Study of the J/Ψ production using a TGEANT simulation embedded with the 2015 setup

Programs used in the Monte-Carlo chain

- **Pythia 8.186**

- **TGEANT** *(private branch).* Few modifications were introduced:

  - Inclusion of the detector parameters for the 2015 setup

  - Correction of a bug in the TGEANT-Pythia8 interface *(aborted J/Ψ generations were being stored by TGEANT and, thereafter, causing coral crashes)*

  - Correction of a bug in the event-by-event calculation of $p_x(\pi^-)$, $p_y(\pi^-)$ and $p_z(\pi^-)$

- **CORAL 14146** → version of the 2015 production

- **Phast.7.151**

Settings of Pythia8 for the J/Ψ generation: production processes

- Only 3S1 *(J/Ψ and Ψ')* charmonium states were simulated:
  - Charmonium:qqbar2ccbar(3S1)[3S1(8)]g = on,on → colour octet model
  - Charmonium:qqbar2ccbar(3S1)[1S0(8)]g = on,on → colour octet model
  - Charmonium:qqbar2ccbar(3S1)[3PJ(8)]g = on,on → colour octet model
  - Charmonium:gg2ccbar(3S1)[3S1(1)]g = on,on → colour singlet model
  - Charmonium:gg2ccbar(3S1)[3S1(8)]g = on,on → colour octet model
  - Charmonium:gg2ccbar(3S1)[1S0(8)]g = on,on → colour octet model
  - Charmonium:gg2ccbar(3S1)[3PJ(8)]g = on,on → colour octet model
  - Charmonium:qg2ccbar(3S1)[3S1(8)]q = on,on → colour octet model
  - Charmonium:qg2ccbar(3S1)[1S0(8)]q = on,on → colour octet model
  - Charmonium:qg2ccbar(3S1)[3PJ(8)]q = on,on → colour octet model

Settings of Pythia8 for the J/Ψ generation: PDFs and Phase-Space cuts

- Beam and Target Parameters:
  - Beams:frameType = 3 → implies the specification of px, py and pz
  - Beams:idA = -211 *(π^-)*, Beams:pxA = 0.0, Beams:pyA = 0.0, Beams:pzA = 190.0 *(the momentum components are recalculated by TGEANT for every event)*
  - Beams:idB = 2212 *(p)*, Beams:pxB = 0.0, Beams:pyB = 0.0, Beams:pzB = 0.0

- Beam and Target PDFs *(internal options from Pythia8)*:
  - π^- : GRV 92 L (PDF:piSet=1)
  - P : NNPDF2.3 QCD+QED NNLO alpha_S(M, Z) = 0.119 (PDF:pSet=16)

- Phase-Space cuts:
  - PhaseSpace:pTHatMin = 0.5 → minimum p_T for the hard process
  - PhaseSpace:pTHatMax = 10
  - PhaseSpace:pTHatMinDiverge = 0.5 → extra p_T cut to avoid divergences

Settings of Pythia8 for the J/Ψ generation: k_T description

- The primordial k_T of the hard-scattering partons is parametrised as follows *(tuning from Yu Shiang)*:
  - BeamRemnants:primordialKT = on
  - BeamRemnants:primordialKTsoft = 0.9 → width of sigma_soft assigned as primordial k_T to initiators in the soft interaction limit
  - BeamRemnants:primordialKThard = 1.8 → width of sigma_hard assigned as primordial k_T to initiators in the hard interaction limit
  - BeamRemnants:halfScaleForKT = 1.5 → the scale Q_half defining the half-way point between hard and soft interactions.

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sigma = (sigma_soft * Q_half + sigma_hard * Q) / (Q_half + Q) * m / (m_half + m)
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The k_T's are selected according to Gaussian distributions in p_x and p_y *(Q is the hard-process renormalization scale for the hardest process and the p_T scale for subsequent interactions)*

