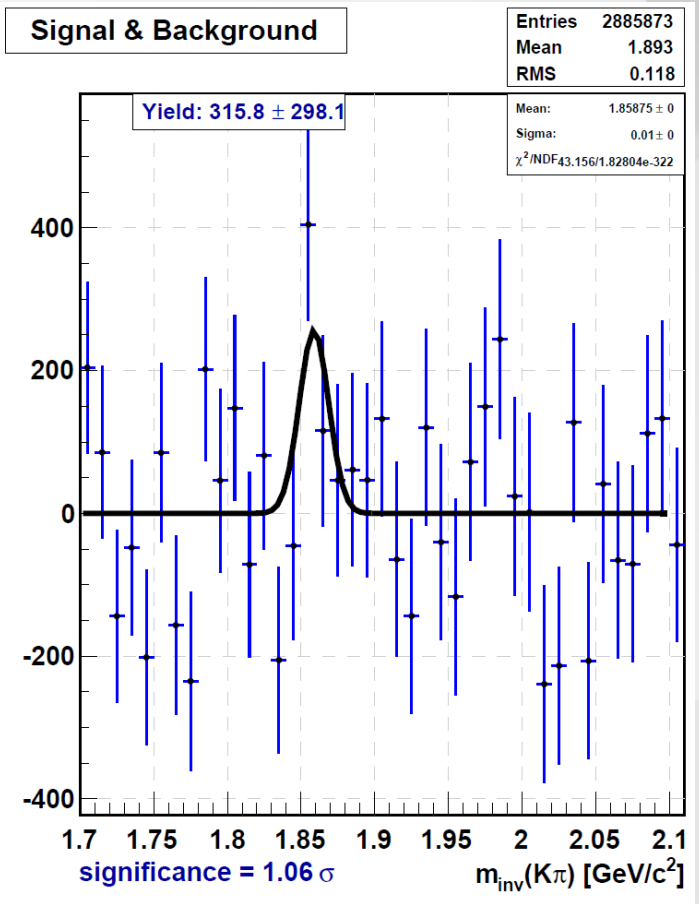
Au+Au 2007 btag

$\Delta\varphi(e\text{-}D0) = \pi \pm 1.2$

$\text{sign}(e) = \text{sign}(K)$

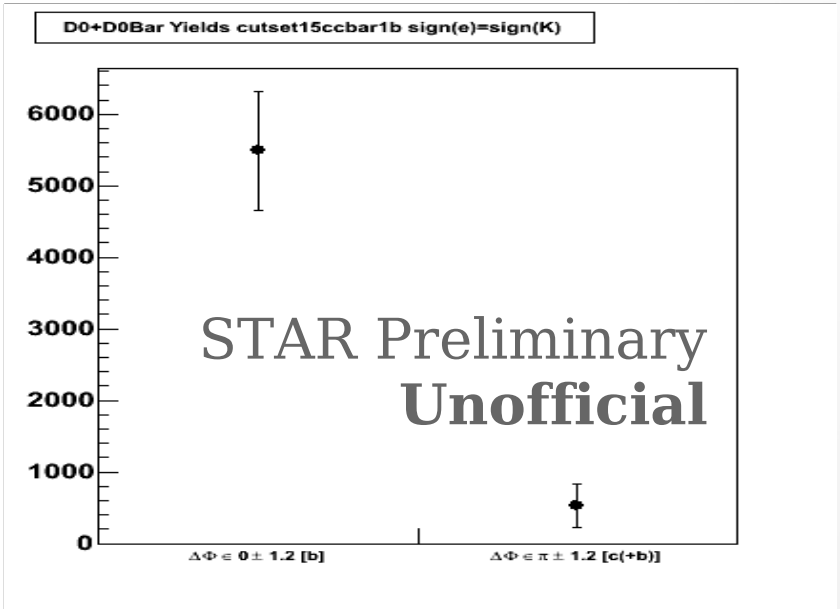






Au+Au 2007 btag

sign(e) = sign(K)



