Dependence of J/ψ Production on Charged-Particle Multiplicity in p+p Collisions at $\sqrt{s}$=200 GeV with the STAR Experiment

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STAR

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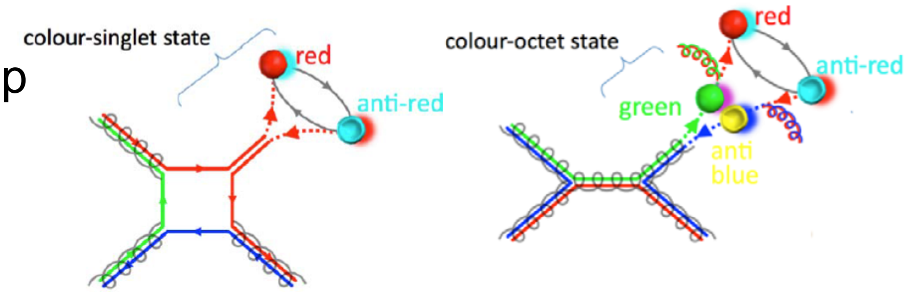
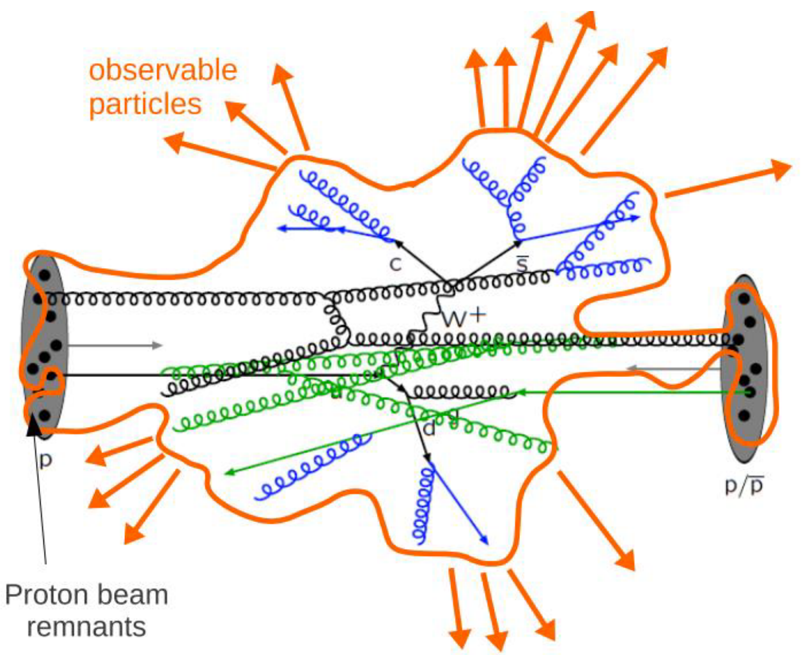
Motivation

- Quarkonium production mechanisms in p+p collisions are not fully understood
    - Hard processes for heavy quark pair production - pQCD
    - Non-perturbative soft processes for hadronization – CEM, CSM, COM

- More differential and comprehensive studies at different energies may shed new lights on quarkonium production and QCD
    - production cross-section
    - polarization
    - yield vs charged-particle multiplicity (N_{ch})
    - …

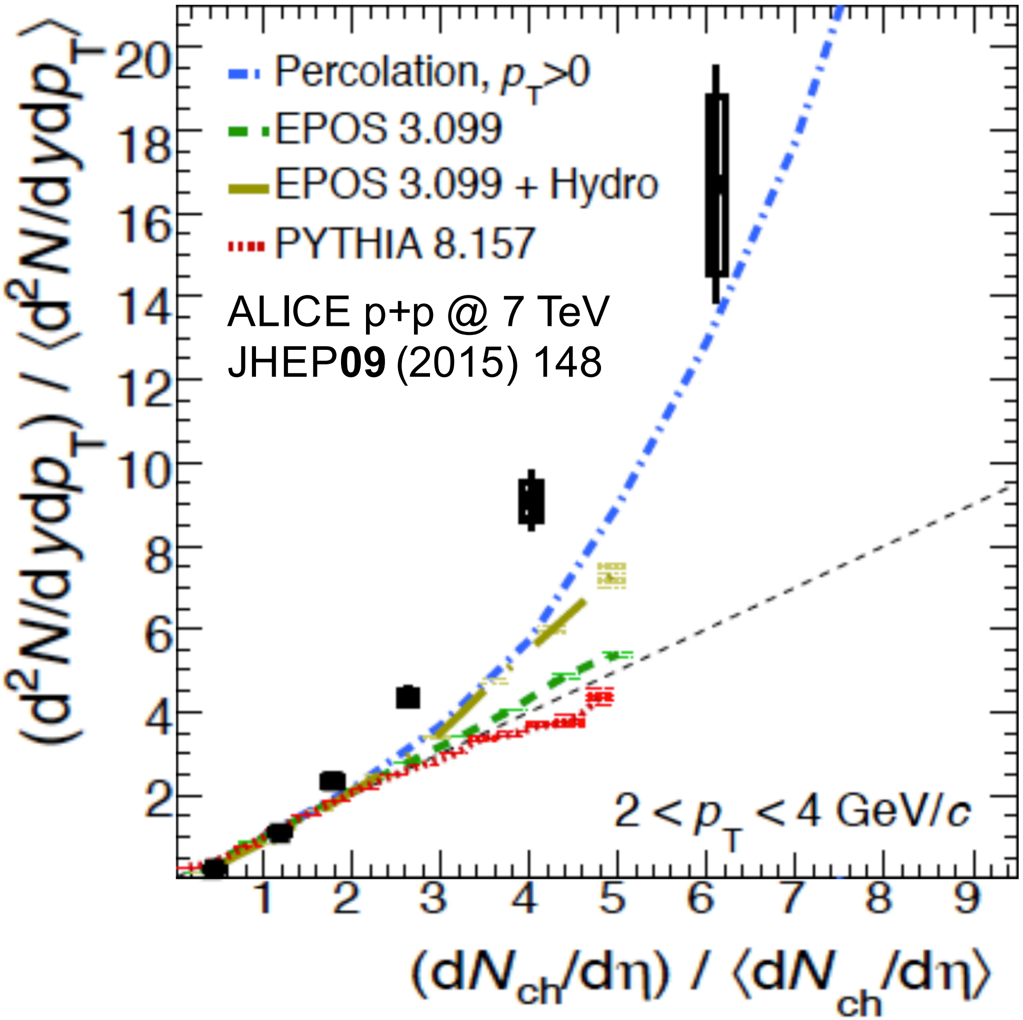
- Quarkonium yield versus N_{ch} can provide insights into multiple parton interactions





