First year J/Ψ measurement in the barrel

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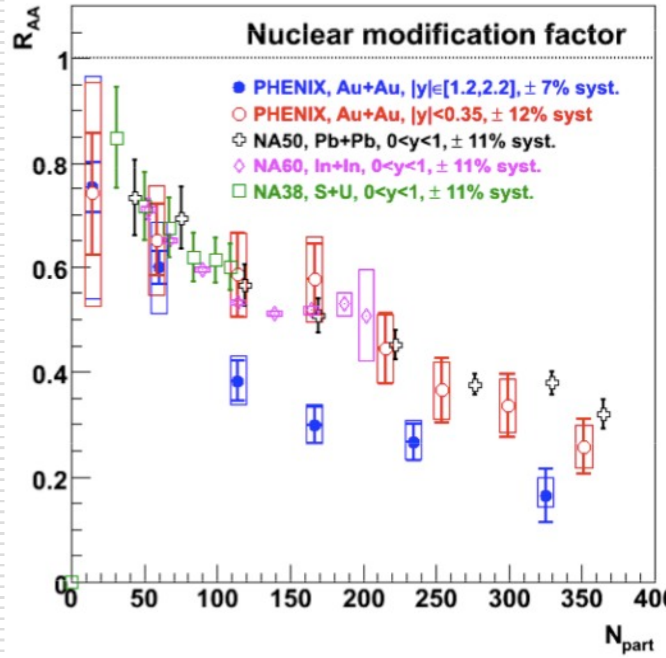
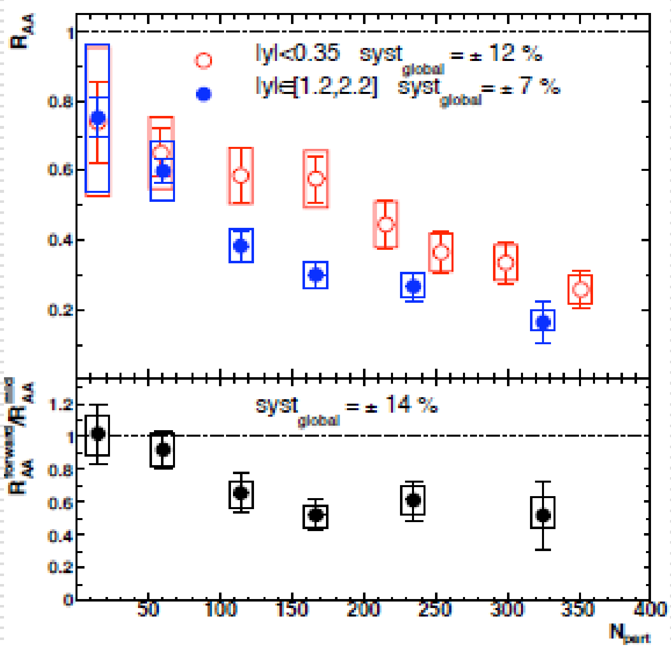
Outline:

- Introduction and motivations.
- Expected total J/Ψ yield in the first year.
- How to measure the J/Ψ feed-down from B-hadrons.
  - Performance plots in one year
- B-hadron cross-section from $J/\Psi(\leftarrow B)+X$ p_T spectrum
  - Results with different statistics.

J/Ψ puzzle in heavy-ion collision

- Suppression at RHIC looks surprisingly similar as SPS, while there are obviously differences
  - Factor of 10 higher collision
    - different energy densities at a given N_{part}
  - Cold nuclear matter effects

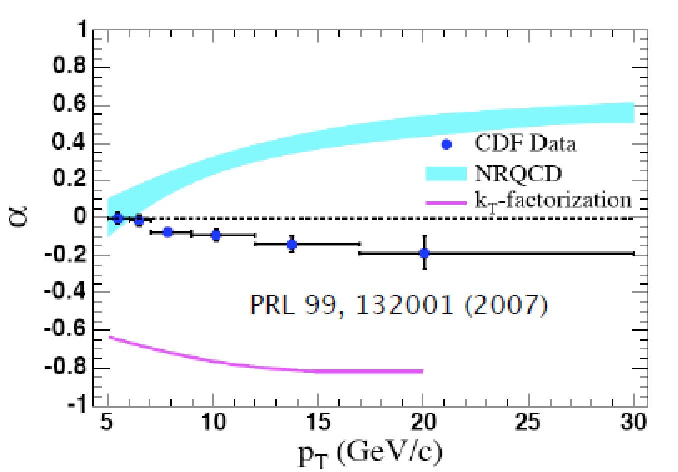


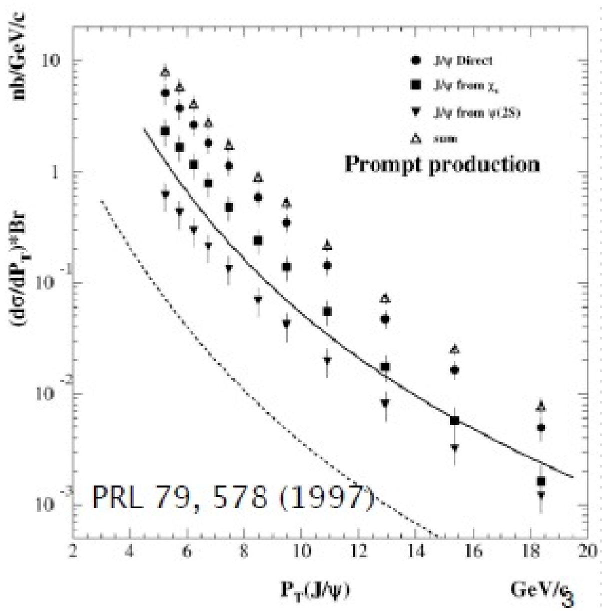


- More J/Ψ suppression at forward rapidity
  - dissociation mechanisms should increase the suppression at mid-rapidity due to the large energy densities
  - regeneration effect? (larger charm content in the medium)

J/Ψ in p+p collisions

- Theoretical model and issue for prompt J/Ψ:
  - CMS (Color Single Model)
    - LO, NLO, NNLO
    - Under-predict cross-section
  - COM (Color Octet Mechanism):
    - Non Relativistic QCD (NRQCD)
    - can explain cross-section but not polarization
  - recent new singlet model seems to get both correct:
    - Haberzzetl, Lansberg, PRL 100, 032006 (2008)
    - still over-estimate at forward rapidity





Prompt and Secondary J/psi

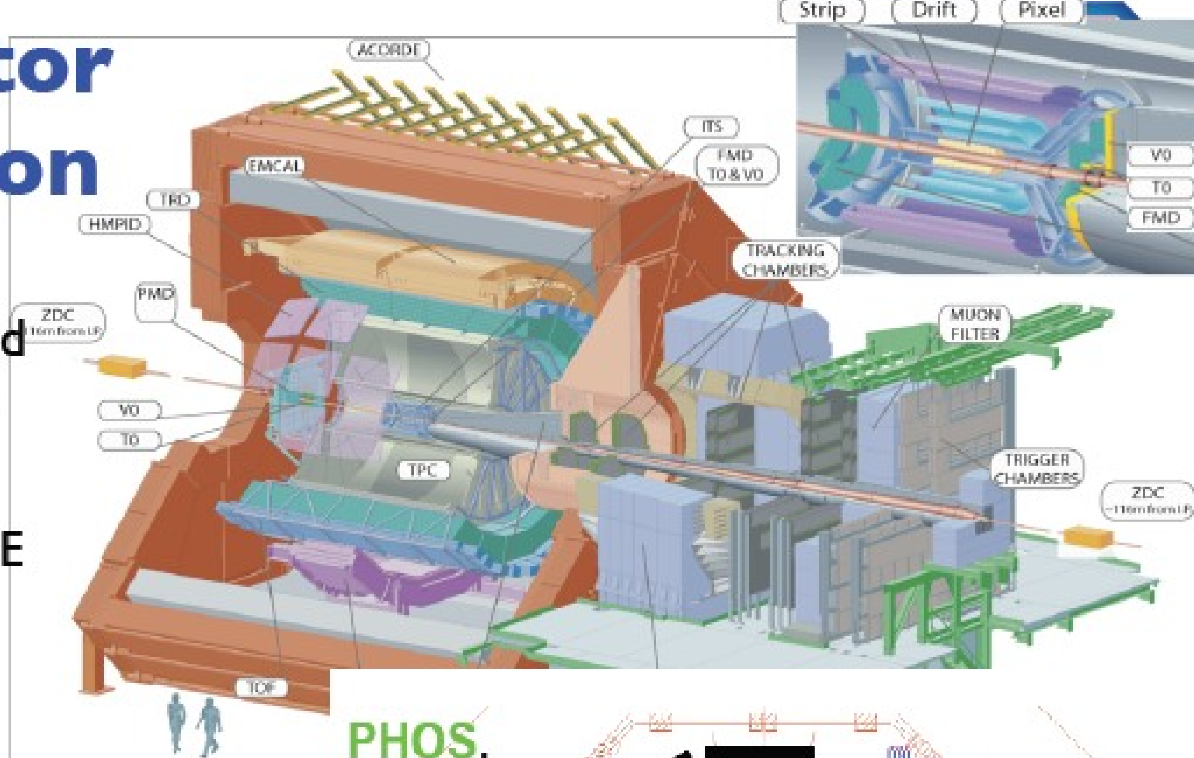
- J/Ψ production at LHC dominated by :
  - *Prompt* J/Ψ $\Leftrightarrow$ *direct* J/Ψ + J/Ψ from higher mass resonances.
  - Non-prompt (secondary) J/Ψ from Beauty-hadrons decay.

