Prompt J/psi-production studies at the LHC

Aafke Kraan
INFN Pisa

Quarkonium 2007
October 17-21
Hamburg, Germany

Outline

- Introduction and motivations
- J/psi production in PYTHIA 6.409
- Cross section studies
- Complementary observables
- J/psi reconstruction
- Non-prompt background
- Plans and conclusions

Introduction and motivations

Goal:

Understanding prompt charmonium production at LHC by using complementary observables (next to cross section measurement)

➡ Besides studying the dynamics of J/psi itself, take into account dynamics of surrounding particles

[Idea together with Torbjörn Sjöstrand, thanks for many discussions!]

Motivations:

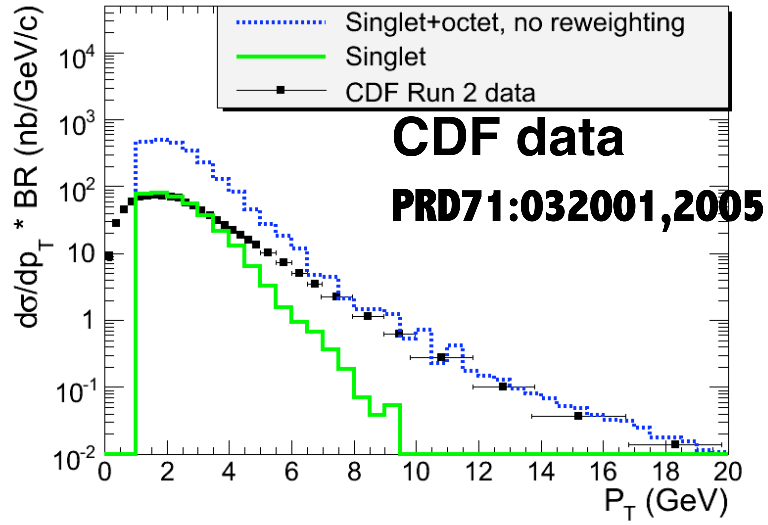
J/psi production properties not well understood!

- **E.g.: NRQCD succcesful in explaining Ptjpsi spectrum at Tevatron (octet mechanism), but not in polarization prediction...**
  [See: CDF J/psi polarization, arXiv: 0704.0638,see also talk today by F. Maltoni!]
- **At LHC: higher P_T values & luminosity allow for new studies!**
- **These kind of analyses can begin in first months of data taking**

J/psi production in PYTHIA

Quarkonium production:

PYTHIA 6.409



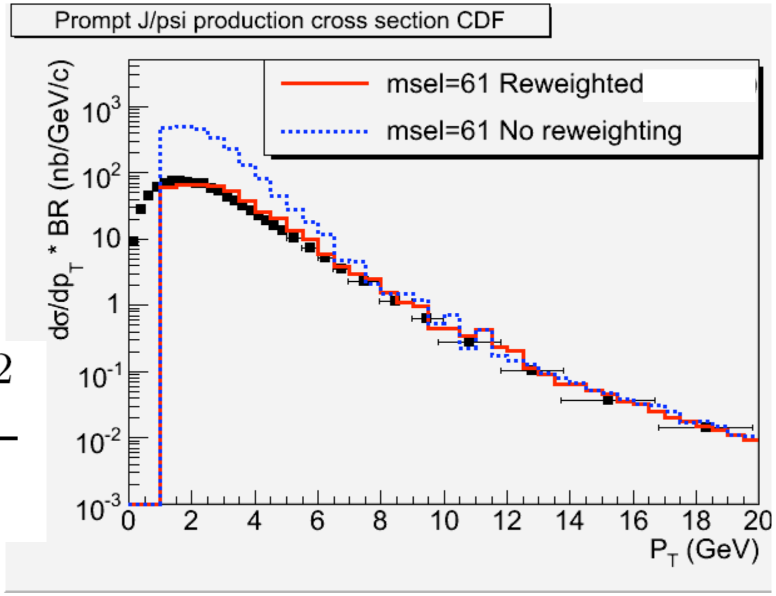
- **Original implementation by S. Wolf (2002), was never in official release**
  - **Based on NRQCD- approach**
  - **Singlet and octet cc produced perturbatively, followed by shower**
  - **Parton showers for radiation off octet cc: shower expected from**
    1. gg→ggg→gggg...
    2. g→$cc^{(8)}$
    3. $cc^{(8)}$ →J/psi

    } switches: MSTP(148) MSTP(149)
- **Recent (2006) progress made:**
  - **Code integrated (Torbjörn Sjöstrand): PYTHIA 6.324**
  - **NRQCD matrix elements tuned** [See M.Bargiotti, CERN-LHCb-2007-042.
  - **Possibility to normalize cross section like in UE (see next slide)**

J/psi production in PYTHIA: PYEVWT.f

- **Problem:** even with octet, quarkonium cross section not right shape (too big at low Pt)
- **Solution:** PYEVWT.f: cross section dampened, like gg→gg in underlying event formalism

T. Sjöstrand and M.v.Z, PRD 1987

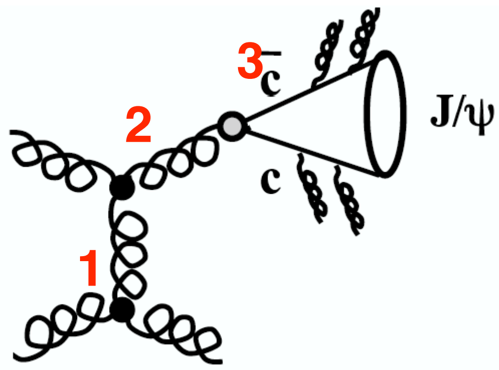


$$\frac{d\sigma}{dp_T^2} \propto \frac{[\alpha_S(p_T^2)]^2}{p_T^4} \Longrightarrow \frac{[\alpha_S(p_{T_0}^2 + p_T^2)]^2}{(p_{T_0}^2 + p_T^2)^2}$$

- Applies naturally here too!