Courtesy: Wei Yang Wang

Open Charm Yield vs N_{ch} at LHC



Faster-than-linear rise of open charm production vs N_{ch} in p+p @ 7 TeV

- **PYTHIA8:** including MPI:

  $$N_{hard} \propto N_{ch} \propto N_{MPI}$$

- **EPOS3:** use Gribov-Regge multiple parton scattering for initial conditions:

  $$N_{hard} \propto N_{ch} \propto N_{MPI}$$

- **EPOS3+Hydro:** energy density in 7 TeV p+p collisions is high enough to apply hydrodynamic evolution to the core of the collisions.
  N_{hard} rises faster than N_{ch} in certain p_T range

- **Percolation model**: exchange color sources in collisions. High energy density suppresses soft process more than hard process
  N_{hard} rises faster than N_{ch}

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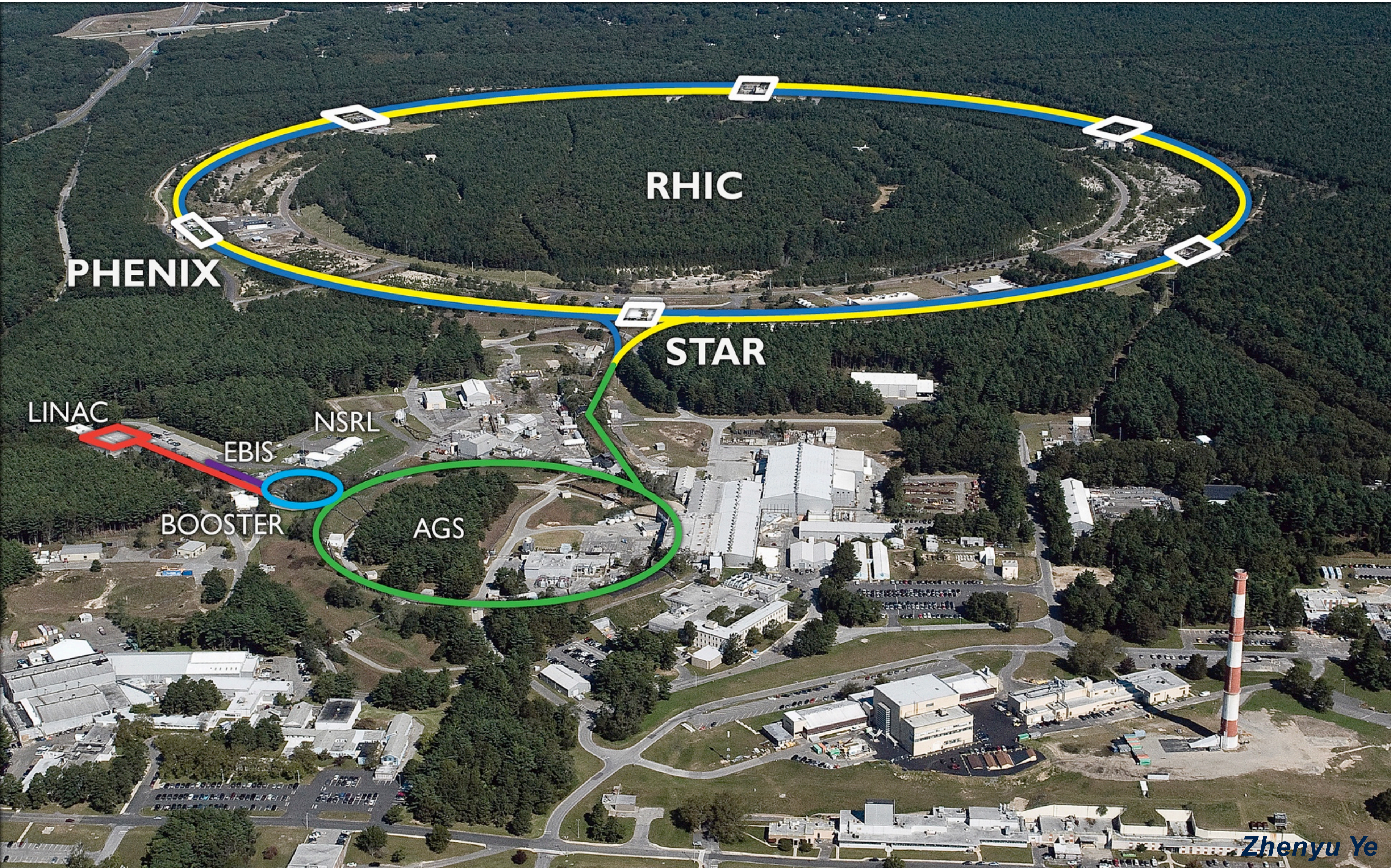
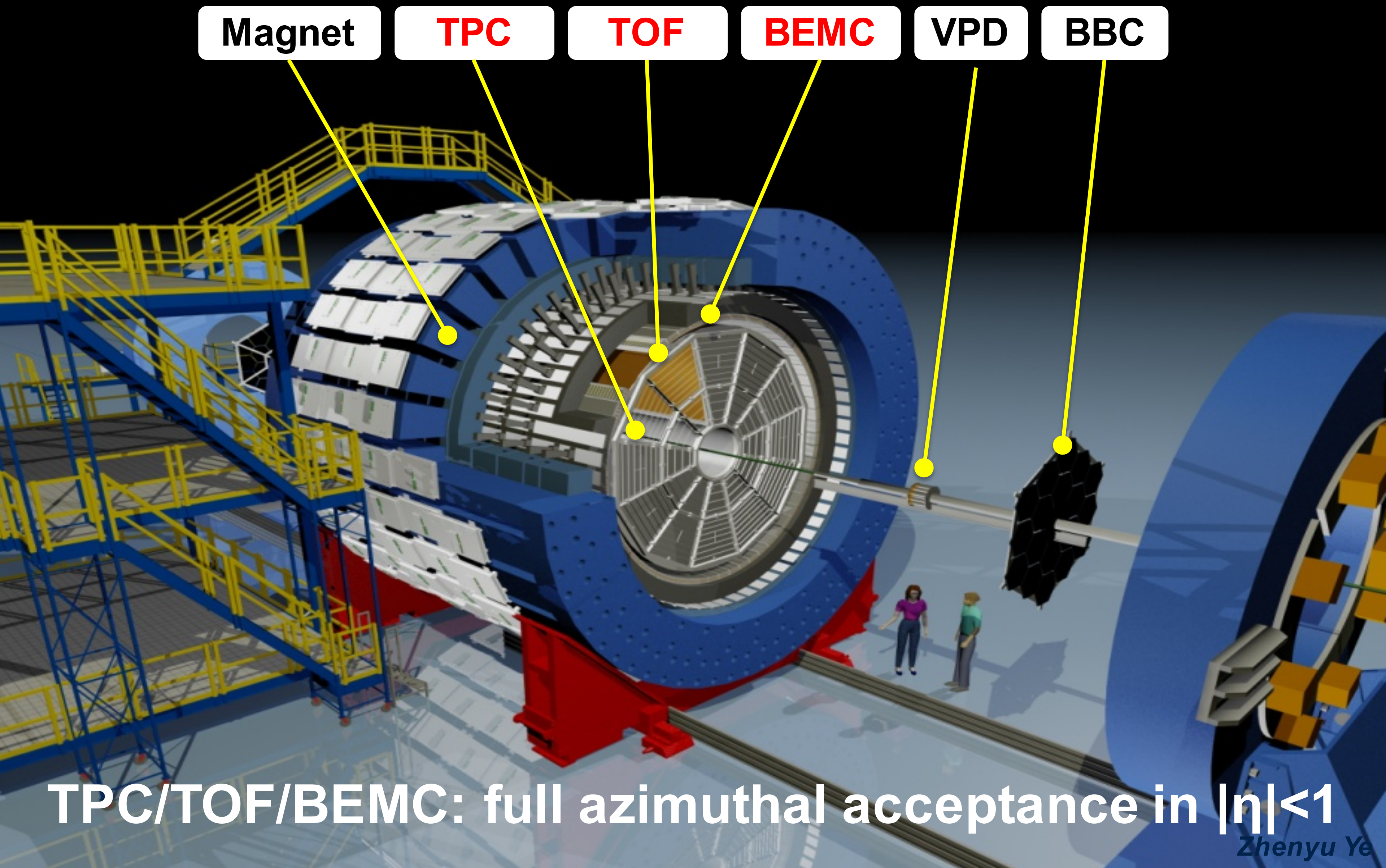
Relativistic Heavy Ion Collider