Settings of Pythia8 for the J/Ψ generation: Parton Showers & J/Ψ decay

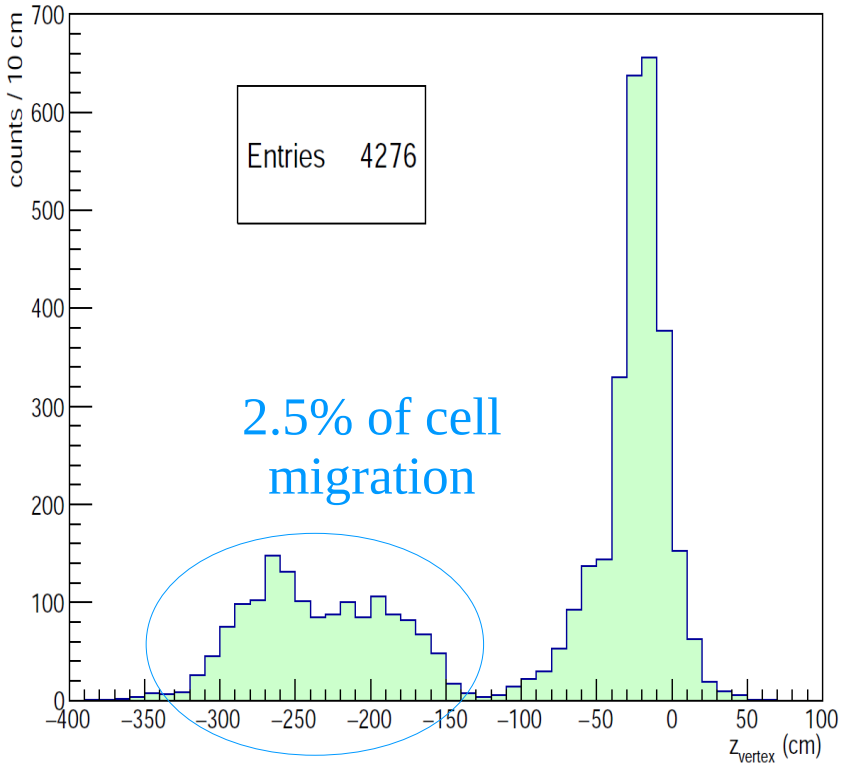
- Multi-parton interactions are allowed but the initial-state and final-state radiations are turned off:
  - PartonLevel:ISR = off
  - PartonLevel:FSR = off

- The J/Ψ's are forced to decay to dimuons:
  - 443:onMode = off → turn off all J/Ψ decays
  - 443:onIfAny = 13 -13 → turn on only the decays to $\mu^+\mu^-$

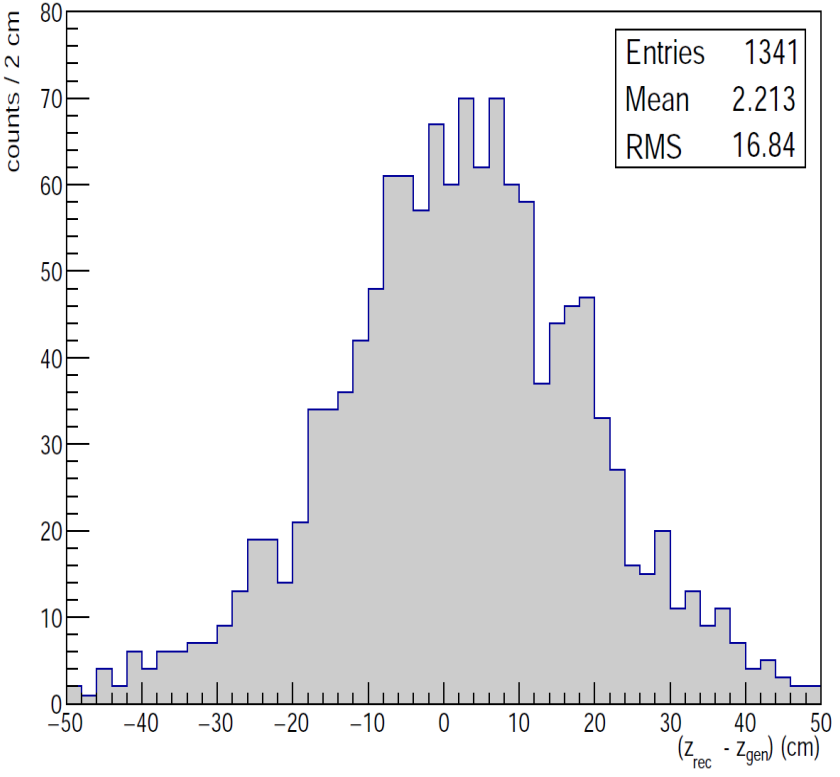
Selection cuts after the J/Ψ reconstruction