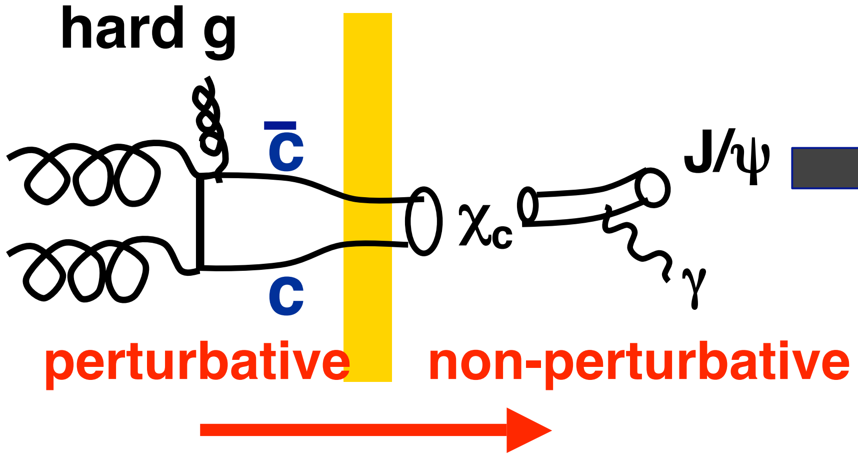
$$w_i = \frac{\sigma_{reweighted}}{\sigma_{not\ reweighted}} = \left(\frac{\hat{p}_T^2}{p_{T_0}^2 + \hat{p}_T^2}\right)^2 \left(\frac{\alpha_S(p_{T_0}^2 + Q^2)}{\alpha_S(Q^2)}\right)^3$$

- p_{T0} ~ scale below which g cannot resolve colours ⇒ coupling decreases ⇒ xs decreases!
- p_{T0} ~ 2 GeV at CDF, is assumed to grow with √s [x smaller ➔ denser packing of gluons ➔ more screening LHC: p_{T0} = 1.94(14 TeV/1.96 TeV)$^{0.16}$=2.66 GeV

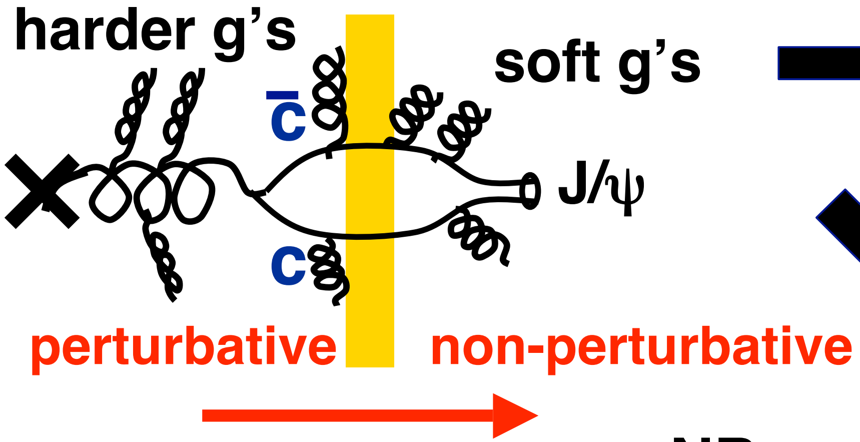


Models for study:

Singlet production



Octet production



Case 1: Singlet

Case 2: octet low radiation

MSTP(148)=0 (MSTP(149) doesn't matter)
AP splitting function:q→qg

Case 3: octet med. radiation

MSTP(148)=1, MSTP(149)=0
A-P splitting function:
g→gg (but follow hardest)

Case 4: octet high radiation

MSTP(148)=1, MSTP(149)=1
A-P splitting function:
g→gg (symm. z=1/2)

NB: case (1+2),(1+3),(1+4) all fit CDF data!

Event generation

- Events generated in Pthat bins
- Force $J/\psi \rightarrow \mu\mu$ (BR 5.98%)
- PYEVWT.f
- Singlet msub 421, 431-439
- Octet msub 422-430
- Generator level cuts: 2 muons with $|\eta|<2.5$ and Pt>2 GeV
- Events processed through typical multi-purpose LHC detector including full GEANT simulation

Nr events PYTHIA

pthat bin	Singlet	Octet low	Octet medium	Octet high
1. 0-10	4000000	1638000	1155000	1015000
2. 10-20	439956	155000	154628	165292
3. 20-30	186000	57500	67000	55000
4. 30-50	187500	53500	56500	54500
5. 50-inf	199500	47500	59000	49000

Luminosities (pb^{-1})

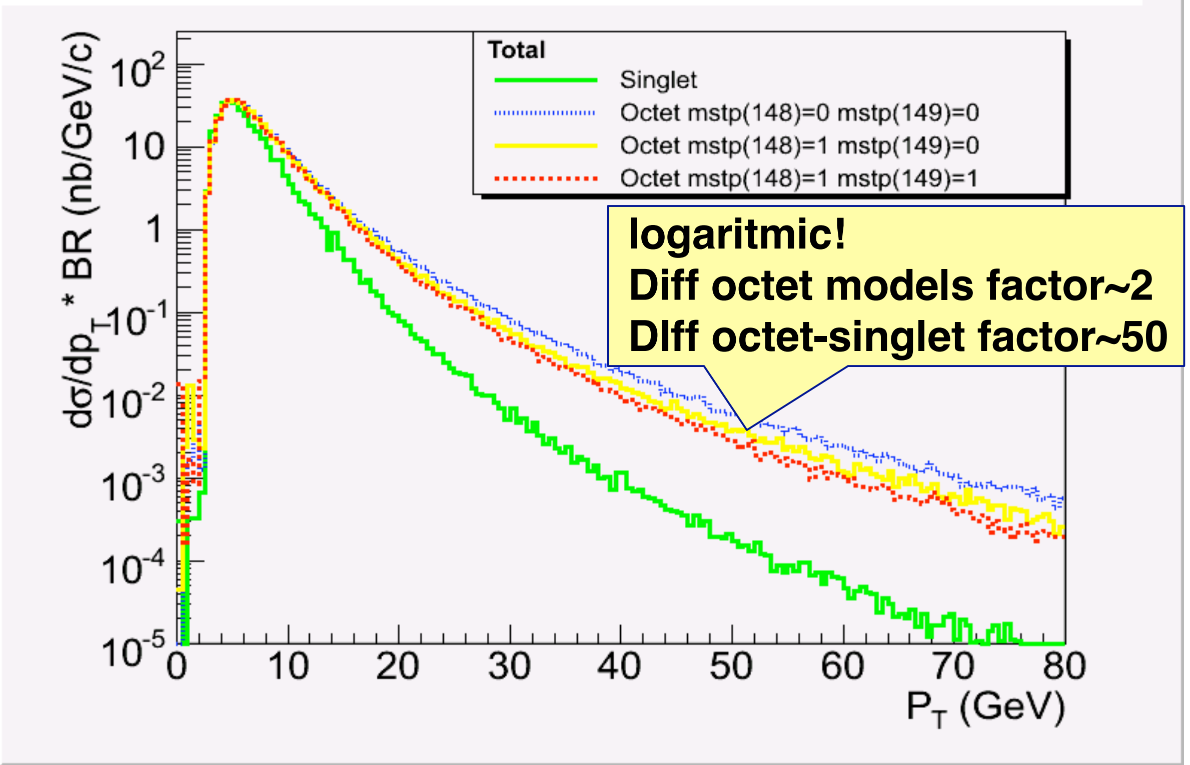
1. 0-10	0.2	0.6	0.5	0.4
2. 10-20	7.8	2.9	2.9	3.0
3. 20-30	162.0	15.0	17.4	14.3
4. 30-50	1683.7	62.2	65.5	63.3
5. 50-inf	38925.3	397.4	494.4	410.2

Outline

- Introduction and motivations
- J/psi production in PYTHIA 6.409
- Cross section studies
- Complementary observables
- J/psi reconstruction
- Non-prompt background
- Plans and conclusions

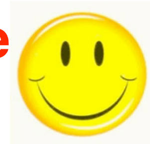
Prompt J/psi differential cross section

Prompt J/psi production cross section at LHC



Factor 2 is good!!