- Measurement of the total J/Ψ cross section:
  - Requires electron PID using ALICE TPC+TRD detectors.

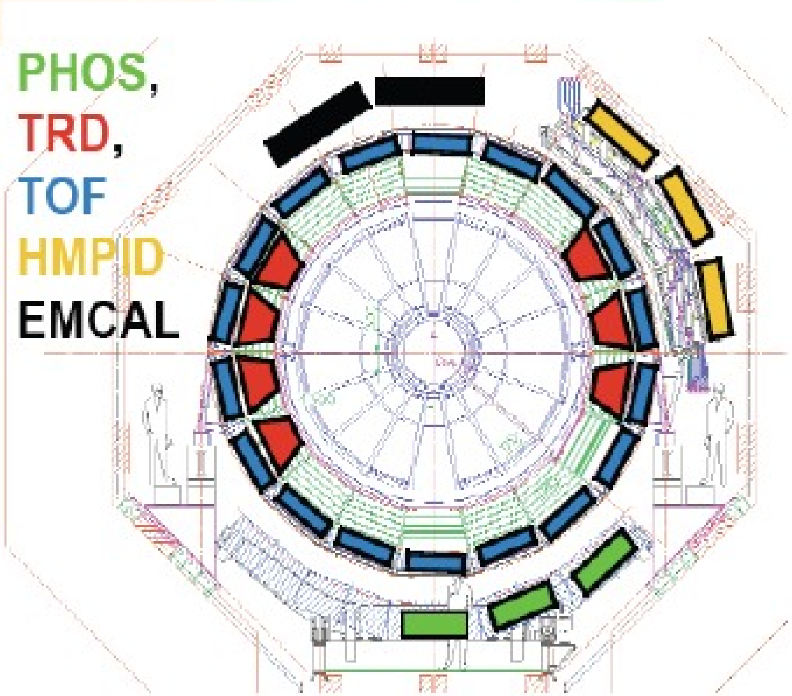
- Measurement of prompt J/Ψ cross section:
  - Needs to extract from the total J/Ψ cross section the J/Ψ contribution from B-hadrons ("feed-down" from B-hadrons).
- Measurement of secondary J/Ψ from B-hadrons decay:
  - Allows to extract the B-hadron differential cross section $d\sigma/dp_T(B)$.

ITS required

2009 Detector Configuration

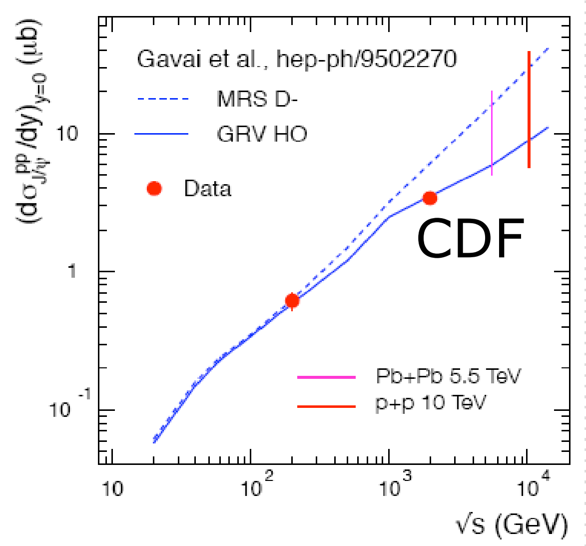


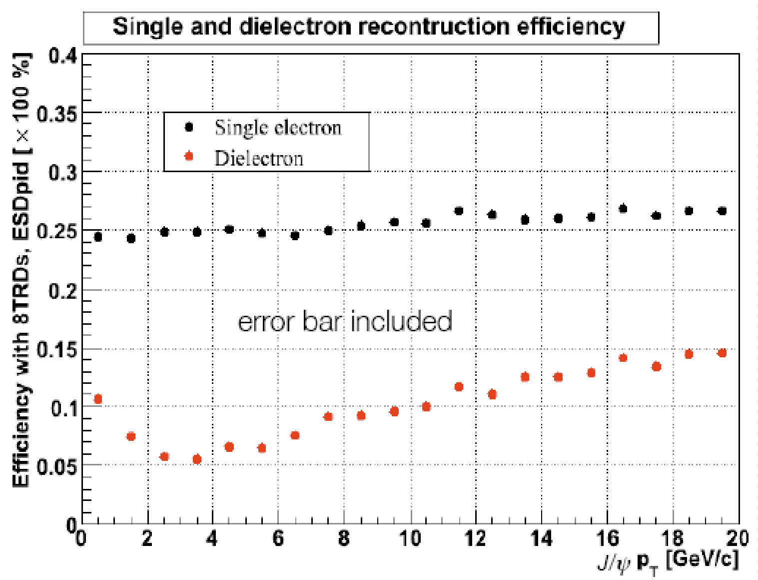
- Fully installed & commissioned
  - ITS, TPC, TOF, HMPID, PMD
  - MUON spectrometer,
  - V0, T0, FMD, ZDC, ACORDE
  - DCS, DAQ
- Partially completed
  - HLT (70%) completed 2010
  - TRD (40%) completed 2010
  - PHOS (60%) completed 2011
  - EMCAL (33%) completed 2011
- **At start-up full hadron and muon capabilities**
- **Partial electron and photon capabilities**



Expected total J/Ψ yield in the first year

- Given:
  - J/Ψ dσ/dy @ √s=10TeV = 4.4 μb up to 10 μb (extrapolation from Tevatron data)
  - LHC integrated luminosity: = (10^9/70 mb) ~15 pb^{-1}
  - J/Ψ → e+e- branching ratio: 5.93 %
  - J/Ψ efficiency with 8 TRDs: 10.3 %
  - TRD acceptance |η| < 0.9

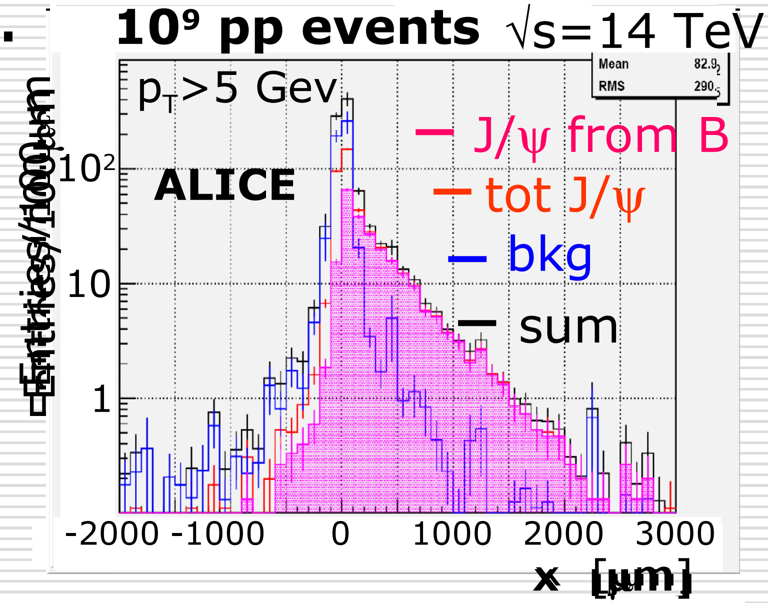




→ # of J/Ψ counts ~ 600-1600 in the first year

How to measure the fraction of J/Ψ from B-hadrons decay

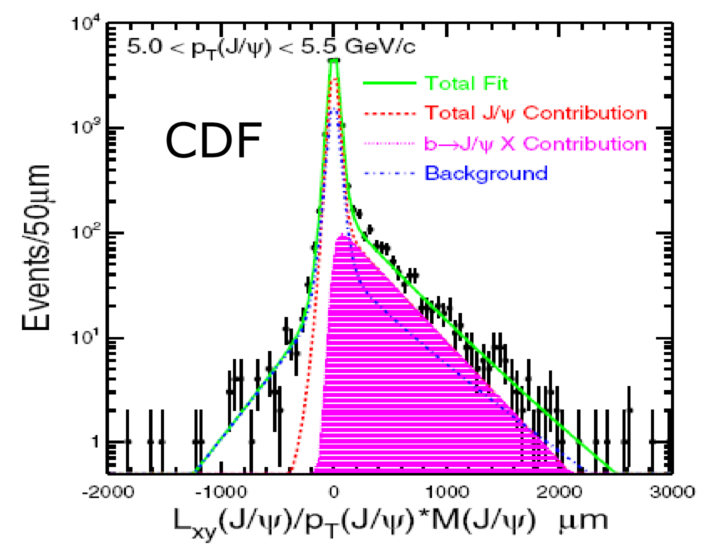
- Basic idea: J/Ψ from B is likely to be displaced from the primary vtx where B-hadrons are produced (dislaced $J/\Psi(\rightarrow ee)$).