STAR Experiment at RHIC



TPC/TOF/BEMC: full azimuthal acceptance in |η|<1

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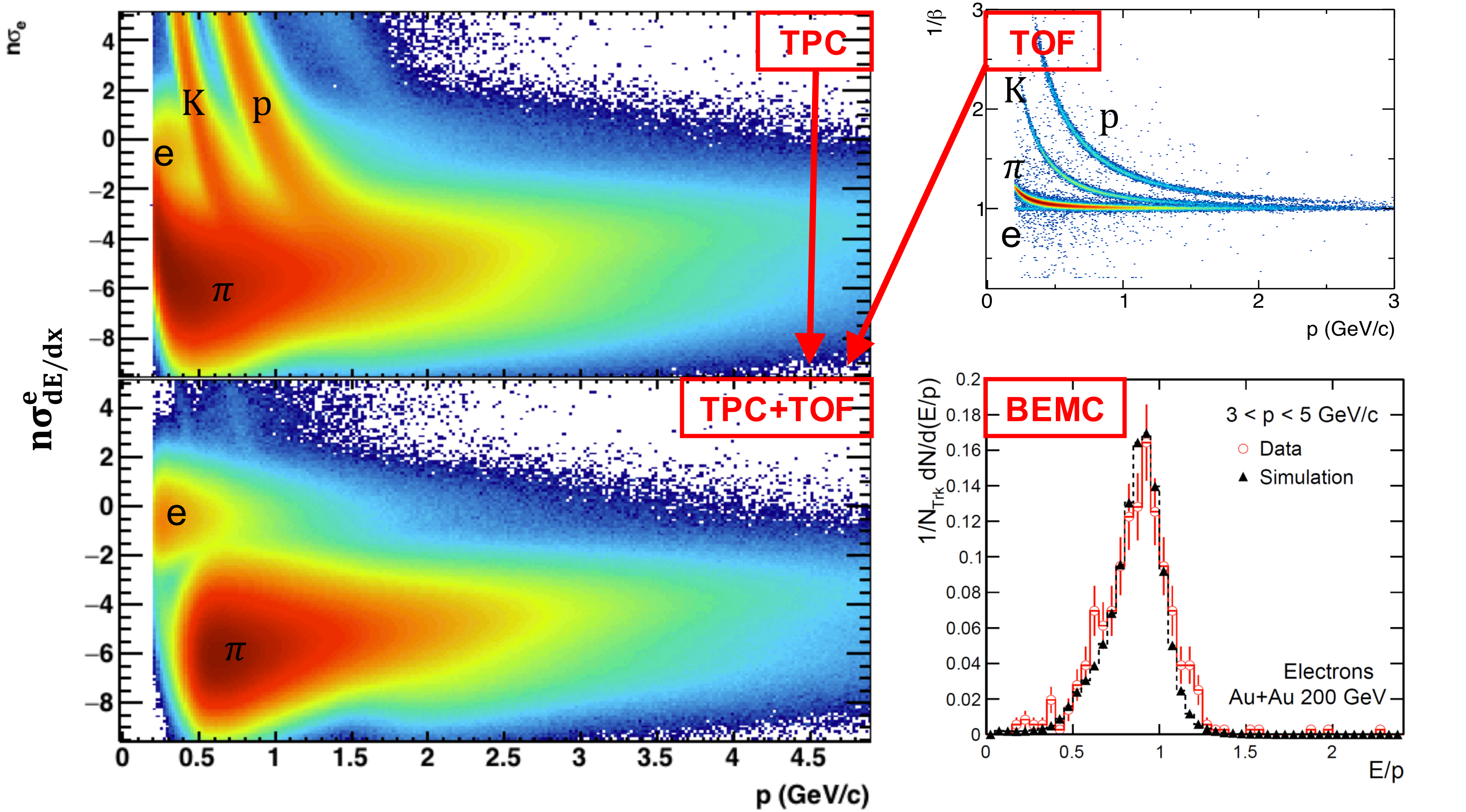
Electron Identification



$$n\sigma^{e}_{dE/dx} = \frac{\ln(dE/dx_{measured}) - \ln(dE/dX_{exp})}{R[\ln(dE/dX_{measured})]}$$

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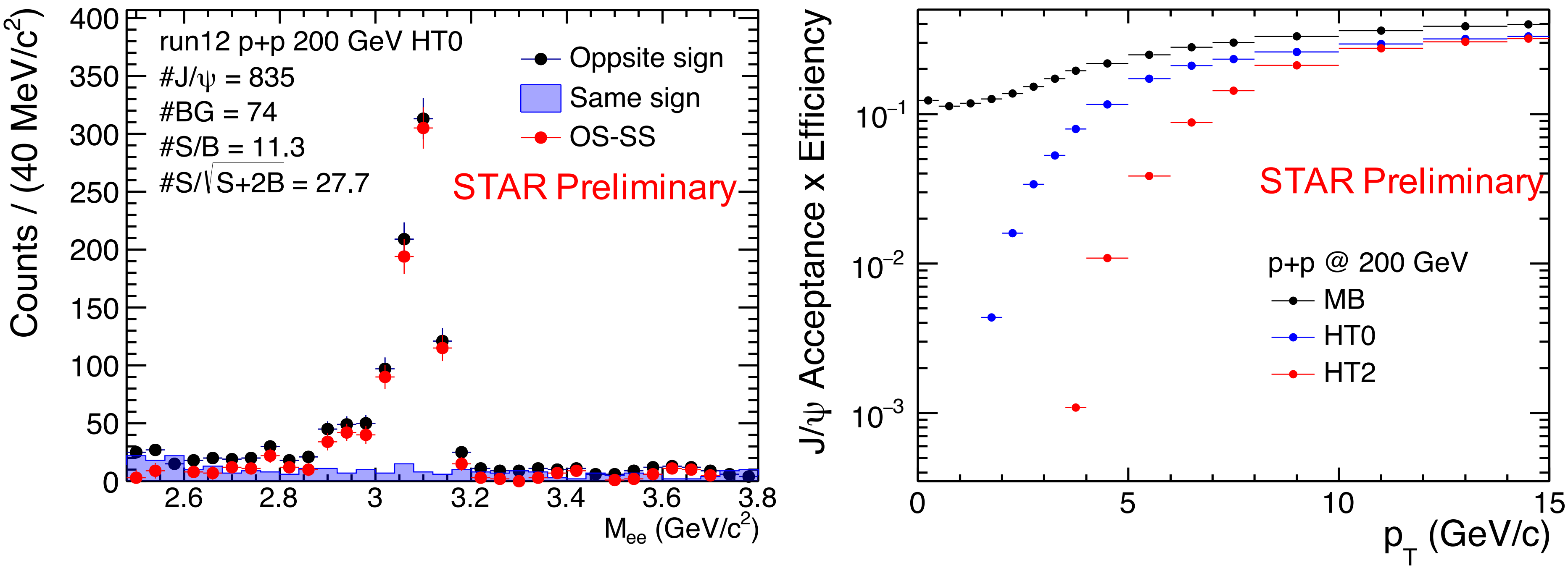
J/ψ Reconstruction



- Trigger: VPD for MB, BEMC for HT0(2) with E_T> ~2.5 (4.3) GeV/c
- HT0(2): triggered electron p_T>2.5 (4.3) GeV/c
- Electron ID: TPC+EMC or TPC+TOF
- $2.9<m_{ee}<3.2$ GeV/c^2, $-1<y_{ee}<1$