Events generated with Pythia8	34000
Events simulated by TGEANT	33898
Simulated events containing J/Ψ's	32447
Simulated J/Ψ's in acceptance	15167 *(acc = 47%)*
Reconstructed dimuons *(with PID)*	13566 ($\varepsilon_{\mu+\mu-}$ = *89%)*
Dimuons sharing the same vertex	4344 ($\varepsilon_{J/\Psi}$ = *29%)*
$Z_{vert} \in]-295, -240[\quad \| \quad Z_{vert} \in]-220, -165[$	1116
$Z_{first} < 300$ cm $\quad \& \quad Z_{last} > 1500$ cm	1082
$\lvert T_{\mu+} - T_{\mu-} \rvert < 5$ ns	1081
Trigger: LAST-LAST, LAST-Outer, LAST-Middle	902
χ^2_{μ} /ndf < 10	902
$x_1 \in]0, 1[\quad \& \quad x_2 \in]0, 1[\quad \& \quad x_F \in]-1, 1[$	900
$R_{vertex} < 1.9$ cm	694
$pT_{dimuon} \in]0.5, 5[$ GeV/c	597
$P_{\mu} > 7$ GeV/c	596
$P_{\mu+} < (180 \times p_{\mu-}) \quad \& \quad \theta_{\mu+} \in]0.2\times\theta_{\mu-}, 5\times\theta_{\mu-}[$	557