- Analysis is based on a simultaneous 2D fit of
  1. the invariant mass spectrum
  2. an "impact parameter" to separate prompt from detached J/ψ, e.g. pseudo-proper decay time (à la CDF)

  D.Acosta et al Phys. Rev. D 71 (2005) 032001

$$x = \boxed{L_{xy}(J/\psi)}\,\frac{M_{J/\psi}}{p_T(J/\psi)}$$



- This measurements can allow a determination of the $d\sigma_{bb}/dp_t$ cross-section down to $p_t \approx 0$ (→ see 2nd part)

$$L_{xy}(J/\psi) = \frac{\boxed{\vec{L}}\cdot\vec{p}_T(J/\psi)}{|p_T(J/\psi)|}$$

$$\boxed{\vec{L} = \vec{r}^{\,sec}_{vtx} - \vec{r}^{\,prim}_{vtx}}$$

- Approach used: simultaneous mass and lifetime fit using the ***log-likelihood*** function:

$$\ln L = \sum_{i=1}^{N} \ln \mathrm{F}(x, m_{ee})$$

$$\mathrm{F}(x, m_{ee}) = \underbrace{f_{Sig} \times F_{Sig}(x) \times M_{Sig}(m_{ee})}_{\text{"Signal" part (prompt + secondary)}} + \underbrace{(1 - f_{Sig}) \times F_{Bkg}(x) \times M_{Bkg}(m_{ee})}_{\text{"Background" part}}$$

$F_{sig}(x)$, $F_{bkg}(x)$, $M_{sig}(M)$, $M_{bkg}(M)$ are the invariant mass and x distribution functions for the signal and bkg part

From the fit: $f_B(p_T)$ "fraction of J/y from B" as a function of $p_T(J/\Psi)$

- more in detail…

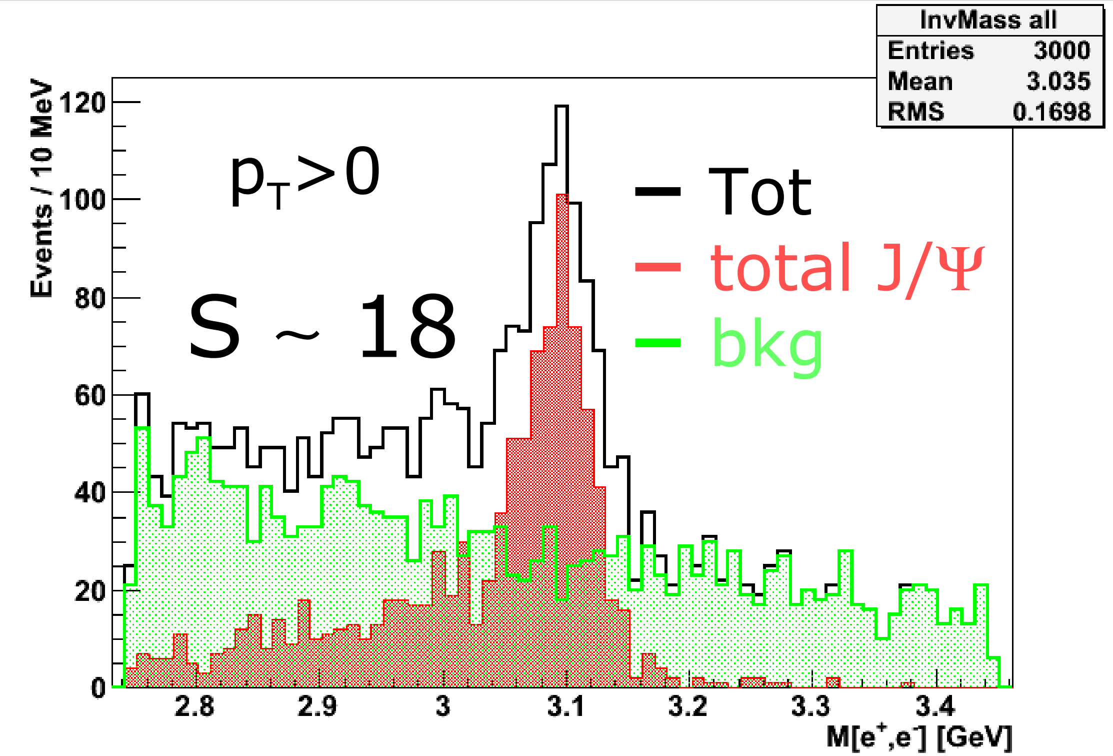
$$F(x, m_{ee}) = f_{Sig} \times F_{Sig}(x) \times M_{Sig}(m_{ee}) + (1 - f_{Sig}) \times F_{Bkg}(x) \times M_{Bkg}(m_{ee})$$

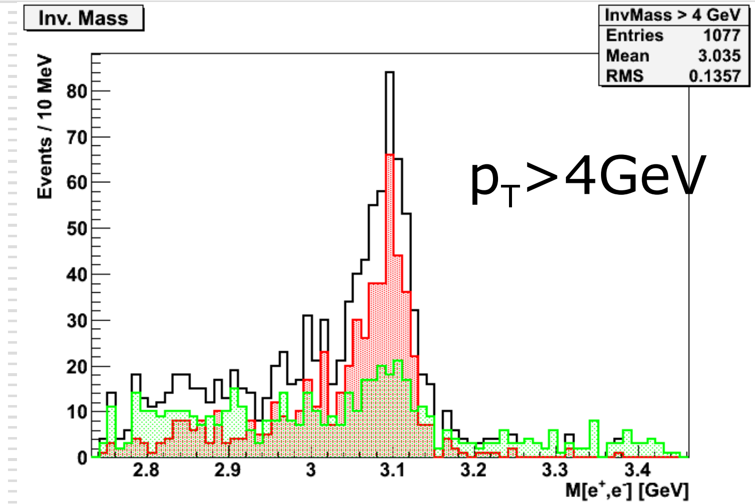
- $F_{Sig}(x) = \left[f_B \times F_B(x) + (1 - f_B) \times F_P(x) \right]$
- $F_P(x) \equiv R(x)$ detector resolution function for primary J/Ψ (since they originate from the primary vtx)
- $F_B(x) = R(x - x') \otimes \chi_{MC}(x')$ χ_{MC} $(x, p_T(J/\Psi))$ MC templates (as obtained by PYTHIA) of the x distribution

- method relies on proper parametrisation of R(X) (⇔ good knowledge of detector response) and $M(m_{ee})$ (since m_{ee} distribution is asymmetric due to breemsstrhalung effect in the material).