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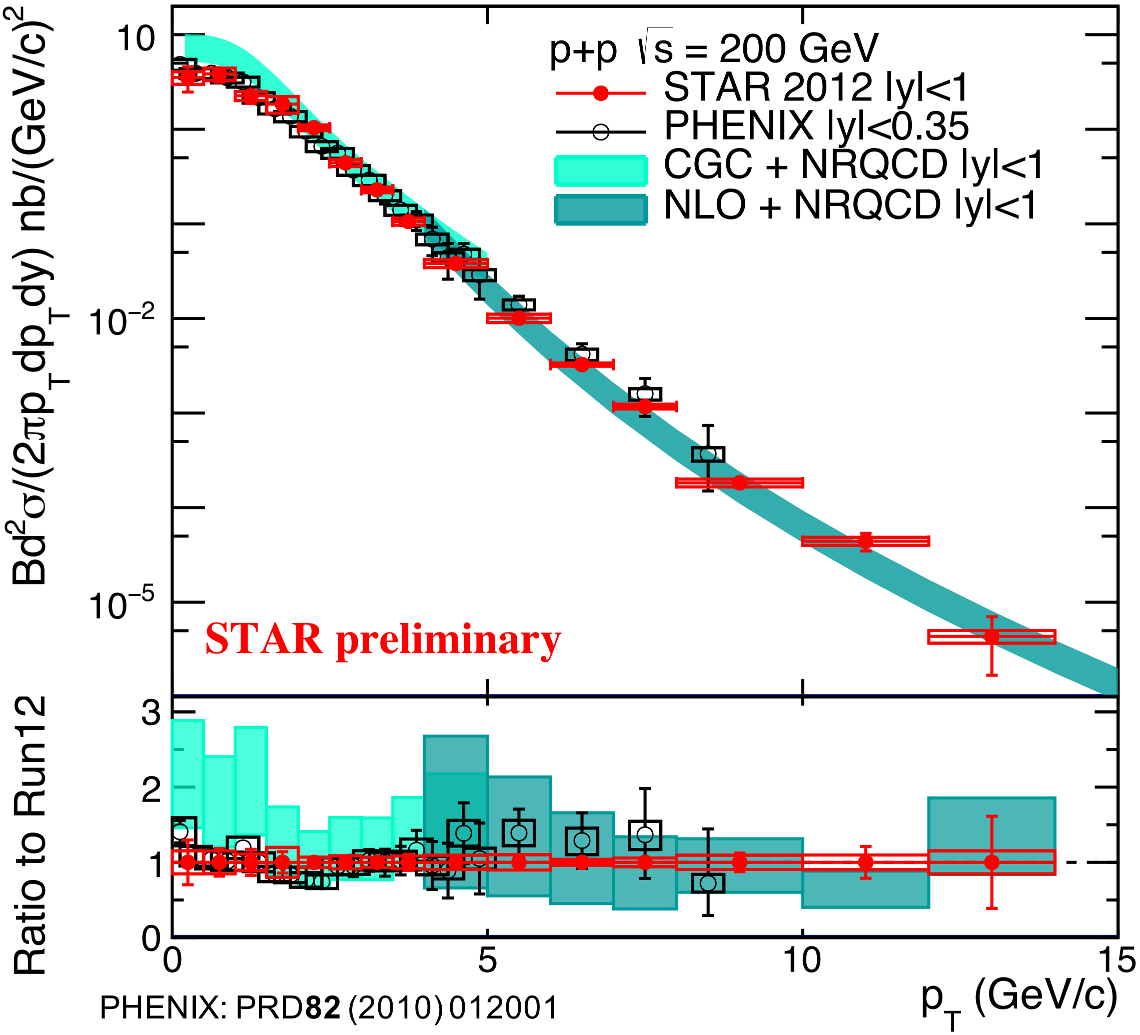
J/ψ Cross-section in p+p@200 GeV



PHENIX: PRD**82** (2010) 012001
NLO NRQCD: Ma et al., PRL106 (2011) 042002
CGC+NRQCD: Ma, Venugopalan, PRL**113** (2014) 192301

STAR 2012 data preliminary

$$B_{ee}\frac{d\sigma_{J/\psi}}{dy} = 47.3 \pm 2.9 \pm 6.1 \pm 3.8\, nb$$

PHENIX Publication

$$B_{ee}\frac{d\sigma_{J/\psi}}{dy} = 42.5 \pm 1.4 \pm 4.8 \pm 3.1\, nb$$

- Consistent with PHENIX result; Better precision at p_T>2 GeV/c
- NRQCD describes data fairly well; Small tension at p_T<1.5 GeV/c with CGC+NRQCD