Vertex distribution and resolution: no cuts applied



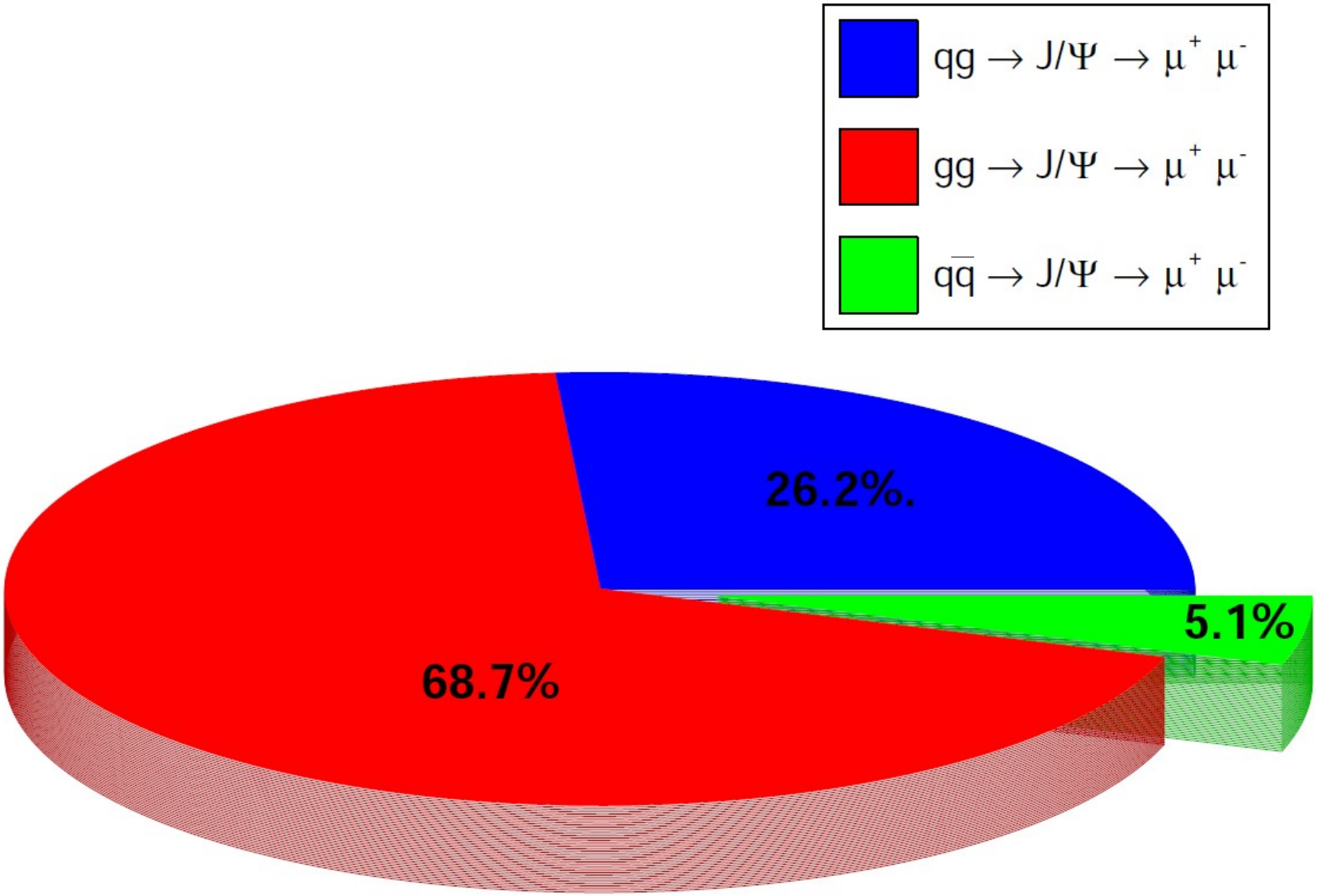
Only J/Ψ's from ammonia



23% of the reconstructed J/Ψ"s, generated in the ammonia cells, are reconstructed outside the target volume

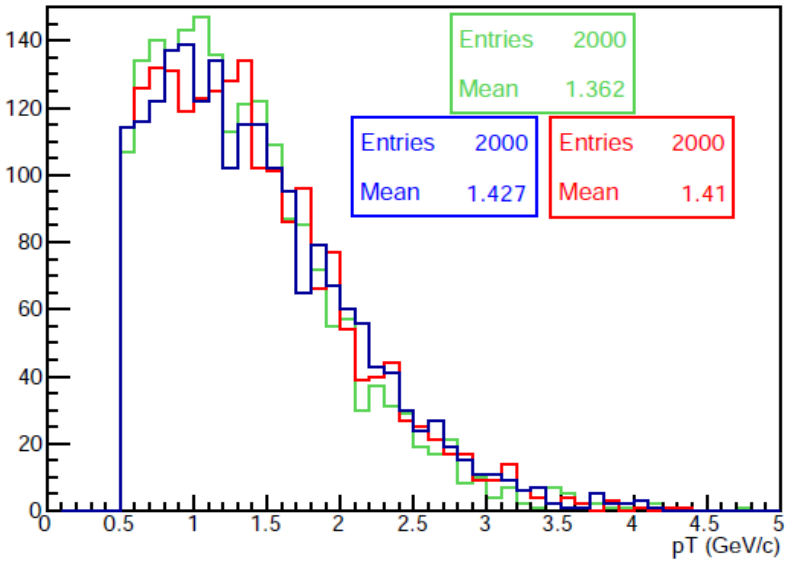
Production processes contributing to the reconstructed J/Ψ's

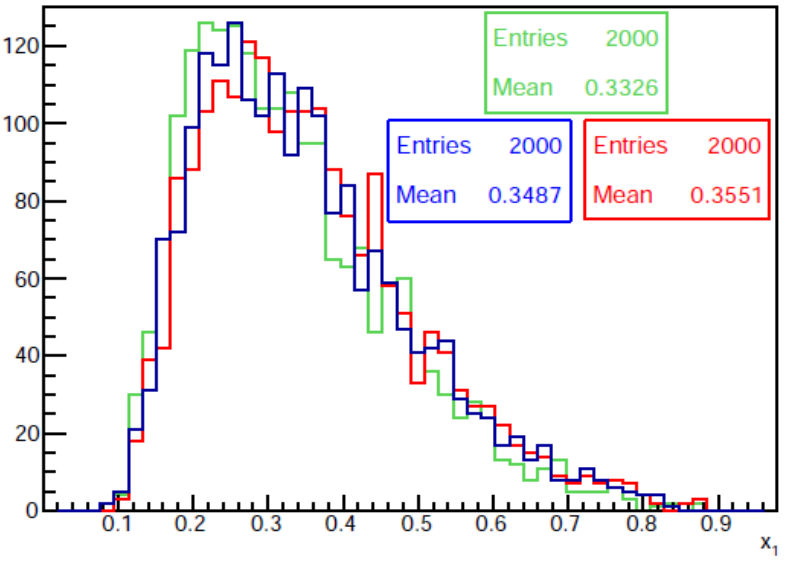
(using the colour octet model)