The cross section is excellent observable

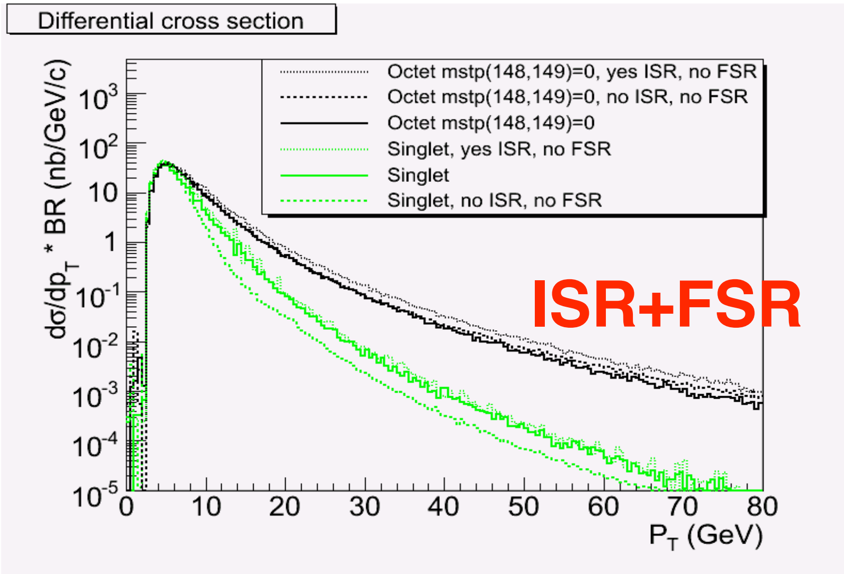


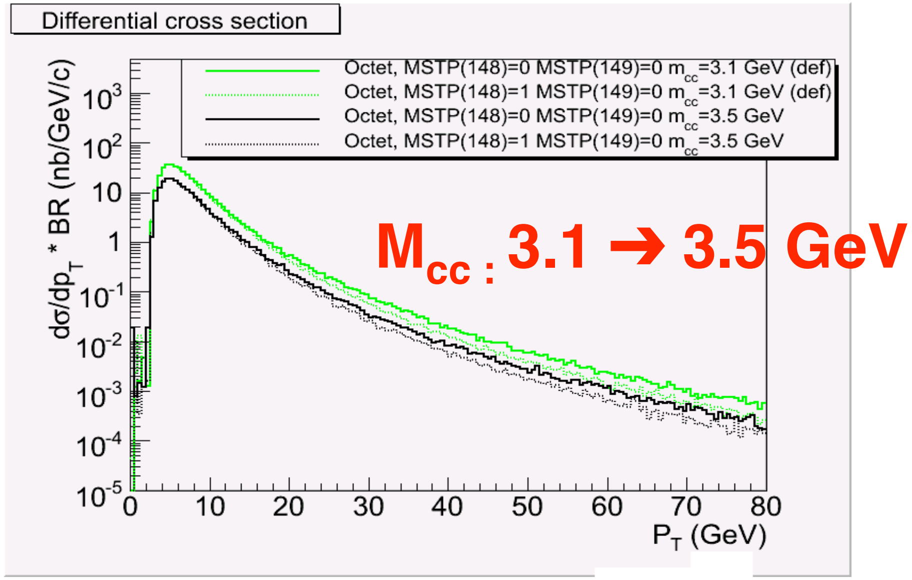
However many parameters influence cross section shape…

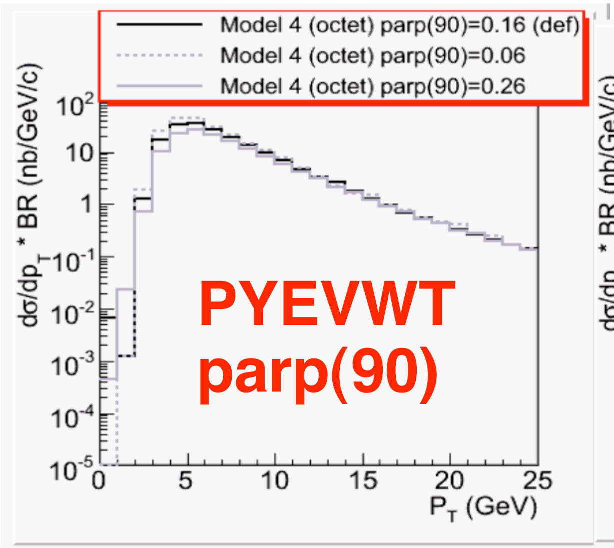
- **ISR**
- **FSR**
- **Mass of cc-octet**
- **Reweighting function**

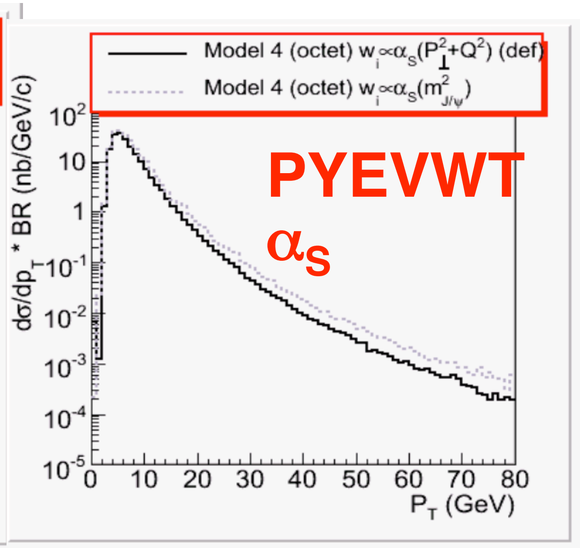
Prompt J/psi differential cross section

Examples of changes in the differential cross section:









Conclusion:

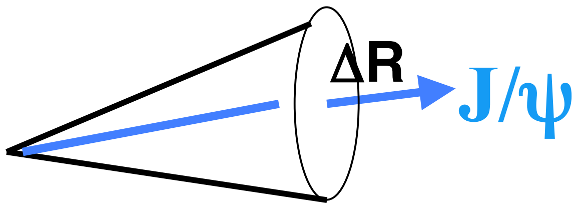
- **Diff. xs can change significantly!**
- **Even is we can measure the spectrum, doesn't mean we understand the production...**

New observables??