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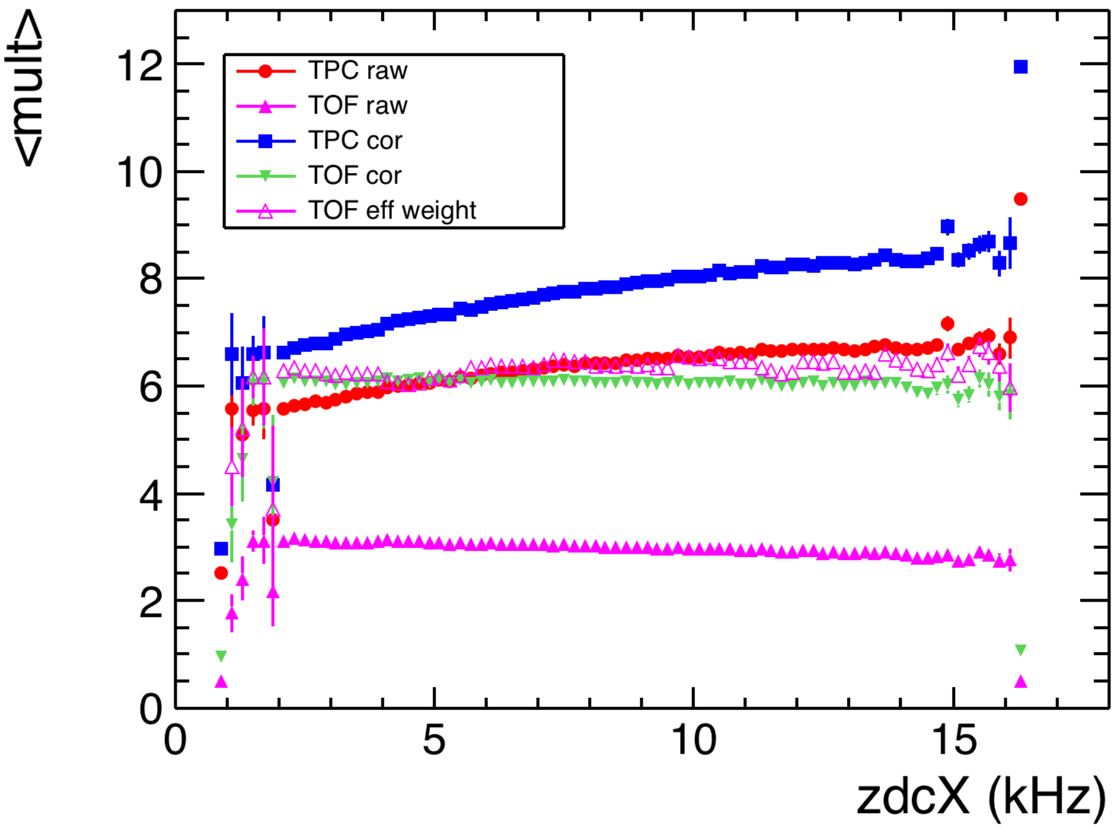
Measuring N_{ch} at STAR



- Reconstruct charged particles with p_T>0.2 GeV/c and |η|<1 with ≥ 20 TPC hits.
- "TPC-only" tracks receive large contribution from pile-up collisions, which can be suppressed by requiring tracks match to fast "TOF" hits.
- Dependences of pile-up effect, TPC and TOF efficiencies on instantaneous luminosity (zdcX) need to be taken into account.

TPC raw: detector-level TPC-only N_{ch}

TOF raw: detector-level TPC+TOF N_{ch}

TPC cor: TPC-only N_{ch} corrected by TPC efficiency

TOF cor: TPC+TOF N_{ch} corrected by lumi-independent TPC+TOF efficiency

TOF eff weight: TPC+TOF N_{ch} corrected by lumi-dependent TPC+TOF efficiency

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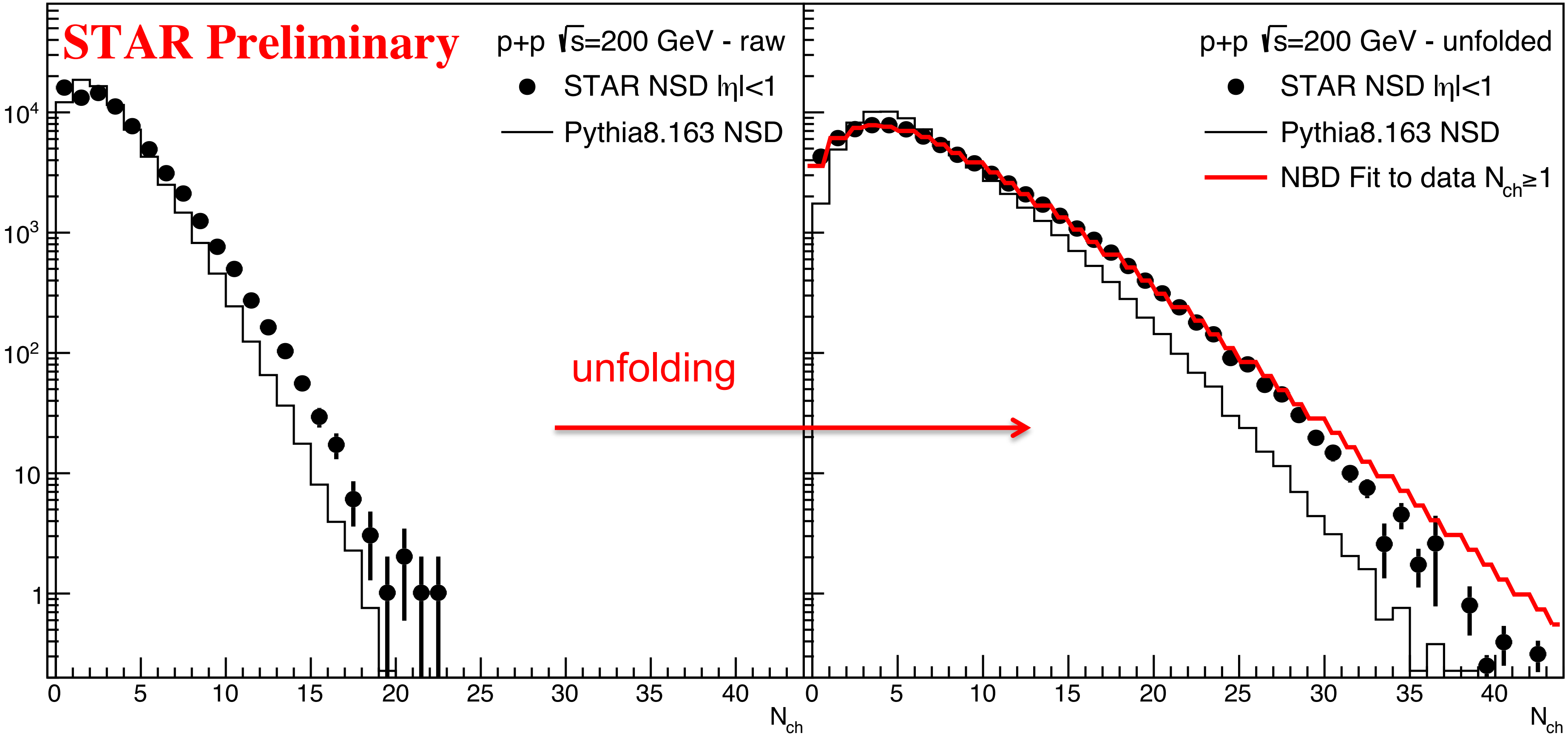
Measuring N_{ch} at STAR