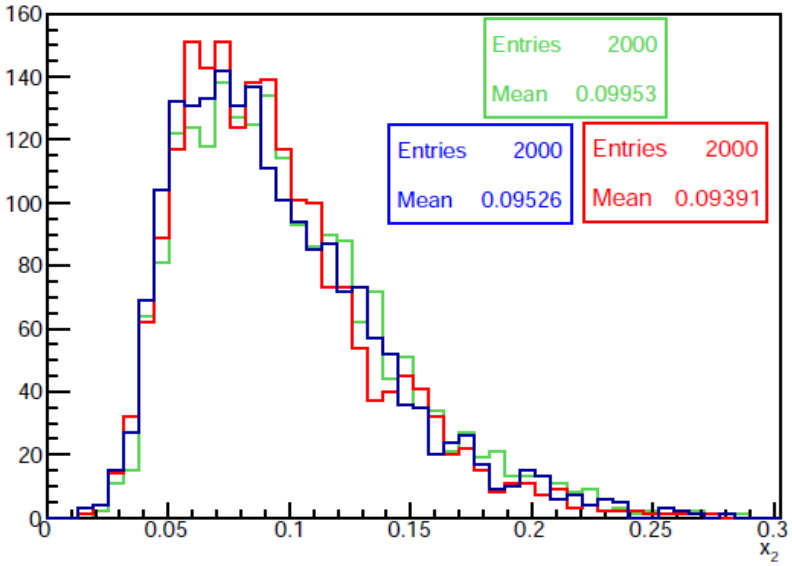


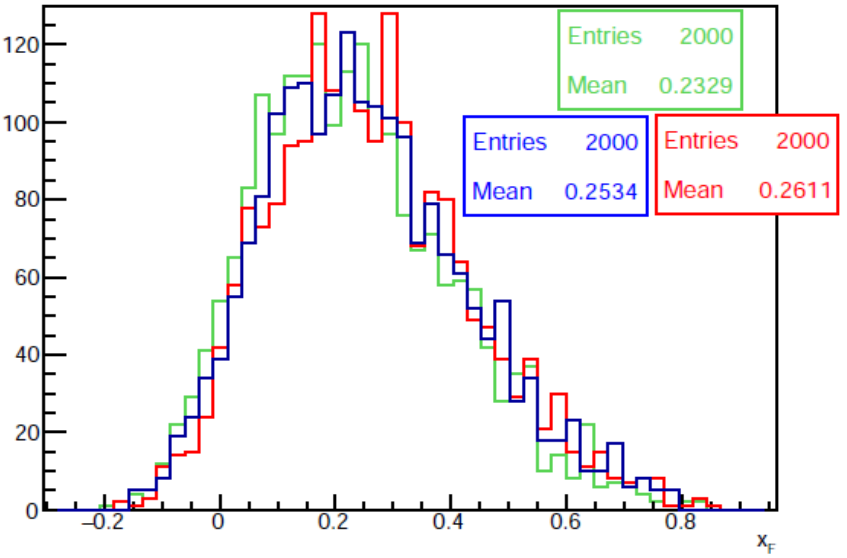
Kinematic distributions of the generated J/Ψ's: after reconstruction

J/Ψ's produced by $q\bar{q}$, gg and qg processes (*all cuts but Z_{vertex} are applied*):