- If differential cross section was known precisely
  ⇒would be good observable to understand J/psi (and other heavy quarks) production mechanism
- As we've just seen many factors influence the differential cross section...

Conclusion: need new set of complementary observables?!

- Most observables have to do with the activity around the J/psi

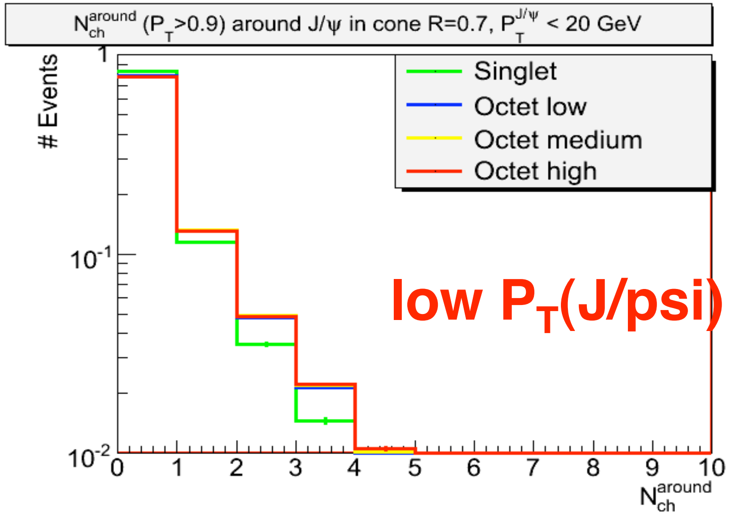


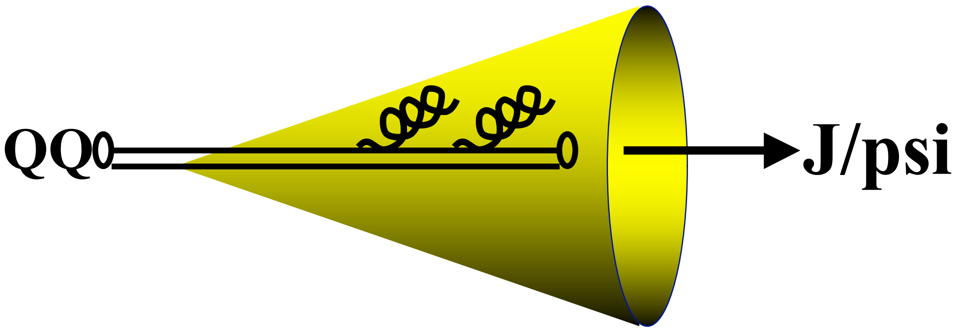
- In the following, show selection of observables
- Study new observables for the 4 production models
  - NB We don't expect the truth to be exactly one of these models!
  - Might be a mix, might be none of them

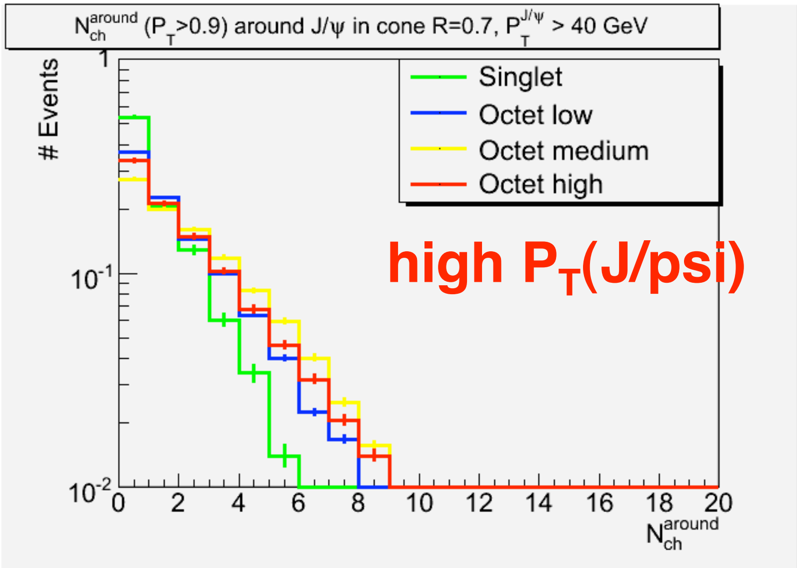
➡We first have a look at Monte Carlo truth!

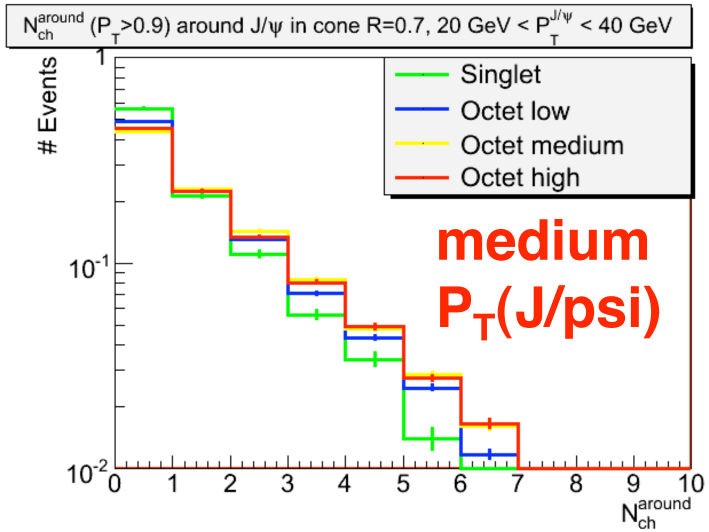
Activity around J/psi

- **Shower activity of 4 models is different (see slide 7) ➔ natural observable: Nr charged particles (P_T>0.9, except μ's) around J/ψ in cone with R=0.7** ➔