- Charged particles with p_T>0.2 GeV/c and |η|<1 are reconstructed by the TPC and matched with TOF hits in NSD-enhanced (BBC 2.2<|η|<5.2) events.
- Raw N_{ch} distributions are unfolded to p_T>0 GeV/c and |η|<1 (corrected for detector efficiency and secondary particles from weak decays)

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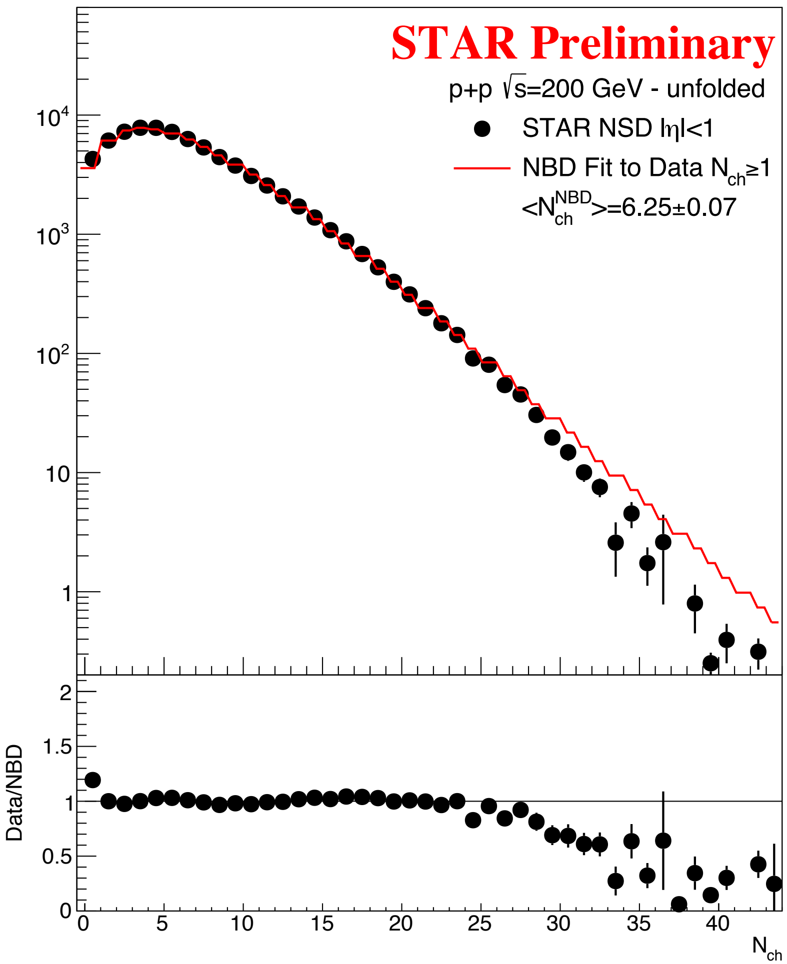
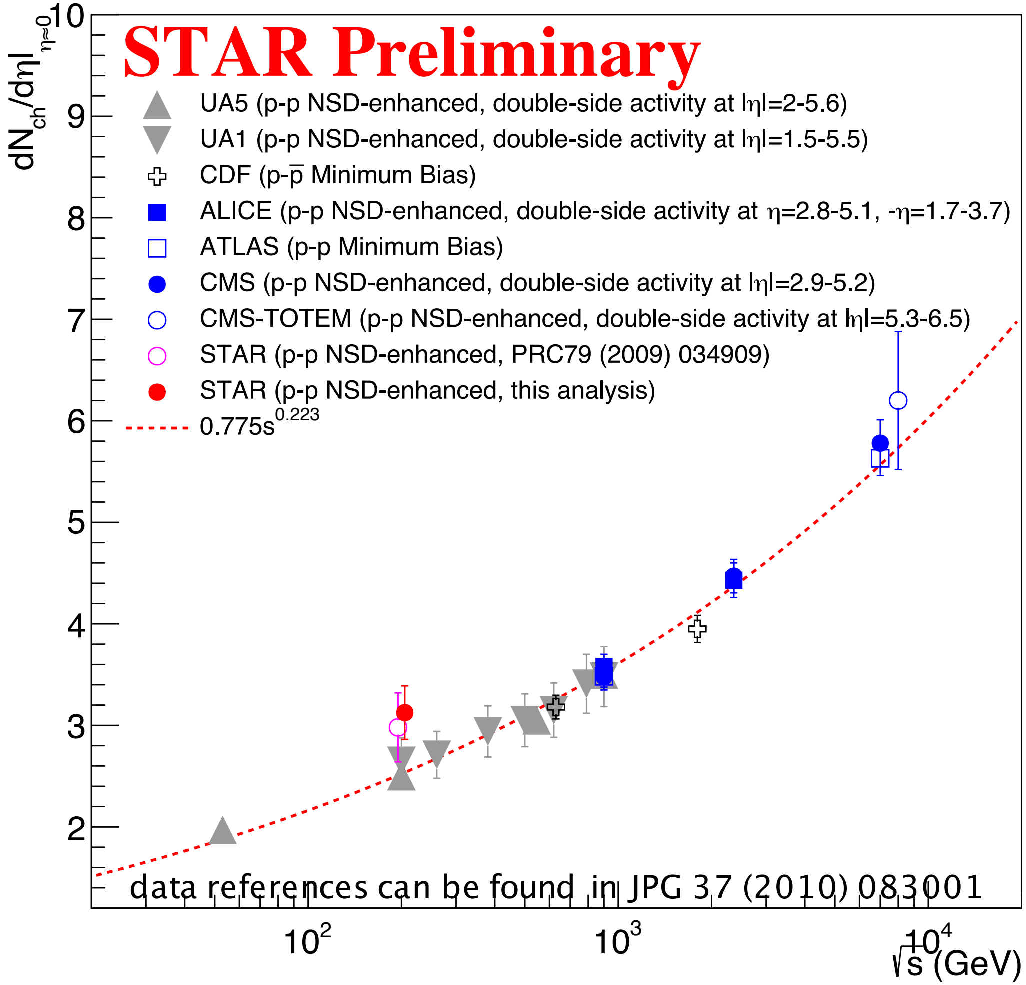
N_{ch} in p+p Collisions at 200 GeV