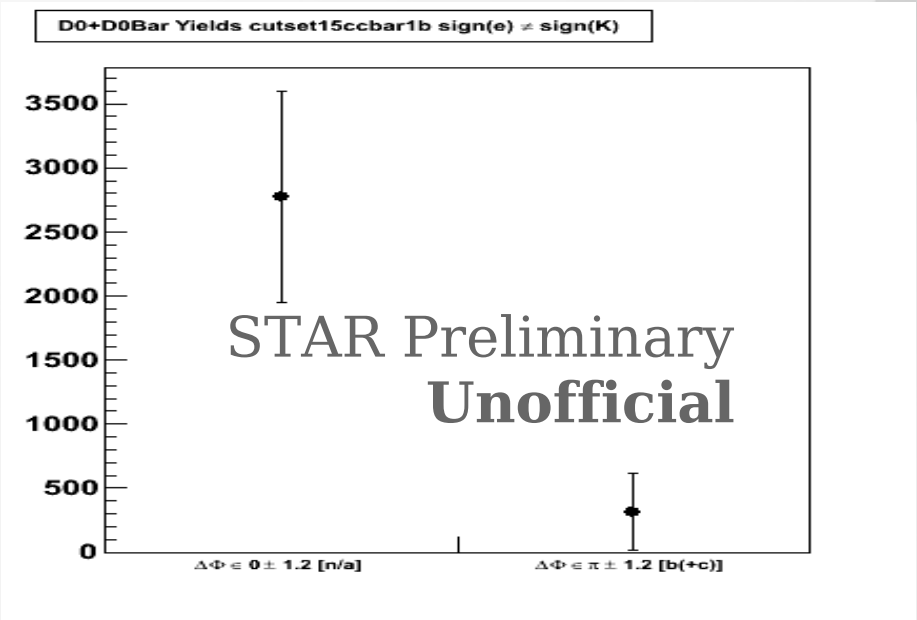
Δφ(e-D0) = 0 ± 1.2

Peak position m = 1860 ± 8 MeV/c^2
Width of the signal σ_m = 20 ± 0.8 MeV/c^2
Signal significance ~6.61

Δφ(e-D0) = π ± 1.2

Peak position m = 1880 ± 5 MeV/c^2
Width of the signal σ_m = 10 ± 8 MeV/c^2
Signal significance ~1.75

sign(e) ≠ sign(K)



Δφ(e-D0) = 0 ± 1.2

Peak position m = 1855 ± 9 MeV/c^2
Width of the signal σ_m = 20 ± 6 MeV/c^2
Signal significance ~3.35

Δφ(e-D0) = π ± 1.2

Peak position m = 1859 ± 4 MeV/c^2
Width of the signal σ_m = 10 ± 1 MeV/c^2
Signal significance ~ 1.06

e-D0 – Conclusions

Conclusions

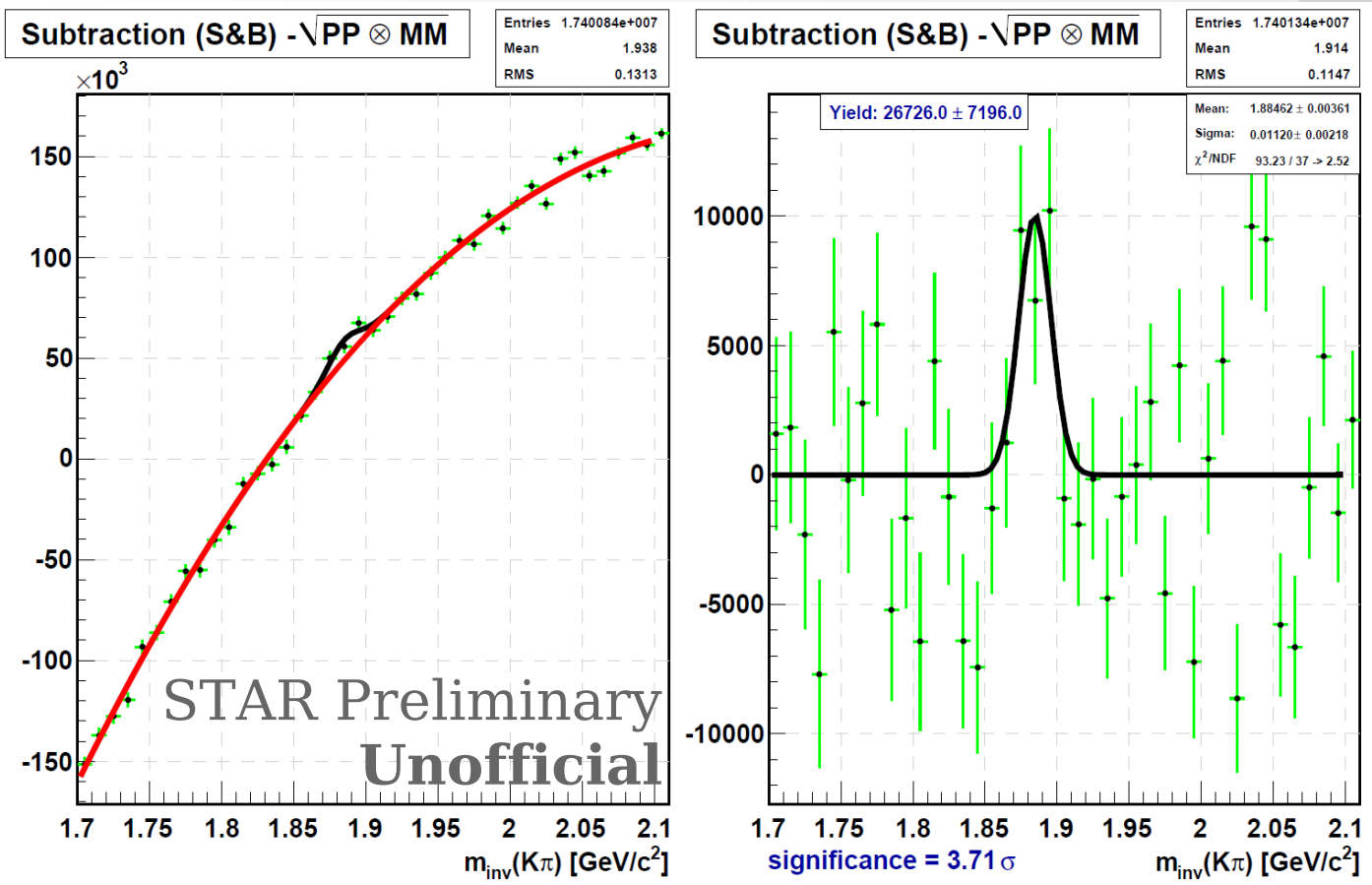
- Publication on e-D0 correlation in pp2006 is ready for submission
  - "The B decay contribution increases with pT and is comparable to the contribution from D meson decay at pT 5 GeV/c"
- D0 peak for AuAu
  - A peak up to significance ~6.7 has been observed
  - The peak is much grater for the near side than away side (for both eK sign cases)
  - This result is stable