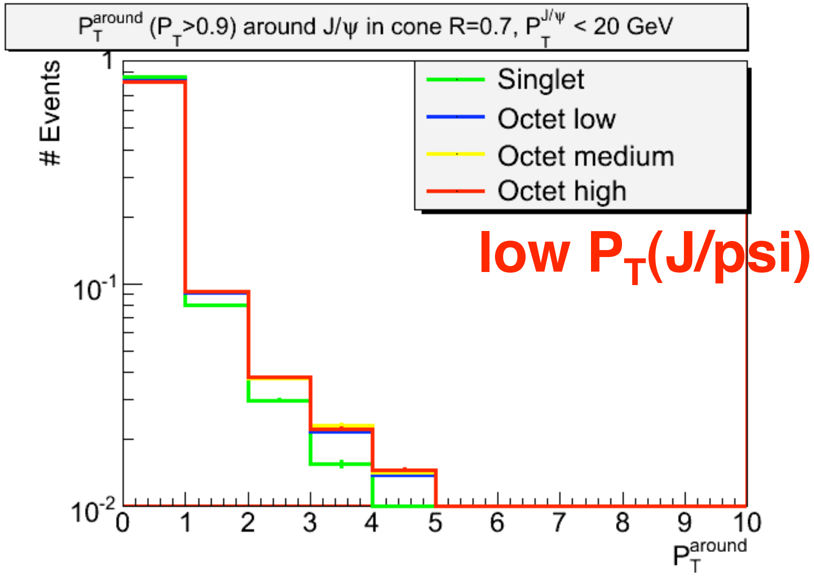


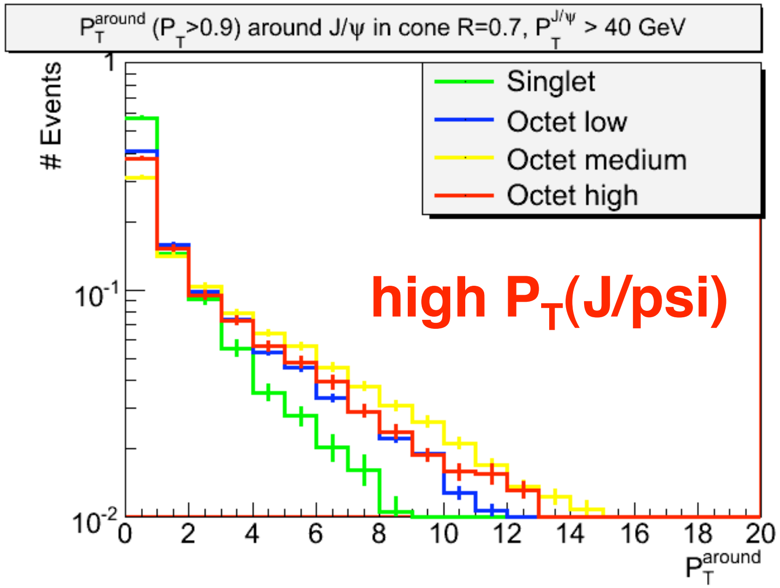


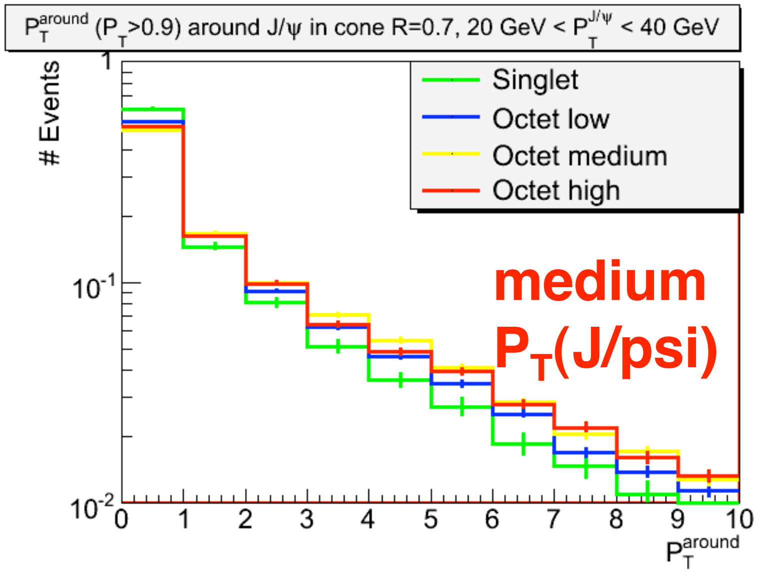




- **Scalar sum of P_T of charged particles around J/ψ in cone with R=0.7**
  - ✓ **The particles around the J/psi are generally low energetic!**
  - ✓ **The differences are at high P_T(J/psi)**

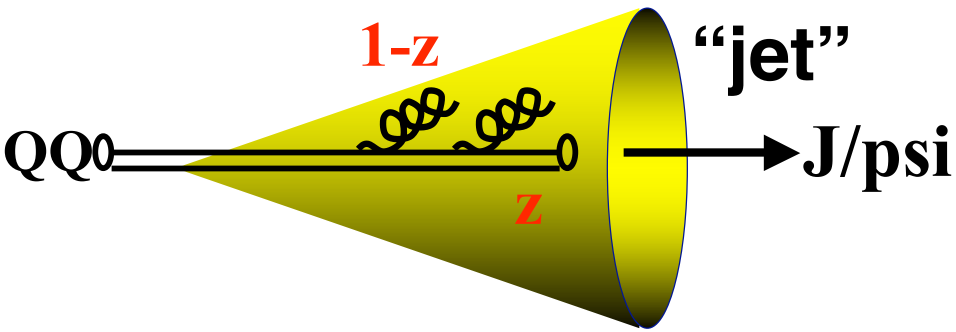






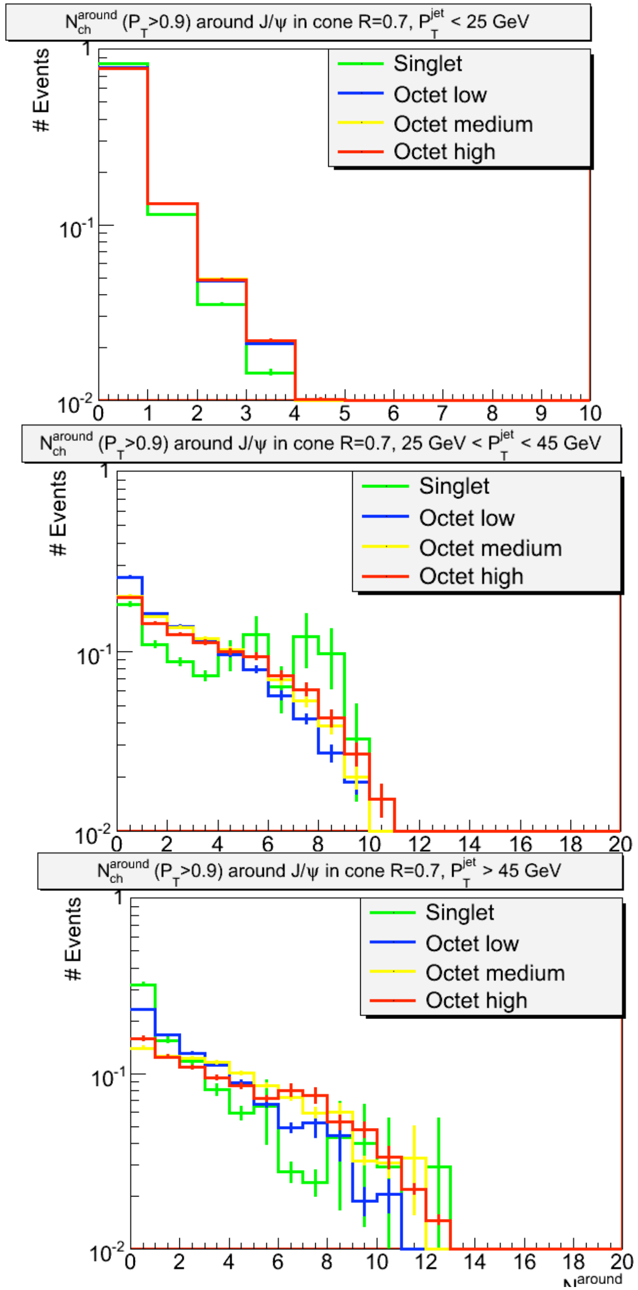
Activity around J/psi

- However, by selecting events according to $P_T^{J/\psi}$, we already bias ourselves to same kind of events (high $P_T^{J/\psi}$: did not radiate much in any model...)