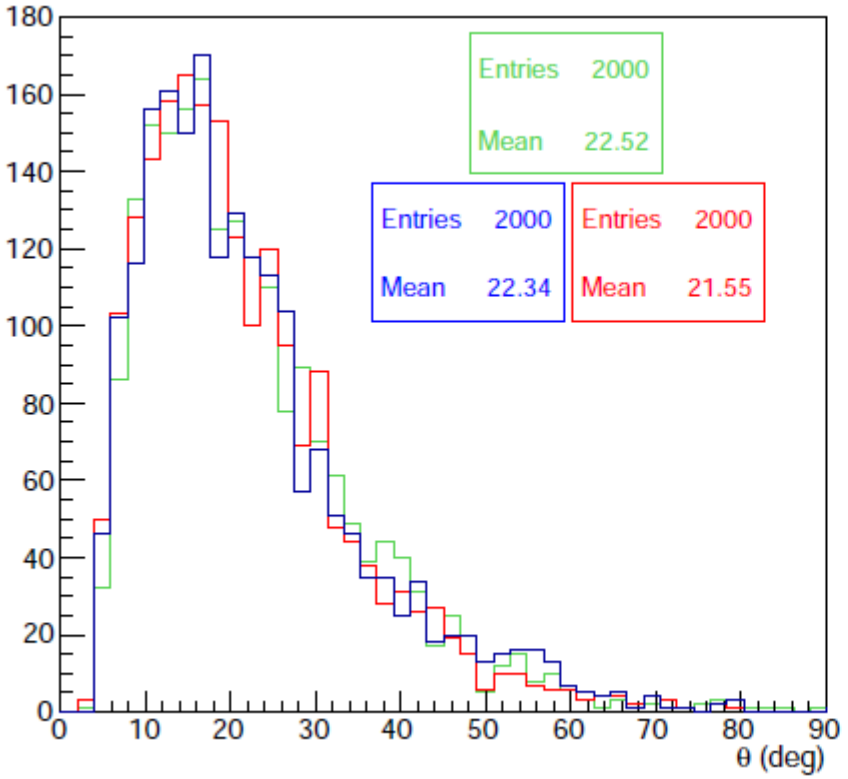




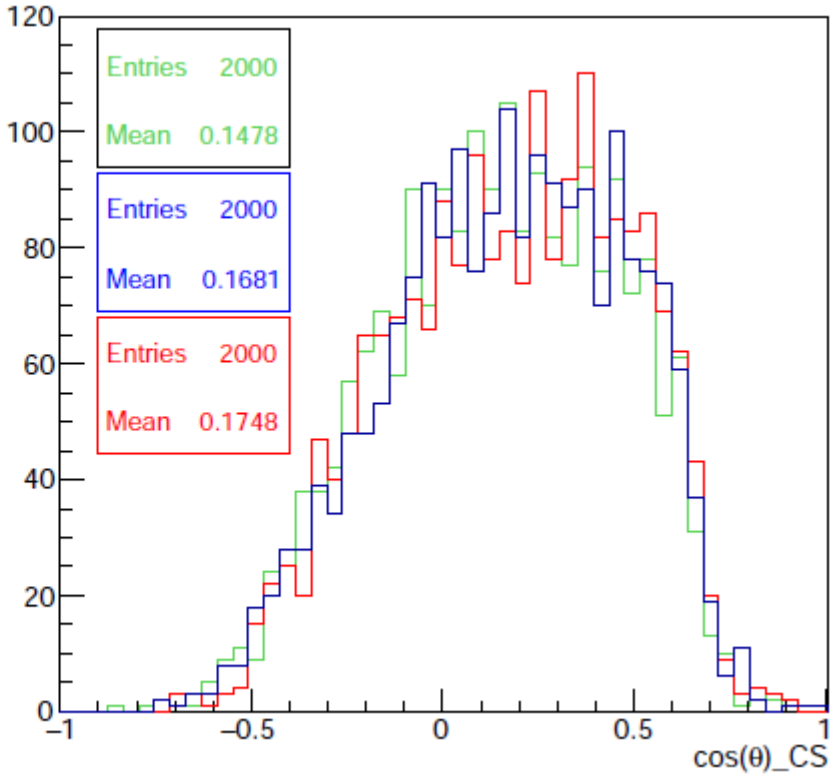


Angular distributions after the dimuon reconstruction

J/Ψ

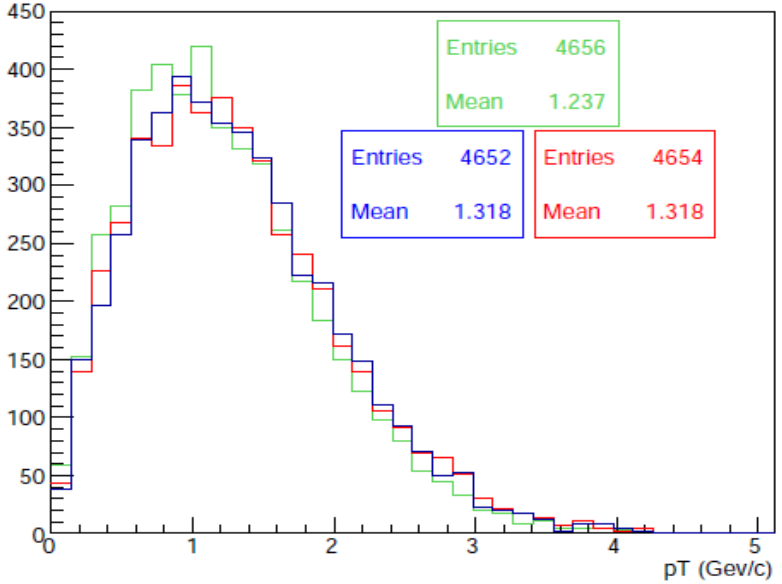


μ^-