Au+Au 2007 Min Bias

Cutset

- SVT + SSD ≥ 2
- DCA btwn. tracks ≤ 0.1 cm
- DCA D0 to PV ≤ 0.1 cm
- Decay length ≤ 0.1 cm

$D^0 + \overline{D}^0$



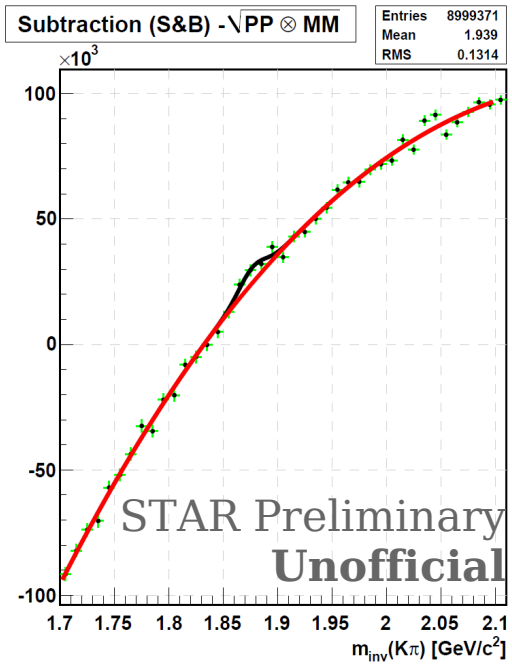
Statistics

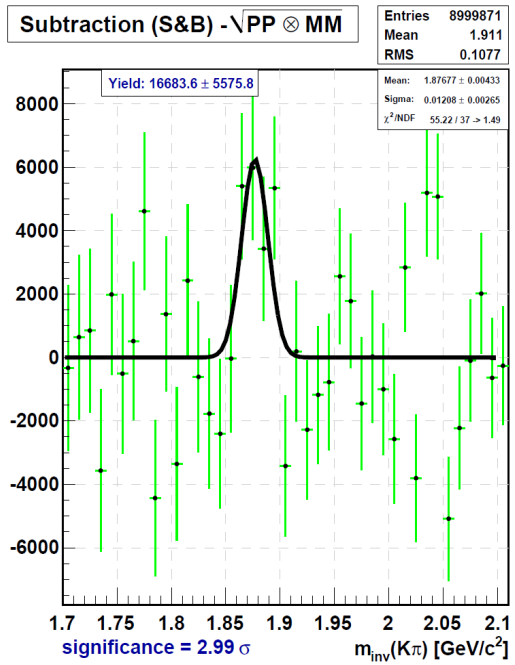
2.5M events

Significance

∫signal/√∫(S+B) [mass ± 2·σ]