- Select instead according to $P_T^{jet} = P_T^{jpsi} + P_T^{around}$

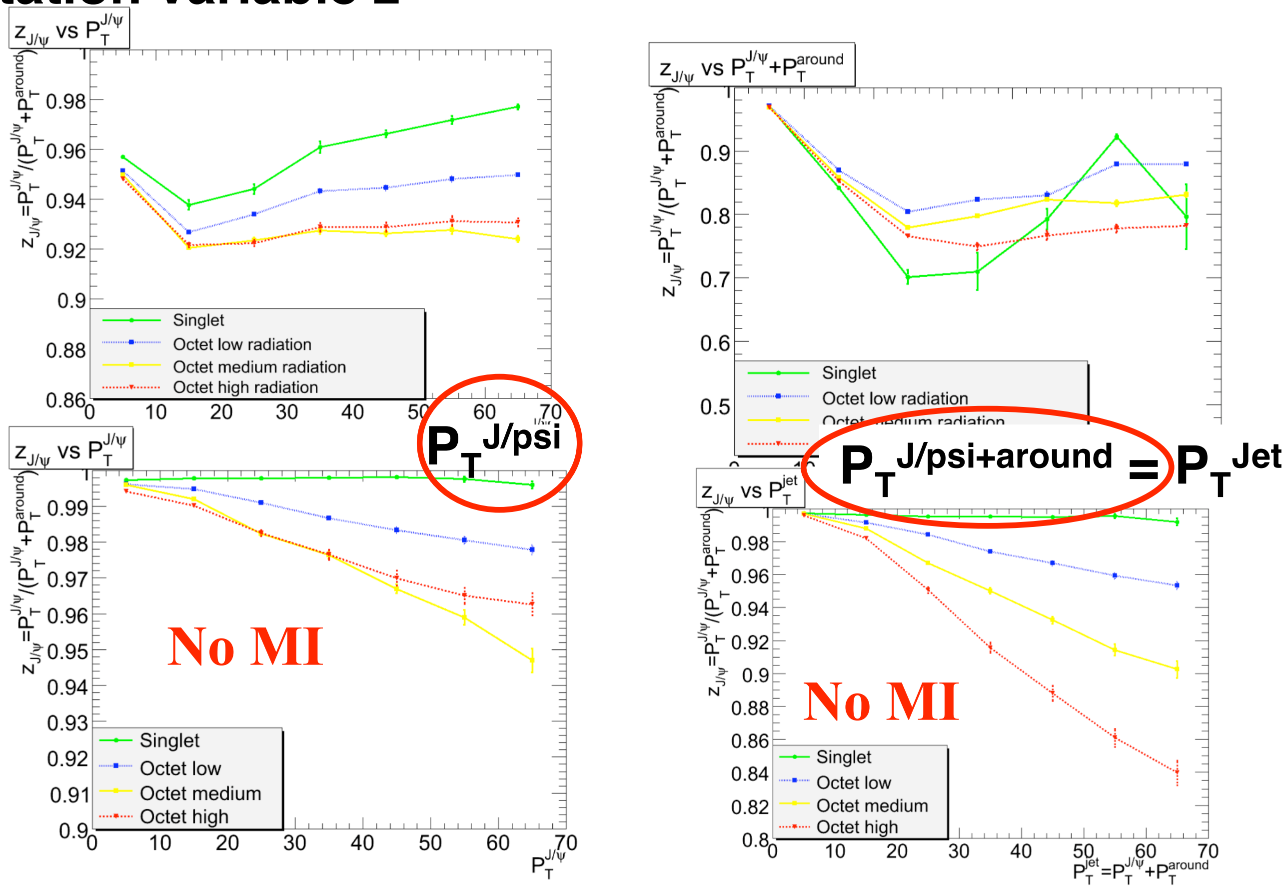
➡ However, now we seem more sensitive to fluctuations from accidental activity around the J/psi...



$$z = \frac{P_T^{\text{J/psi itself}}}{P_T^{\text{jet}}}$$

Possible observable: $z_{J/\psi}$

- Since for 4 models fragmentation function is different, try $z_{J/\psi}$ ~ theoretical fragmentation variable z
- $z_{J/psi}$ vs $P_T^{J/psi}$
- $z_{J/\psi}$ vs P_T^{Jet}
- Interesting shape!
- Investigate effect multiple interactions,
- 2M new events



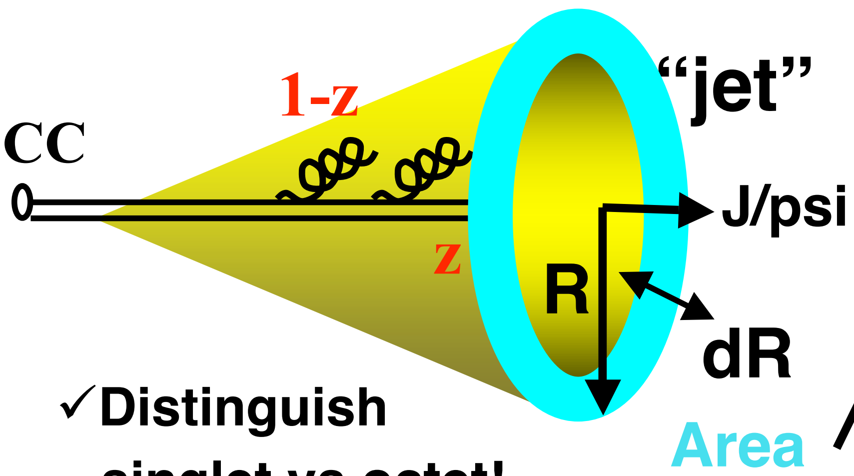
Conclusion: accidental underlying event activity around J/psi can be important