Performance plot in the first year

- assuming ~ 1000 total J/Ψ in pp
  - Invariant mass

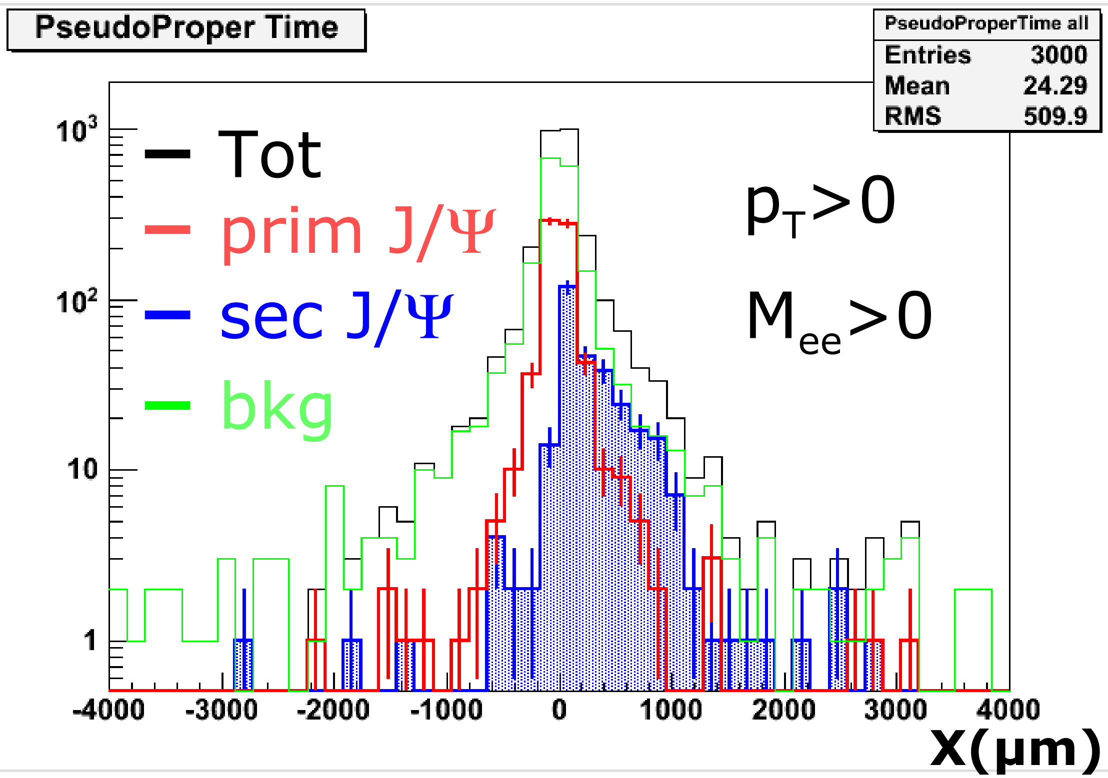


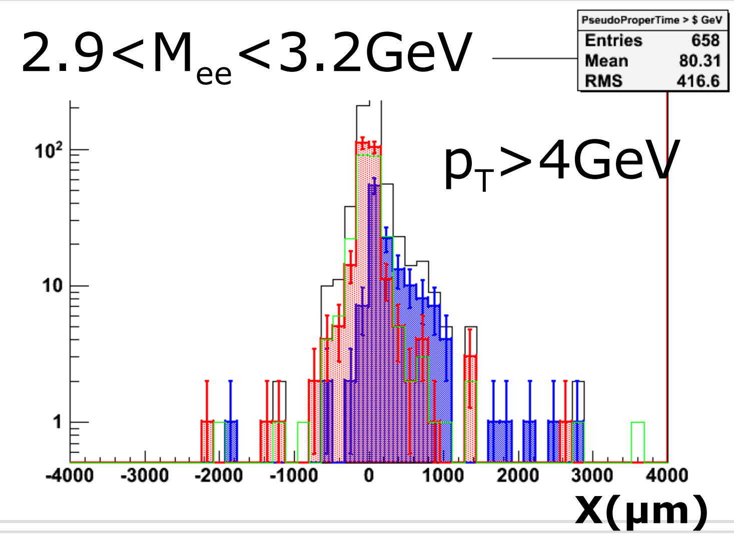


- PDC09 Grid data LHCO9a4(MB), LHC09a7(prompt J/Ψ)
- PDC08 Grid data LHC08s(sec J/Ψ)

Performance plot in the first year

- Pseudo-proper decay time





- PDC09 Grid data LHCO9a4(MB), LHC09a7(prompt J/Ψ)
- PDC08 Grid data LHC08s(sec J/Ψ)

From $\left.\frac{d\sigma^{pp\to J/\psi_{tot}+X}}{dp_t dy}\right|_{|y|<1}$ to $\left.\frac{d\sigma^{pp\to B+X}}{dp\,dy}\right|_{|y|<1}$

- Assuming to have measured the differential total J/Ψ cross section and the fraction of f_B of secondary J/Ψ, the differential B-hadrons cross section would be given, as a function of p_T(J/Ψ):

$$\frac{d\sigma(pp\to B+X)}{dp_T(J/\psi)}\cdot Br(B\to J/\psi+X')\cdot Br(J/\psi\to e^+e^-)$$

$$= f_B\frac{d\sigma(pp\to J/\psi_{tot}+X)}{dp_T(J/\psi)}\cdot Br(J/\psi\to e^+e^-)$$

- Finally the differential cross section as function of pT(B) can be derived.

How to extract the B-hadron cross-section from $J/\Psi(\leftarrow B)+X$ p_T spectrum

Introduction

- The method allows to extract dN/dp_T (or $d\sigma/dp_T$) for Beauty hadrons starting from the measured dN/dp_T (or $d\sigma/dp_T$) spectra of secondary J/ψ

It is based on Monte Carlo and relies on the fact that the B-hadron decay kinematics, studied in several experiments, is well understood

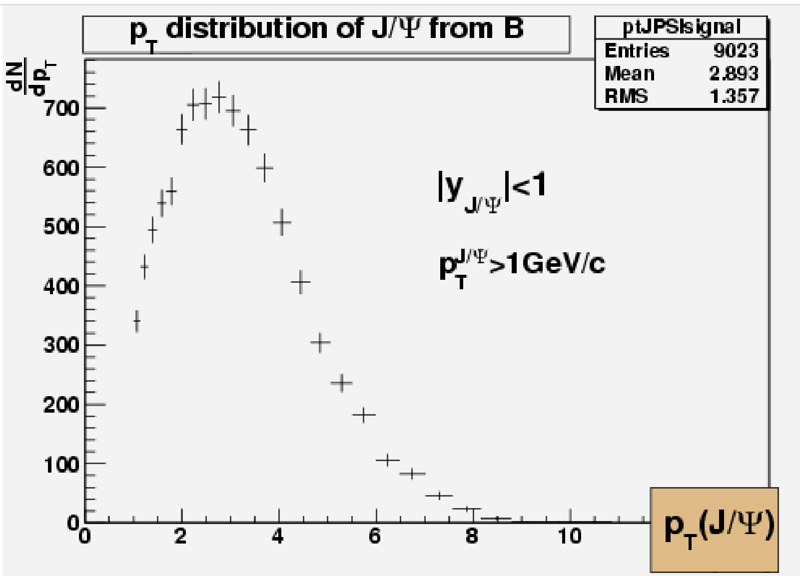
UA1 (1988) (semi-muonic channel)
ALICE in p-p e Pb-Pb (semi-leptonic channels)
D0 (semi-muonic channel)

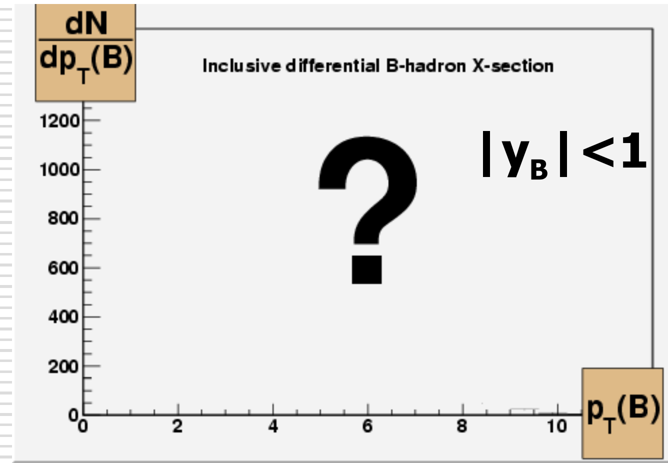
$\rightarrow \boxed{\dfrac{dN}{dp_T^{MIN}(B)}}$

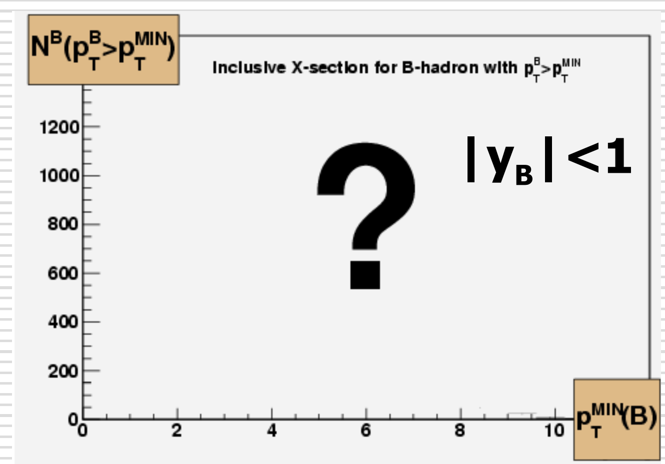
CDF (2005) (channels B→J/**Ψ**+X) $\rightarrow \boxed{\dfrac{dN}{dp_T(B)}}$

Task

- the starting point is the spectrum of secondary (i.e. detached) J/Ψ







Differential B-hadron X-section: from $p_T(J/\Psi)$ to $p_T(B)$ spectrum

the w_{ij} and f_i are calculated from Monte Carlo simulation and are used to weight the entries of each $p_T(J/\psi)$ bin

Content of j-th $p_T(J/\psi)$ bin of the X-section

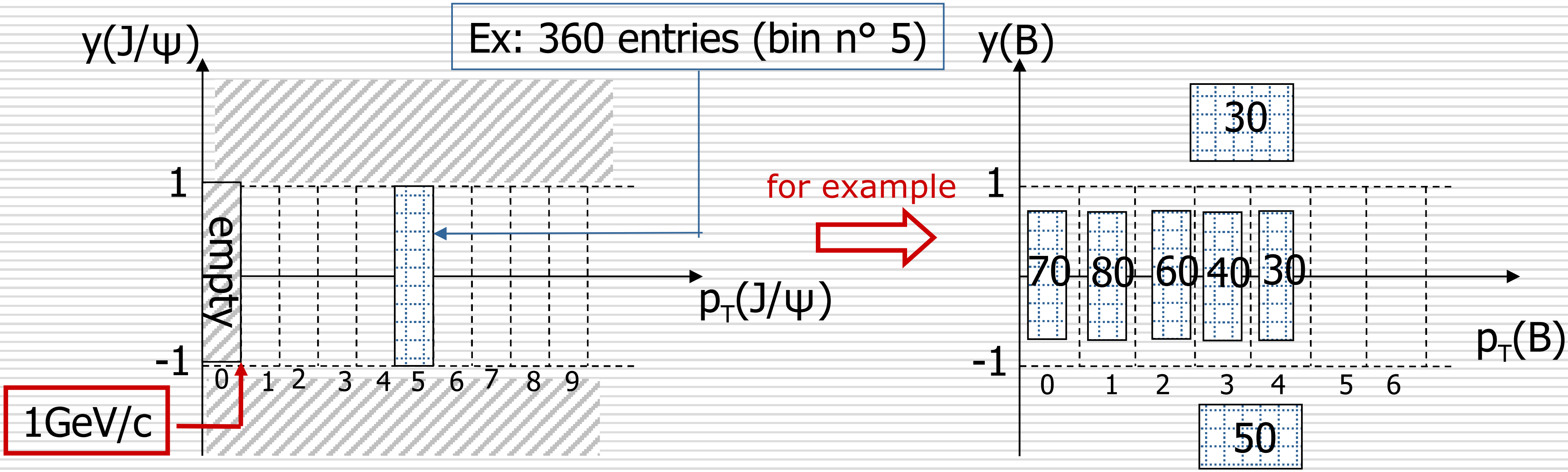
$$\frac{d\sigma(pp \to B + X, B \to J/\Psi + X)}{dp_T(J/\psi)}$$

$$\sigma_i(B) = \frac{\sum_{j=1}^{N} w_{ij}\sigma_j(J/\psi)}{f_i} = \frac{\sigma_i^{RAW}}{f_i}$$