Au+Au 2007 Min Bias



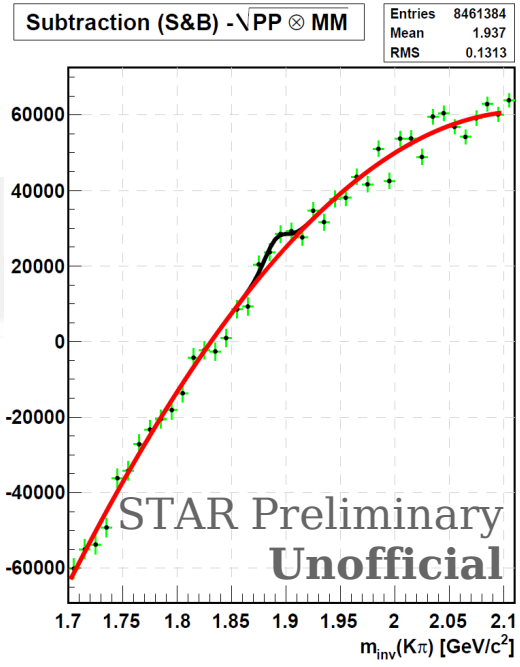


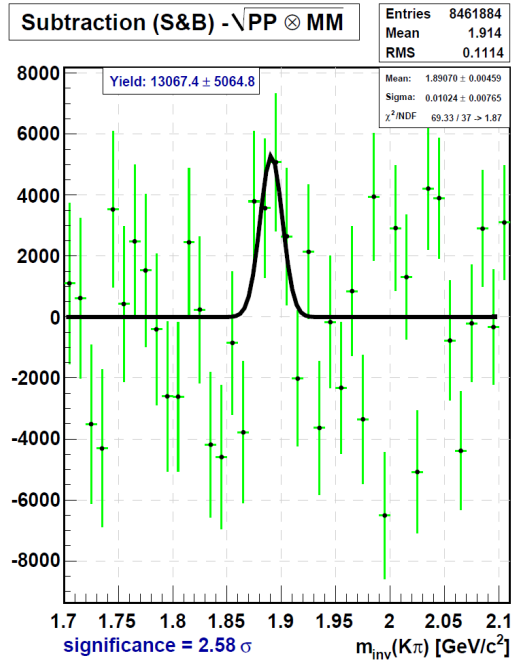
D^0

Peak position m = 1877 MeV/c^2
Width of the signal σ_m = 10 MeV/c^2
Signal significance ~ 2.99

$\overline{D}^0$

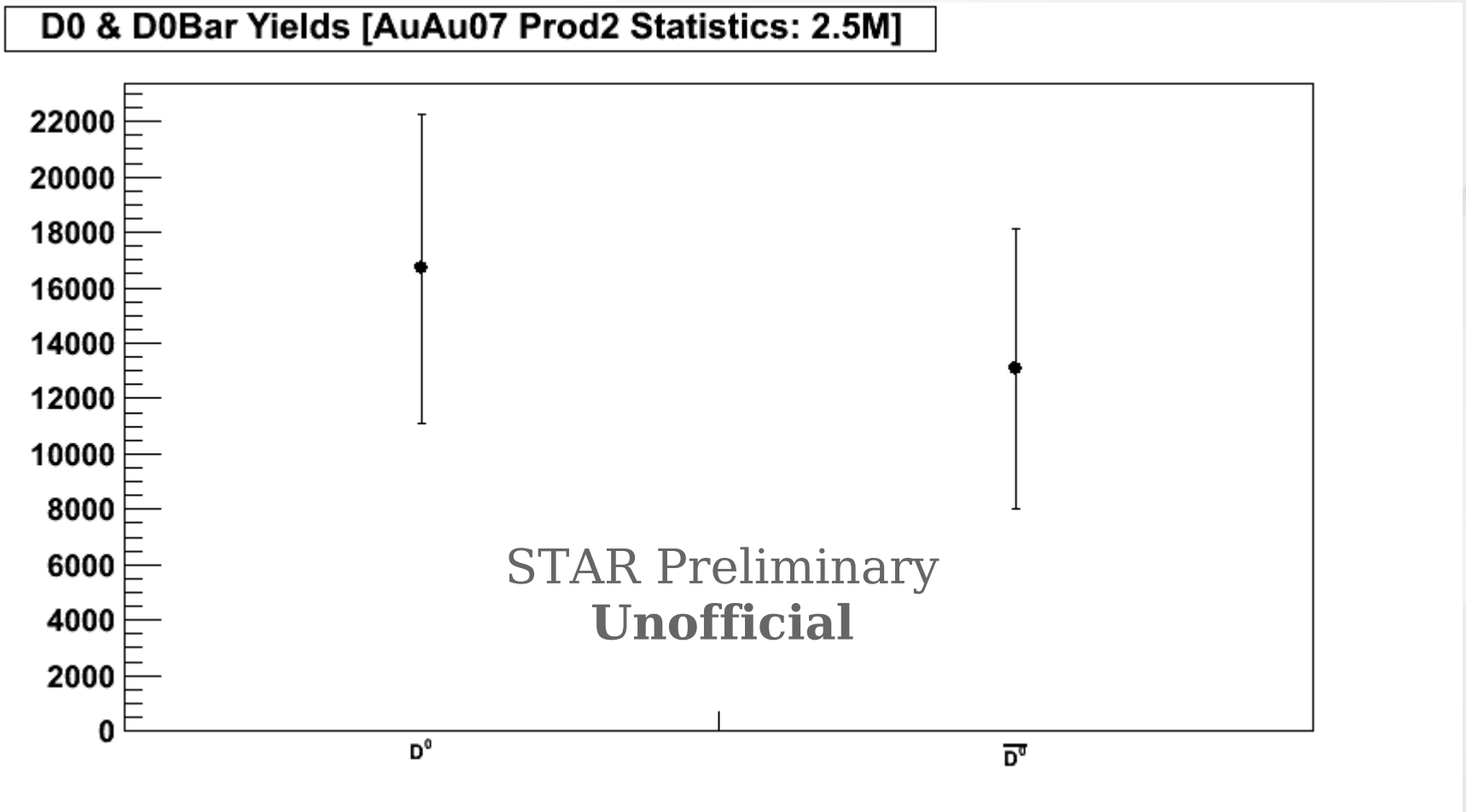
Peak position m = 1891 MeV/c^2
Width of the signal σ_m = 10 MeV/c^2
Signal significance ~2.58