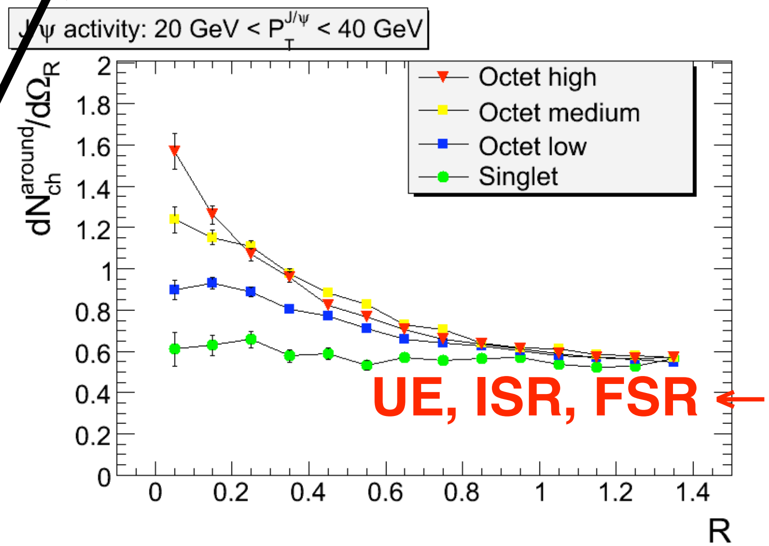
- $z_{J/\psi}$ possible observable, but have to understand underlying event

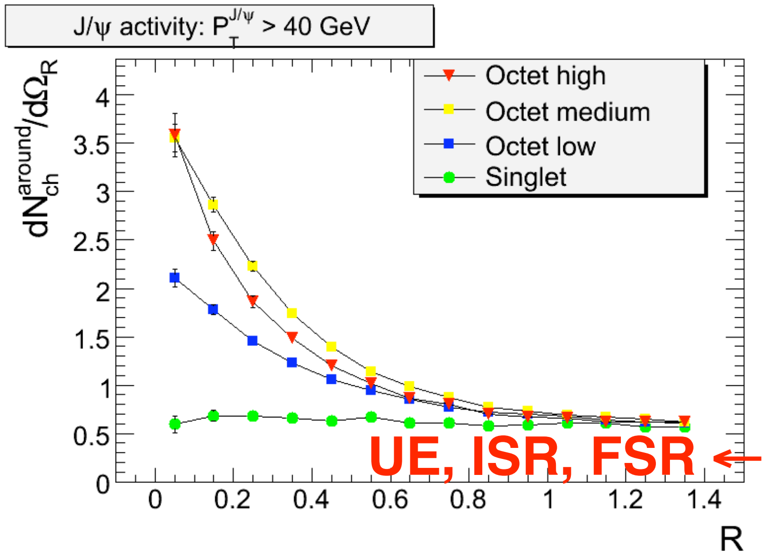
Possible observable: tracks vs. ΔR

- Instead of looking at 'average' activity, look at dN/dΩ vs ΔR between J/psi and surrounding 'tracks'
- Higher energetic g has more collinear hadronization!

$$\frac{dN_{ch}^{around}(R)}{d\Omega_R} = \frac{N_{ch}^{around}(R+dR/2) - N_{ch}^{around}(R-dR/2)}{\pi[(R+dR/2)^2 - (R-dR/2)^2]}$$







✓Distinguish singlet vs octet!

✓Distinguish octet (2) from octet (3) and octet (4)

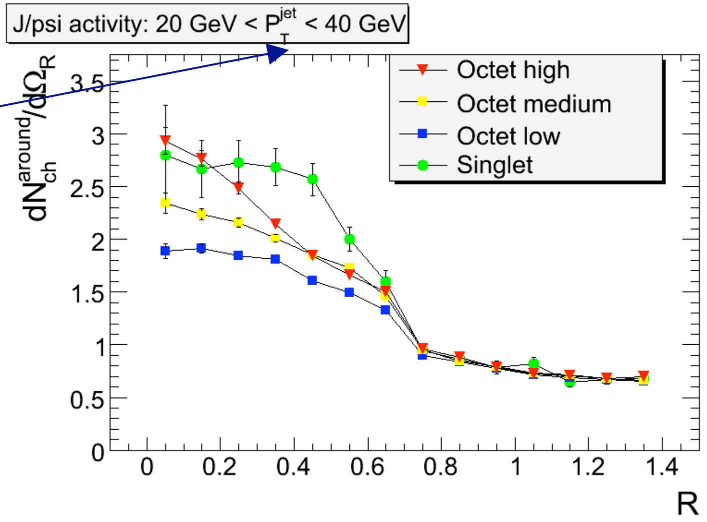
✓Models (3) and (4) same... because we select events with large z in both cases

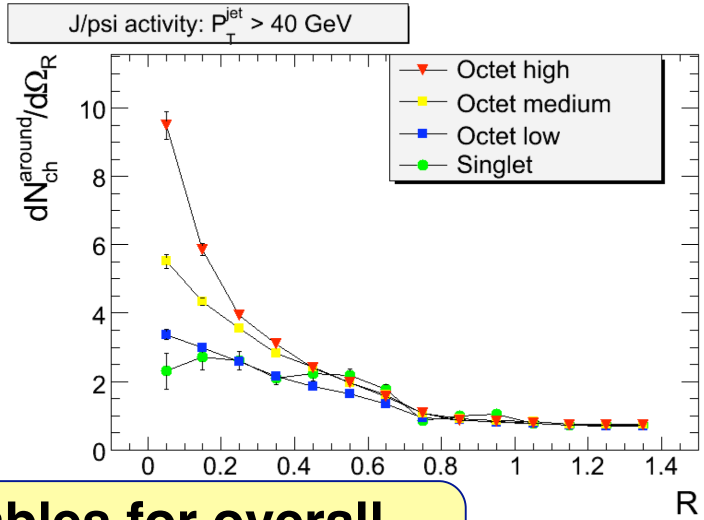
Possible observable: tracks vs. ΔR

- Instead of plotting for $P_T^{J/psi}$, look at P_T^{jet}
  (= $P_T^{J/psi\ itself}$ + $P_T^{around\ J/psi}$)
- Now 'bias' is gone!
- But much more sensitive to fluctuations from UE activity

  ✓Distinguish singlet vs octet!
  ✓Distinguish octet (2) from octet (3) and octet (4)
  ✓Distinguish models (3) and (4)!

- Similar plots made where N ➔ P_T, same behaviour.