Acceptance correction factor

Content of i-th bin of $p_T(B)$ of the X-section $\frac{d\sigma(pp \to B + X, B \to J/\Psi + X)}{dp_T(B)}$

- Each w_{ij} gives the relative contribution to the $p_T(B)$ distribution in the i-th bin from secondary J/ψ mesons that are in the j-th $p_T(J/\psi)$ bin and in the y range where J/ψ are measured



- The f_i (<u>acceptance correction factor</u>) is the fraction of bottom hadrons in the i-th $p_T(B)$ bin that give rise to a J/ψ in the range of p_T and rapidity where J/ψ are detected

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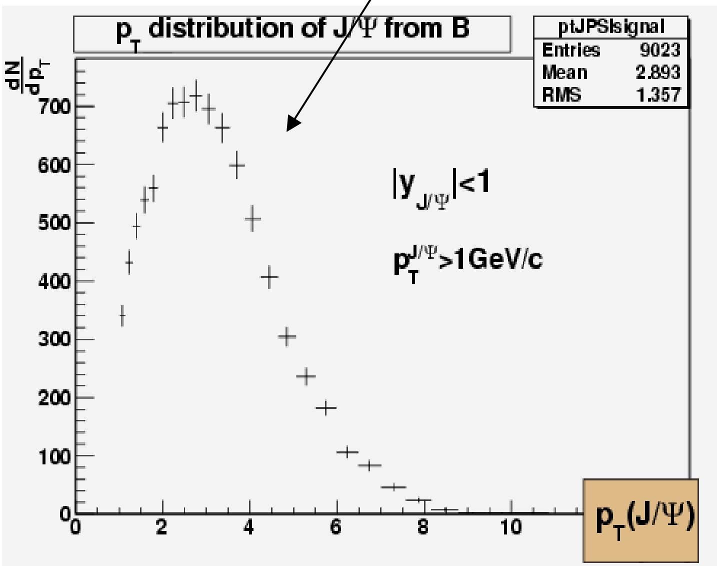
from $p_T(J/\Psi)$ to $p_T(B)$

- Data sample used: 100k pp events @ 10 TeV with 1 bbbar/ev (only kinematics)

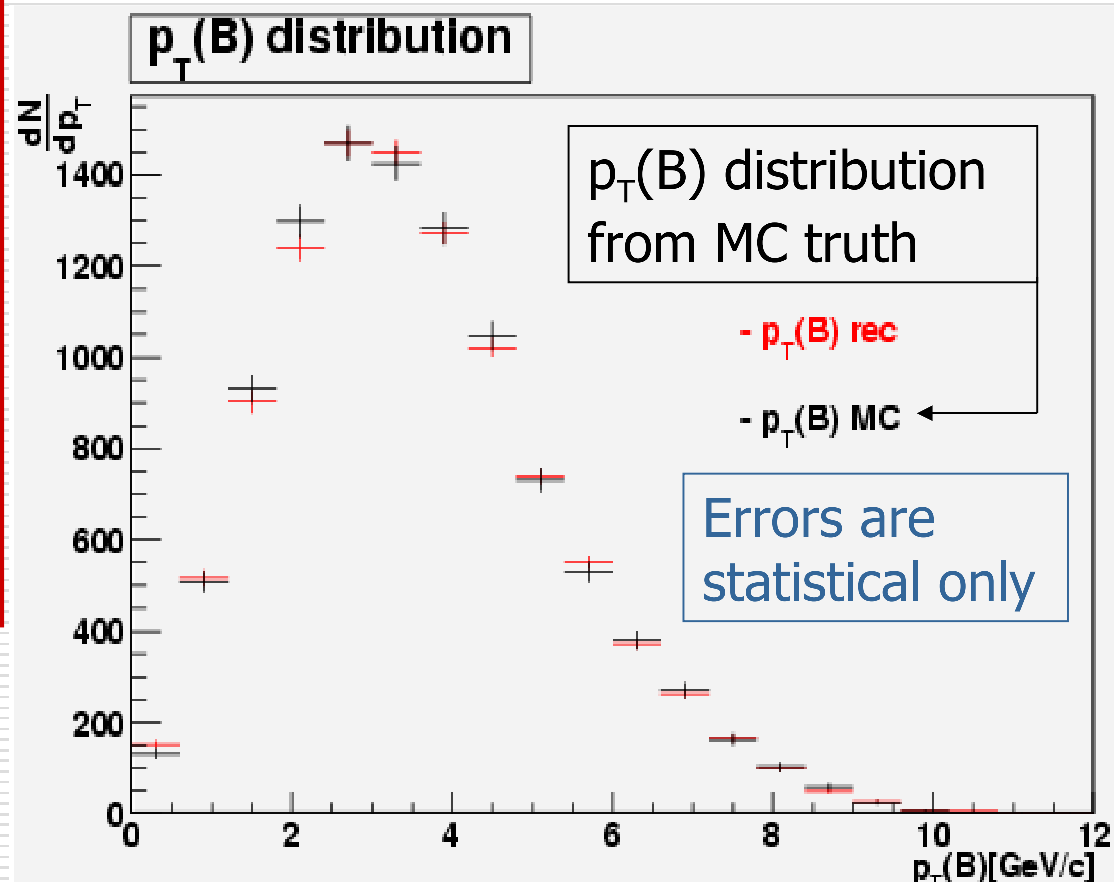
Extracted on 20K events

$$\sigma_i(B) = \frac{\sum_{j=1}^{N} w_{ij}\sigma_j(J/\psi)}{f_i} = \frac{\sigma_i^{RAW}}{f_i}$$



$$w_{ij} + f_i$$

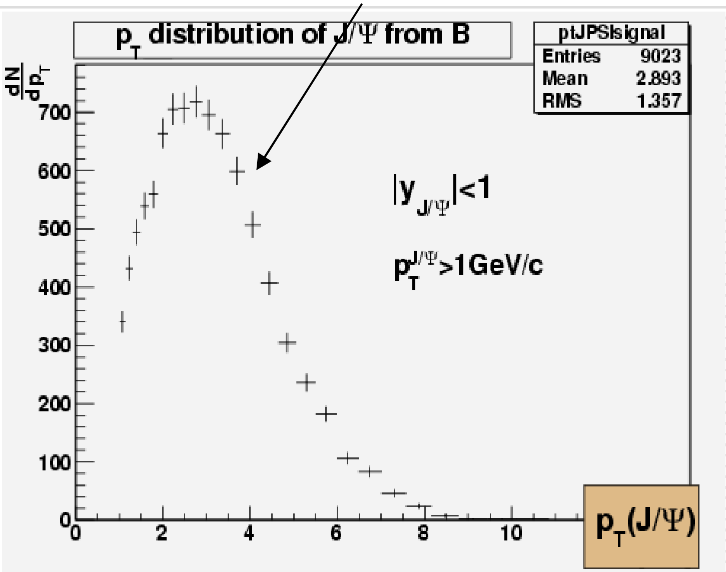
correction factors evaluated on 80K events



from $p_T(J/\Psi)$ to $p_T^{MIN}(B)$

- Data sample used: 100k pp events @ 10 TeV with 1 bbbar/ev (only kinematics)