Au+Au 2007 Min Bias

$\overline{D}^0/D^0$ ratio

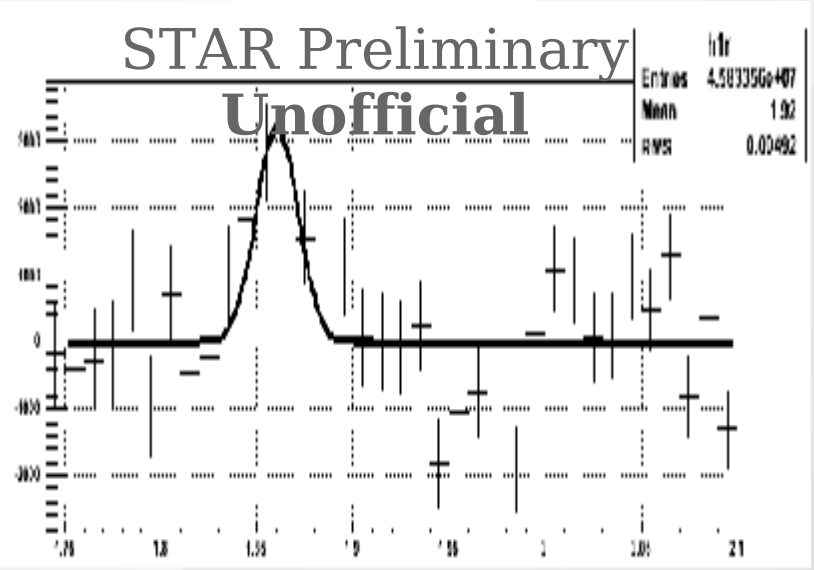


$\overline{D}^0/D^0 = 0.78 \pm 0.40$ (~51%)

Au+Au 2007 Min Bias

Conclusions

- Peak exists only for the first 2.5M events (out of 10M)
  - We are investigating that problem (in collaboration with KSU)
- Ongoing work on D0 embedding
  - First embedding ever with SVT ans SSD
  - Leeds to D^0 yields correction for the MinBias
- A peak for full statistics has been observed (**5.7σ**) which is stable with different cuts
- D0/D0 ratio – first estimate



Outlook

- p+p
  - Analysis of the 2009 data have just started (Increased statistics)
- Au+Au btag
  - Separate analysis for D^0 and $\overline{D}^0$
  - Background improvement (Mixed events)
  - Investigation on the physics behind the yields (EPOS?)
  - Juts launched collaboration with Klaus Werner at al. and WUT group
  - Fit for the secondary vertex
  - Studies in the bins of multiplicity and pT
  - Analysis of the correlation with different opening angles