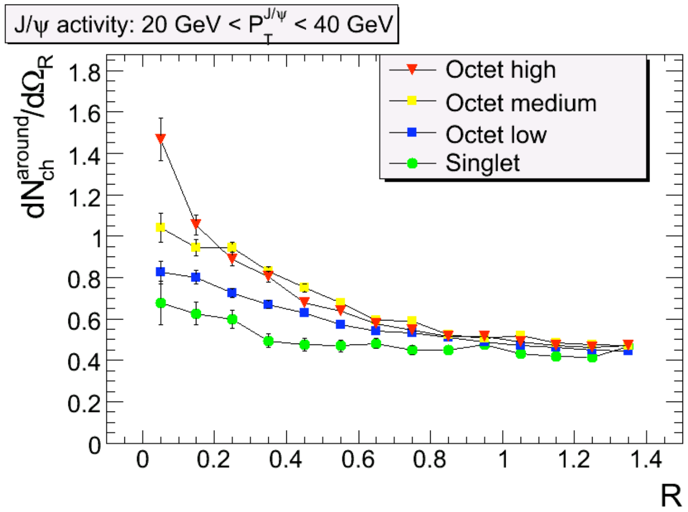


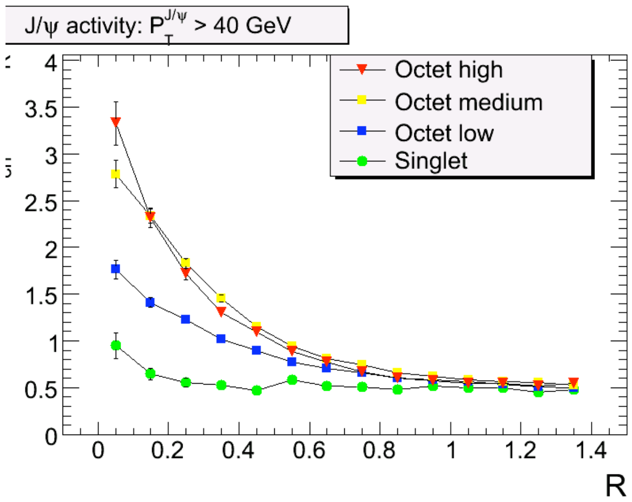


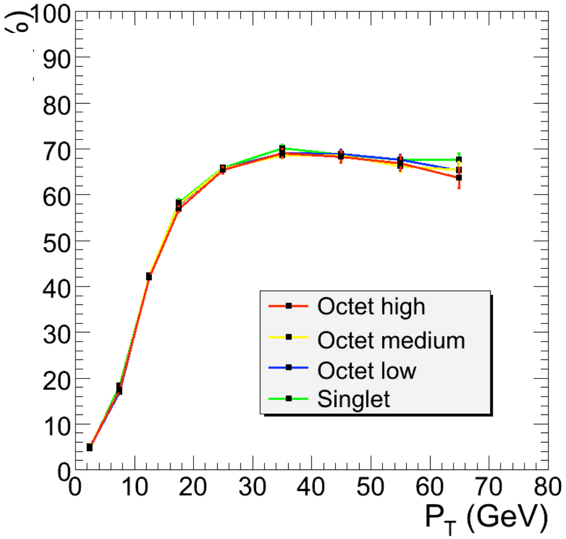
Conclusion: need to combine many observables for overall understanding of production!

J/psi reconstruction

- These plots were all Monte Carlo truth...
- We now reconstruct the J/psi in a typical LHC detector
    - ↳Two muons, use muon chambers and tracker information
- An example of an observable







Good news!

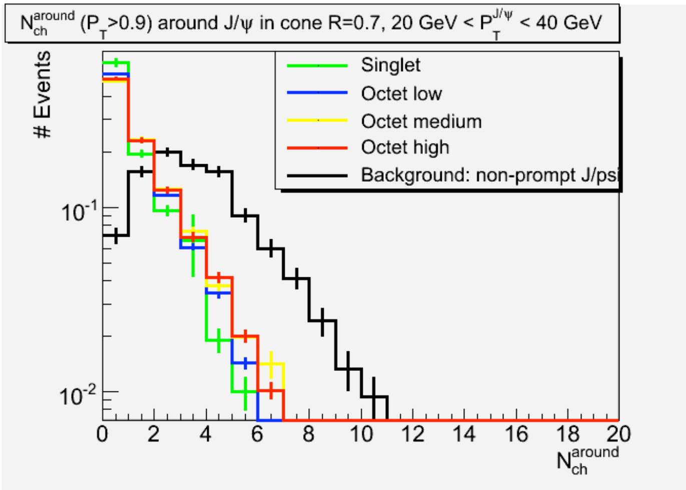
1) reconstruction efficiency is model independent
2) LHC detectors seem to be sensitive to detect these kind of observables

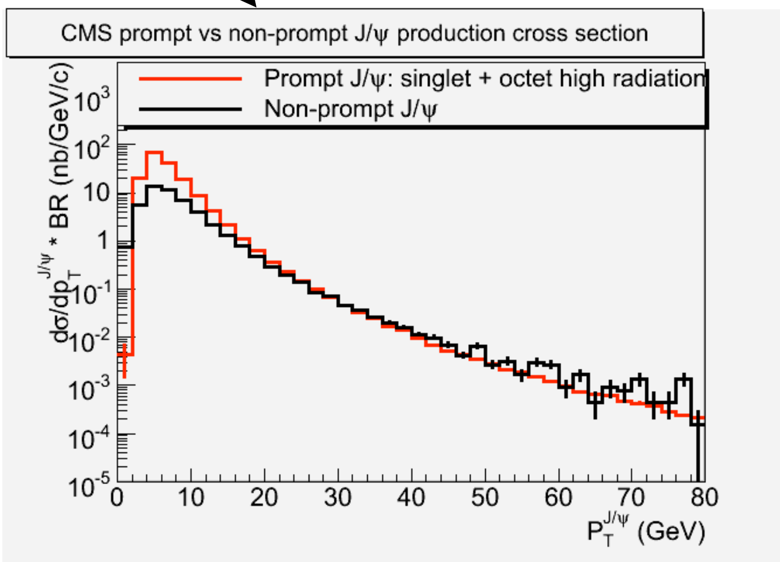
Outline

- Introduction and motivations
- J/psi production in PYTHIA 6.409
- Cross section studies
- Complementary observables
- J/psi reconstruction
- Non-prompt background
- Plans and conclusions

J/psi production studies

- **Main problems in this study:**
  - **Technical. Accumulating Monte Carlo statistics (no official production), this will be solved, use fast simulation.**
  - **Background. Non-prompt J/psi background (high cross section at large P_T!!)**





A wrong estimation of the non-prompt J/psi background could lead to a totally wrong conclusion!!

Conclusions

- Recent progress of quarkonia in PYTHIA opened door to new studies!
- Cross section measurement is first observable to understand underlying J/psi production mechanism.
- However, cross section is sensitive to several factors ➡ would be good with more observables!
- Several examples of observables shown, taking into account dynamics of particles around the J/psi.
- Based on 4 "strawman" models in PYTHIA, clear separations visible, at larger values of P_T(J/psi) (>30 GeV)
- Technical limitation: need millions of J/psi's without Pthat bins
- Experimental problems:
  1) When looking at PTjet: underlying event activity. Data will help in understanding!
  2) non-prompt background
  - Any wrong estimation can lead to totally wrong conclusions
  - Main effort at moment: precise determination of amount of prompt and non-prompt J/psi's (model independent)
- Given that problems will be overcome, this study can be done with early LHC data (100 pb-1)!

Thanks to Torbjorn Sjostrand for discussions!