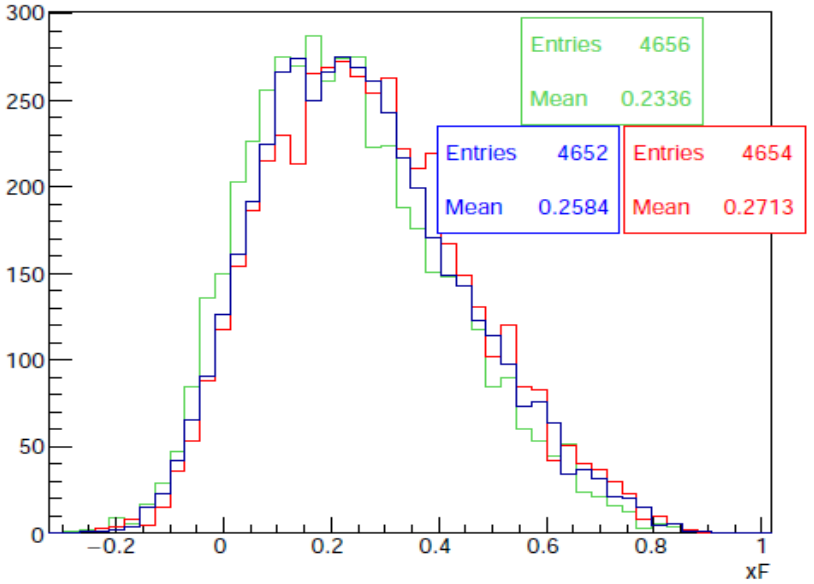


Kinematic distributions of the generated J/Ψ's: after reconstruction

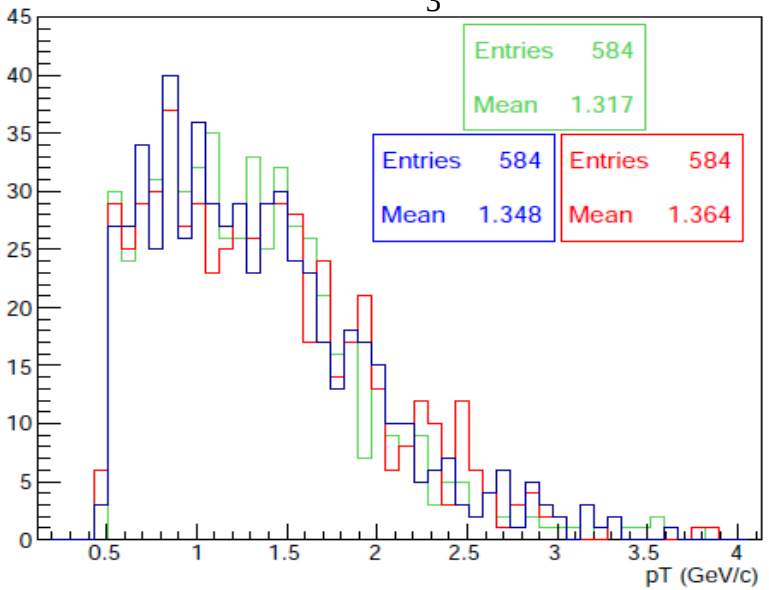
Without cuts



Without cuts



From NH_3 + cuts



From NH_3 + cuts