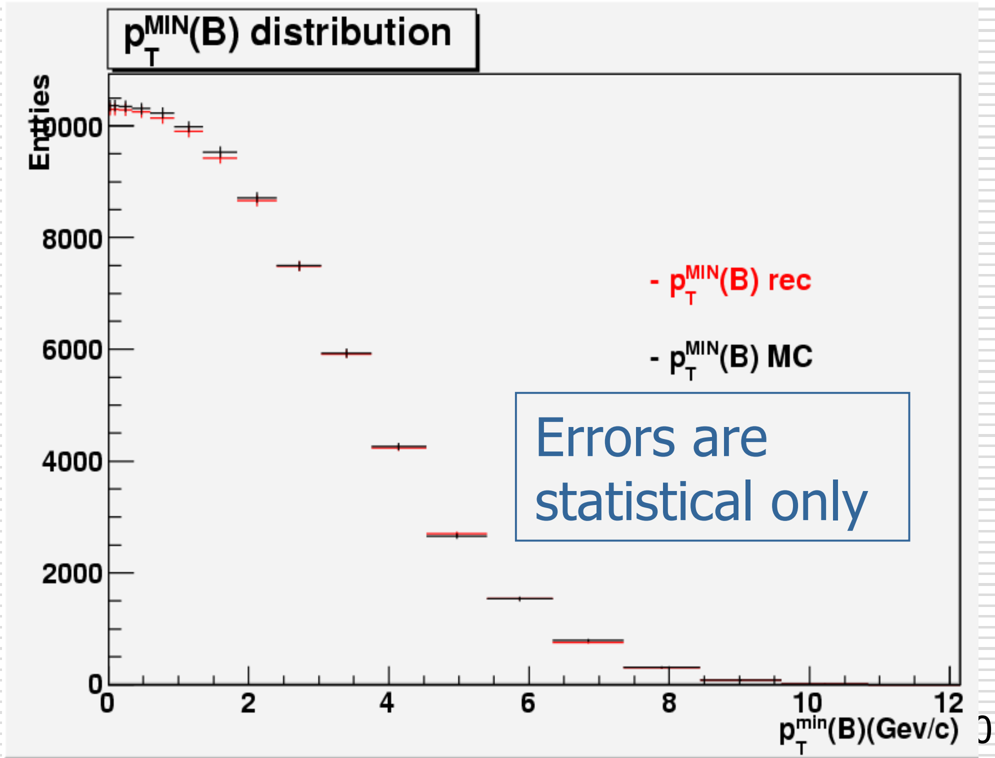
Extracted on 20K events



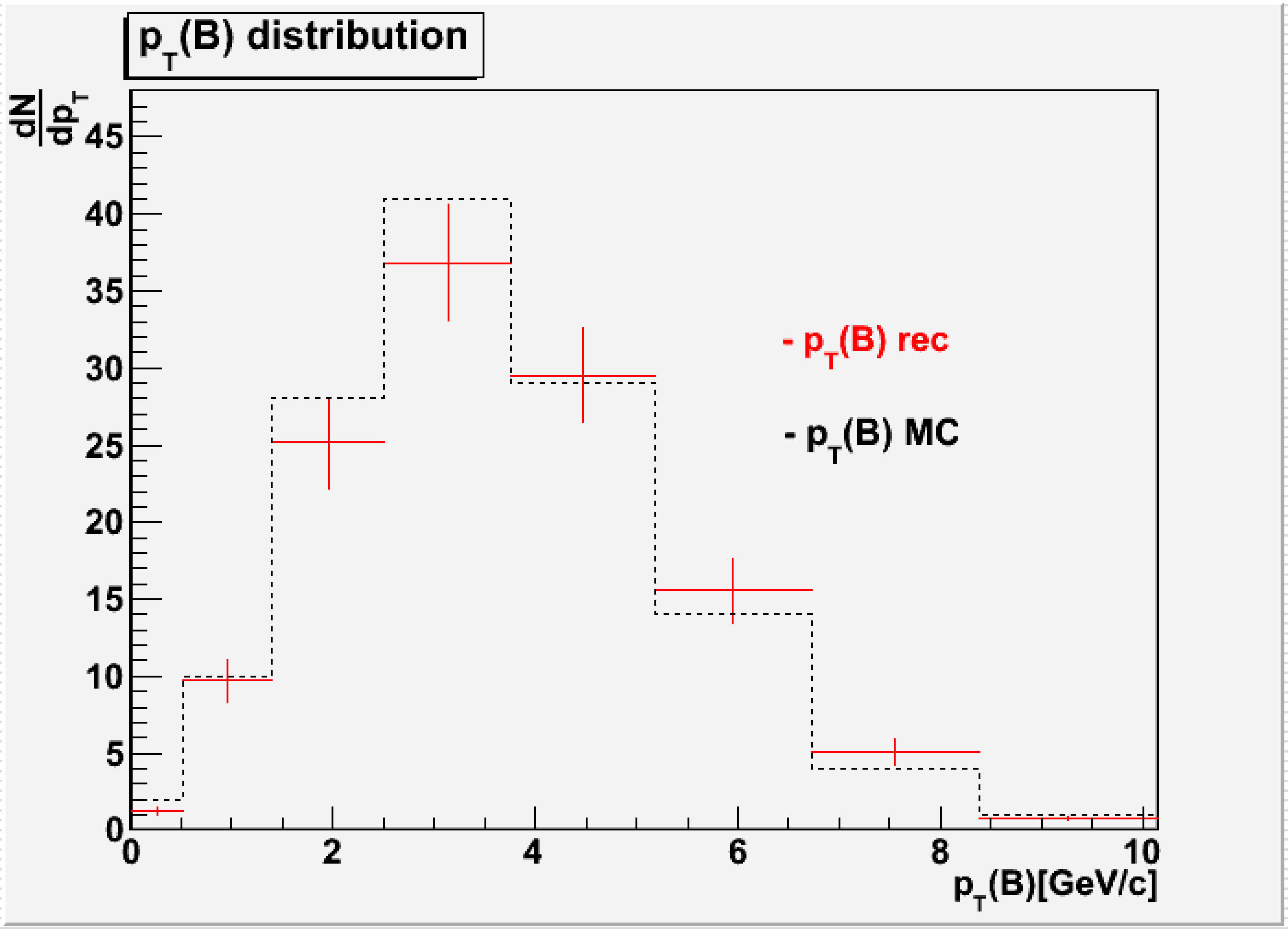
$$w'_{ij} + f'_i$$

correction factors evaluated on 80K events

$$\sigma_i^{MIN} = \frac{\sum_{j=1}^{N} w'_{ij}\,\sigma_j(J/\psi)}{f'_i} = \frac{\sigma_i^{MIN}{}_{(RAW)}}{f'_i}$$



Result for the first year



Systematic errors

1. (main?): systematic error from measured $p_T(J/\psi)$ distribution

CDF: weighted sum of systematic errors from the $p_T(J/\psi)$ spectrum

$$\boxed{\delta_{syst}^{\sigma_i^B} = \frac{1}{f_i} \sum_j w_{ij} \delta_{syst}\left(\sigma_j\left(J/\Psi\right)\right)}$$

2. systematic error from the method (not considered by CDF)
   - Relative fractions of B-hadrons in MC
   - Shape of $p_T(B)$ spectrum used in MC simulation
   - Decayer used in the simulation
     - Decay model (eg. polarization,…)
     - Branching-Ratio

BR Pythia-EvtGen-PDG$_{2008}$

B-hadron	J/ψ-channel	BR (PYTHIA)	BR (EVTGEN)	BR (PDG 2008)
B^0	$J/\psi\ K^0$	$8 \cdot 10^{-4}$	$8{,}72 \cdot 10^{-4}$	$(8{,}71 \pm 0{,}32) \cdot 10^{-4}$
	$J/\psi\ K^*(892)^0$	$1{,}4 \cdot 10^{-3}$	$1{,}33 \cdot 10^{-3}$	$(1{,}33 \pm 0{,}06) \cdot 10^{-3}$
	$J/\psi\ \pi^0$	--	$2{,}05 \cdot 10^{-5}$	$(2{,}05 \pm 0{,}24) \cdot 10^{-5}$
	$J/\psi\ \rho^0$	--	$1{,}6 \cdot 10^{-5}$	$(2{,}7 \pm 0{,}4) \cdot 10^{-5}$
	$J/\psi\ K^*(1430)^0$	--	$5 \cdot 10^{-4}$	--
	$J/\psi\ K(1400)^0$	--	$1 \cdot 10^{-4}$	--
	$J/\psi\ K(1270)^0$	--	$1.3 \cdot 10^{-3}$	$(1.3 \pm 0{,}5) \cdot 10^{-3}$
	$J/\psi\ K^0\ \pi+\ \pi-$	--	--	$(1 \pm 0{,}4) \cdot 10^{-3}$
	$J/\psi\ w$	--	$3 \cdot 10^{-4}$	$< 2{,}7 \cdot 10^{-4}$
	$J/\psi\ K^{\pm}\ \pi^{\pm}$	--	$1{,}2 \cdot 10^{-3}$	$(1{,}2 \pm 0{,}6) \cdot 10^{-3}$
	$J/\psi\ K^0\ \pi^0$	--	$1 \cdot 10^{-4}$	--
	$J/\psi\ \Phi\ k^0$	--	$9{,}4 \cdot 10^{-5}$	$(9{,}4 \pm 0{,}26) \cdot 10^{-5}$
	$J/\psi\ K^*(892)^+\ \pi-$	--	--	$(8 \pm 4) \cdot 10^{-4}$
	$J/\psi\ K^*(892)^0\ \pi+\ \pi-$	--	--	$(6{,}6 \pm 2{,}2) \cdot 10^{-4}$
$B^{\pm}$	$J/\psi\ K^{\pm}$	$8 \cdot 10^{-4}$	$1{,}007 \cdot 10^{-3}$	$(1{,}007 \pm 0{,}035) \cdot 10^{-3}$
	$J/\psi\ K^{\pm}\ \pi+\ \pi-$	--	--	$(1{,}07 \pm 0{,}19) \cdot 10^{-3}$
	$J/\psi\ \pi^{\pm}$	--	$4{,}9 \cdot 10^{-5}$	$(4{,}9 \pm 0{,}6) \cdot 10^{-5}$
	$J/\psi\ \rho^{\pm}$	--	$6 \cdot 10^{-5}$	$(5 \pm 0{,}8) \cdot 10^{-5}$
	$J/\psi\ K^*(892)^{\pm}$	$1{,}4 \cdot 10^{-3}$	$1{,}41 \cdot 10^{-3}$	$(1{,}43 \pm 0{,}08) \cdot 10^{-3}$
	$J/\psi\ K(1270)^{\pm}$	--	$1{,}8 \cdot 10^{-3}$	$(1{,}8 \pm 0{,}5) \cdot 10^{-3}$
	$J/\psi\ K(1400)^{\pm}$	--	$1 \cdot 10^{-4}$	$< 5 \cdot 10^{-4}$
	$J/\psi\ \Phi\ k^{\pm}$	--	$5{,}2 \cdot 10^{-5}$	$(5{,}2 \pm 1{,}7) \cdot 10^{-5}$
	$J/\psi\ K^*(1430)^{\pm}$	--	$5 \cdot 10^{-4}$	--
	$J/\psi\ \eta\ K^{\pm}$	--	--	$(1{,}08 \pm 0{,}33) \cdot 10^{-4}$
B^0_S	$J/\psi\ \Phi$	$1{,}4 \cdot 10^{-3}$	$1{,}35 \cdot 10^{-3}$	$(9{,}3 \pm 3{,}3) \cdot 10^{-4}$
	$J/\psi\ \eta$	$4 \cdot 10^{-4}$	$3{,}2 \cdot 10^{-4}$	$< 3{,}8 \cdot 10^{-3}$
	$J/\psi\ \eta'$	$4 \cdot 10^{-4}$	$6{,}4 \cdot 10^{-4}$	--
	$J/\psi\ \pi^0$	--	--	$< 1{,}2 \cdot 10^{-3}$
Λ^0_B	$J/\psi\ \Lambda$	$2{,}2 \cdot 10^{-3}$	$4{,}7 \cdot 10^{-4}$	$(4{,}7 \pm 2{,}8) \cdot 10^{-4}$

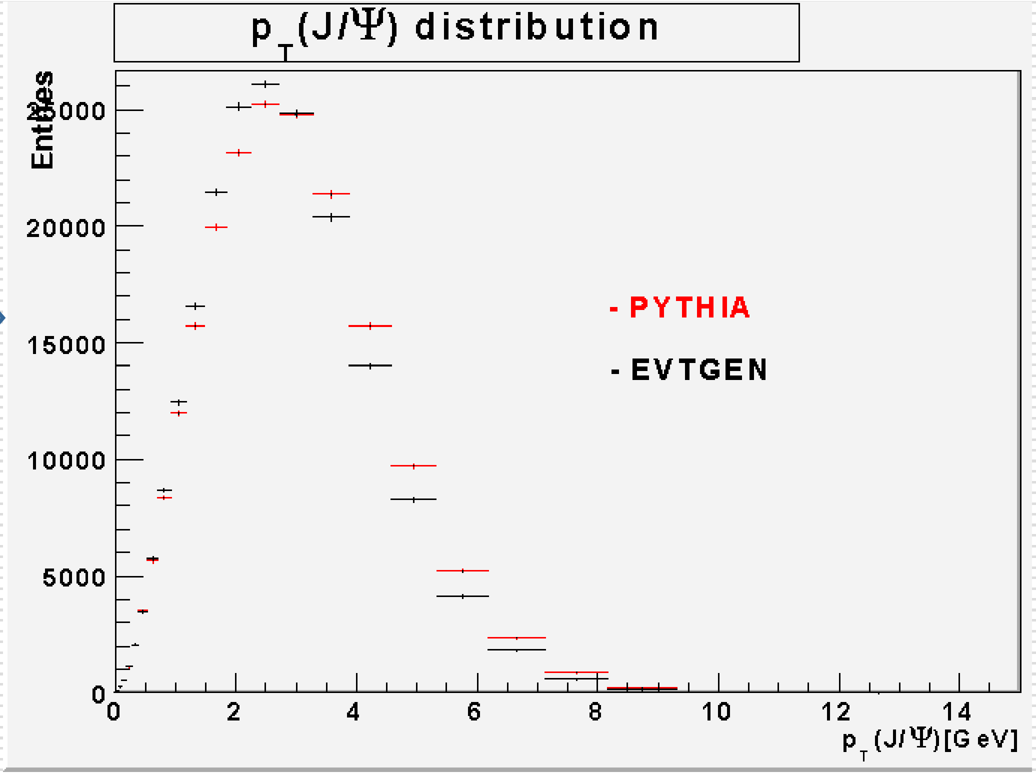
EvtGen is a PARTICLE DECAY SIMULATOR which is specifically designed for the needs of B-physics studies

EvtGen is surely more reliable as decayer than Pythia → our baseline

Differences between decayers

- 100K events generated by Pythia with one bb-bar pair/event (only kinematic)
- The B-hadrons are forced to decay by either **Pythia** or **EvtGen** (in the allowed channels B→J/Ψ +X →e+e- +X)

Same p_T(B) spectrum;
either Pythia or EvtGen as decayer



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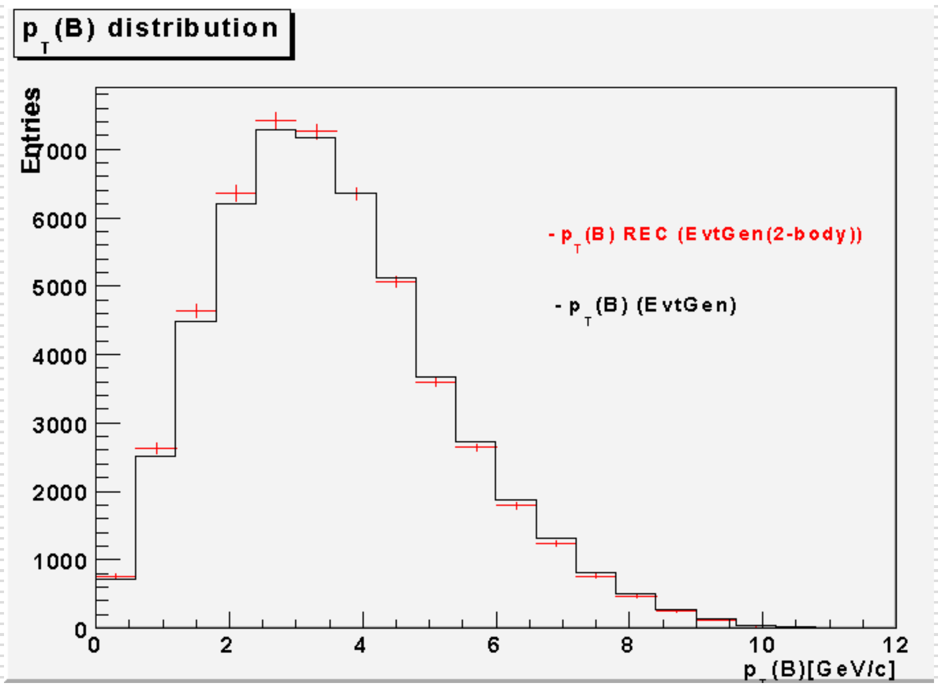
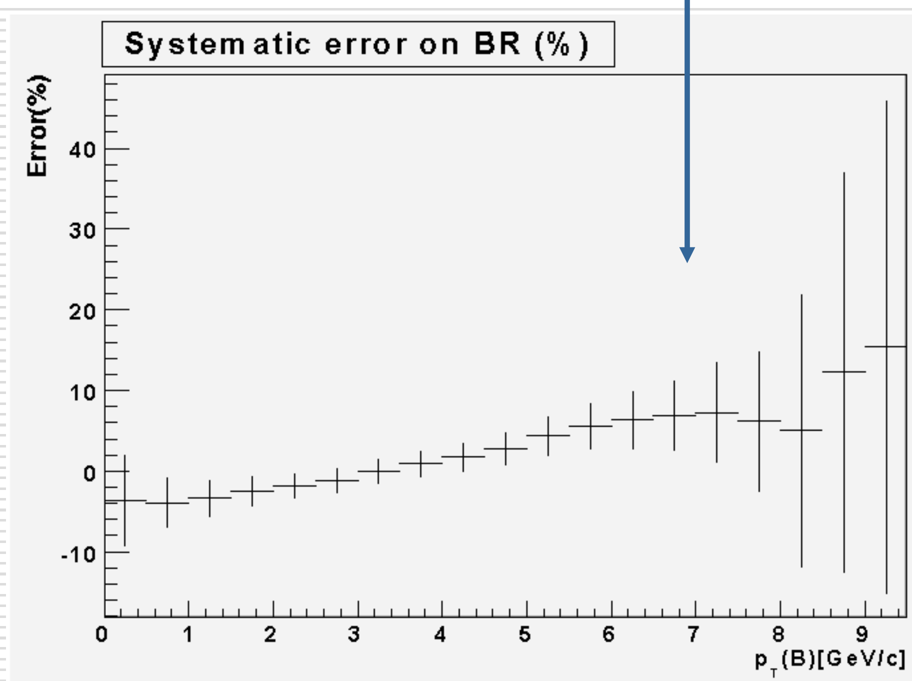
Evaluation of systematics on decayer

To evaluate the systematics we compare:

- $p_T(B)$ REC which is obtained by the application of correction factors (w_{ij} and f_i) calculated using EvtGen (after swith-off all decay channels with three and four bodies) to the $p_T(J/\Psi)$ spectrum
- $p_T(B)$ taken from the same 100K events

$$Err = \frac{p_T^{\,B}(EvtGen2body) - p_T^{\,B}(EvtGen)}{p_T^{\,B}(EvtGen)}$$





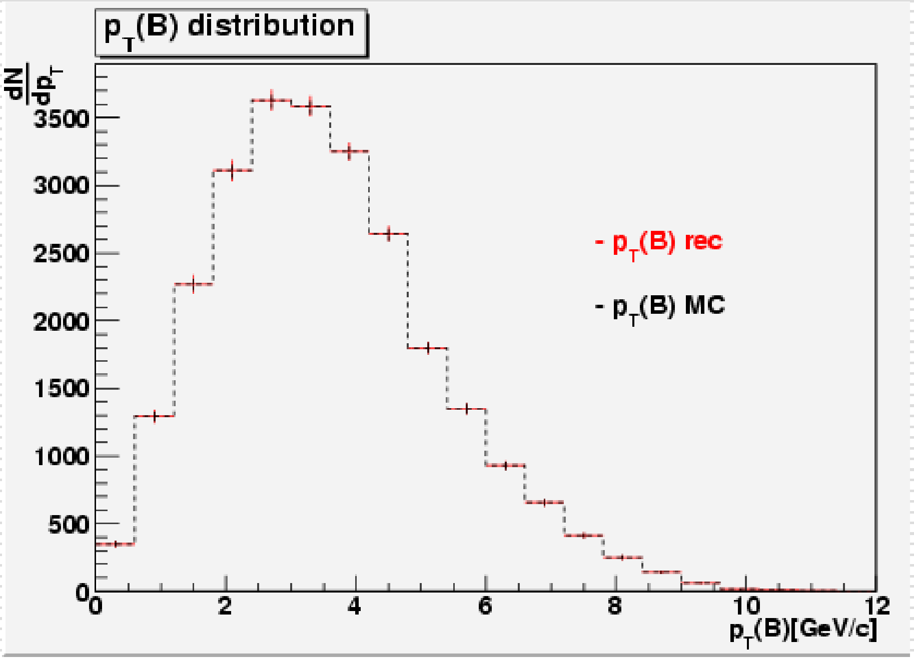
Conclusion

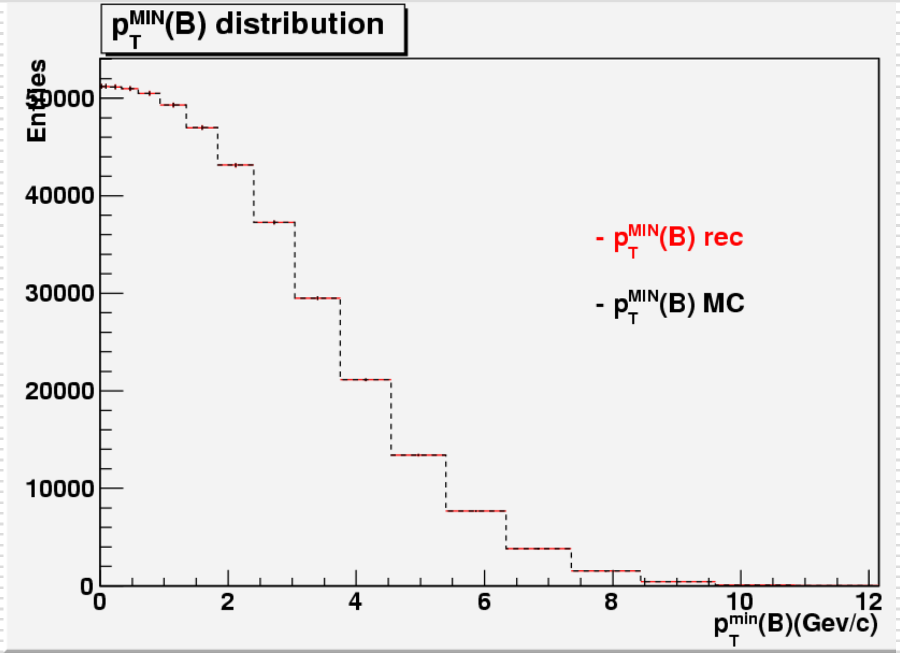
- Measurments of total J/Ψ production and J/Ψ from beauty at central rapidity should be possible already in the first year

BACK-UP

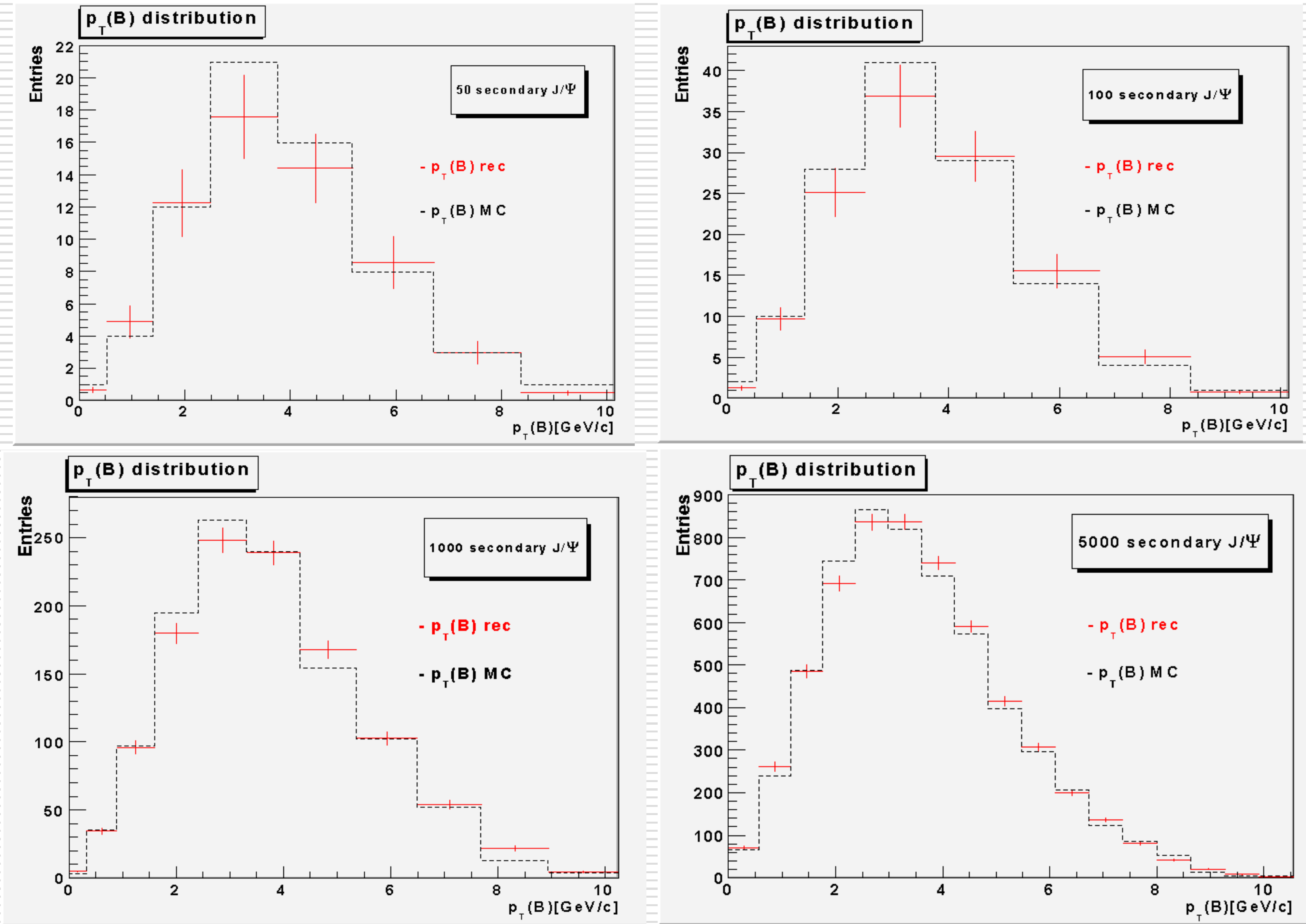
- A way to check the rightness of the method is to apply the weights w_{ij} (w'_{ij}) and f_i (f'_i) to the $p_T(J/\psi)$ distribution taken from the same events sample which is used to evaluate the correction factors

The distributions are evaluated over the whole sample of 100K events





Different scenarios depending on the collected statistics



Statistical errors

- Error on j-th $p_T(J/\psi)$ bin of the $dN/dp_T(J/\psi)$ distribution: outcome of $B \rightarrow J/\Psi$ analysis (for the time-being: the square-root of the entries)
- Error on weights w_{ij} (w'_{ij}) and f_i (f'_i): those are ratios of two counts and are less than 1:

$$w_{ij} = \frac{n_{ij}}{N_j} \quad \Rightarrow \quad \delta_{w_{ij}} = \frac{\sqrt{n_{ij}\left(1 - \frac{n_{ij}}{N_j}\right)}}{N_j}$$

- Those errors are propagated on the j-th $p_T(B)$ ($p_T^{MIN}(B)$) bin of the B-hadrons X-section:

$$\delta_{stat}^{\sigma_i^B} = \frac{1}{f_i}\sqrt{\sum_j \left(w_{ij}^2 \left(\delta_{stat}^{\sigma_j(J/\Psi)}\right)^2 + \sigma_j^{J/\Psi\,2}\,\delta_{w_{ij}}^2 \right) + \left(\sigma_i^B\right)^2 \delta_{f_i}^2}$$