- Unfolded N_{ch} distribution can be described by negative binomial distribution.
- $dN_{ch}/d\eta = 3.13 \pm 0.27$ consistent with previous STAR result 2.98 ± 0.34

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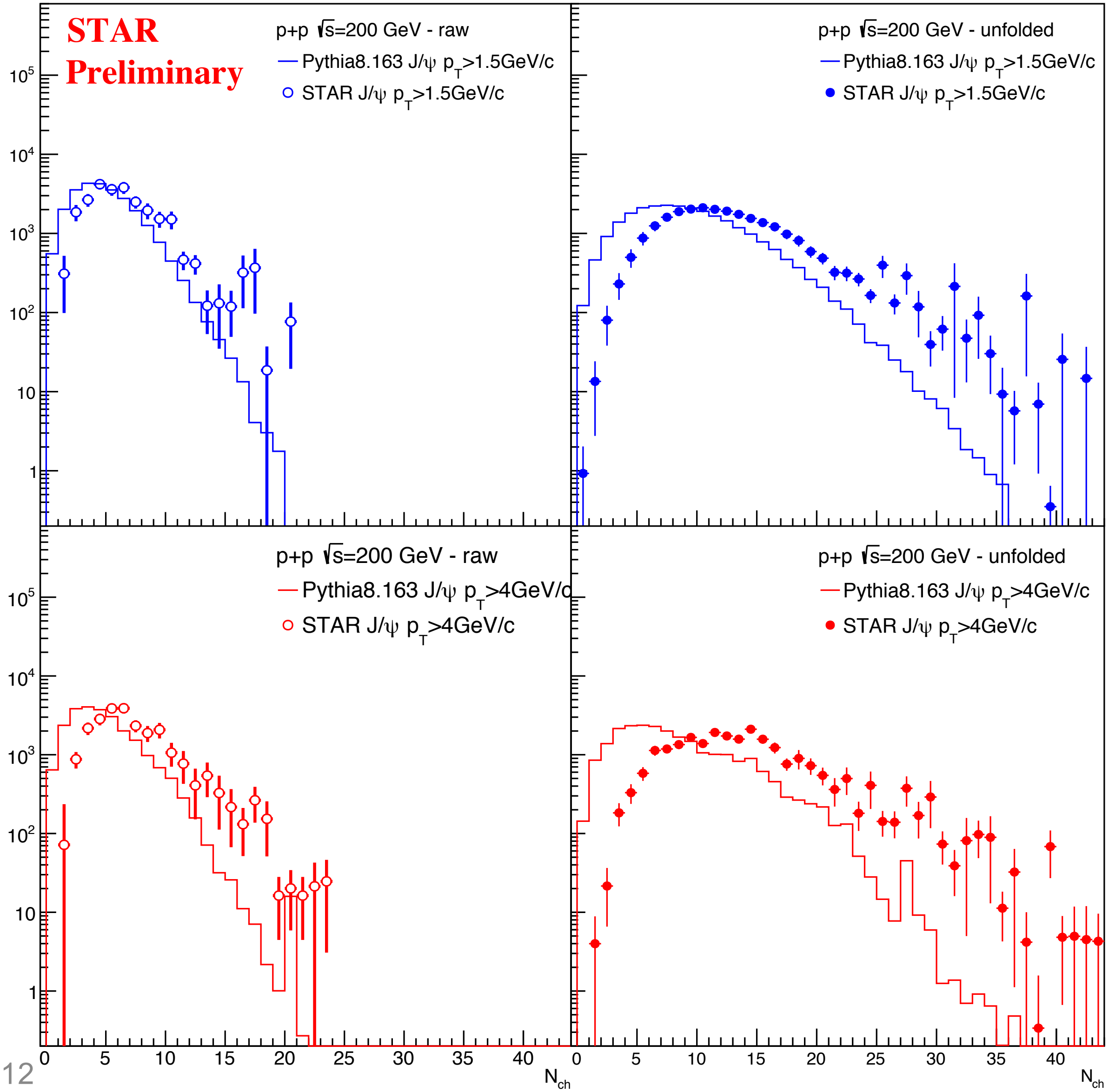
J/ψ Yield vs N_{ch} in p+p @ 200 GeV



- Unfolded N_{ch} distribution for J/ψ events can not be described by PYTHIA8. $<N_{ch}>$ in data higher than that in PYTHIA8 for J/ψ production.

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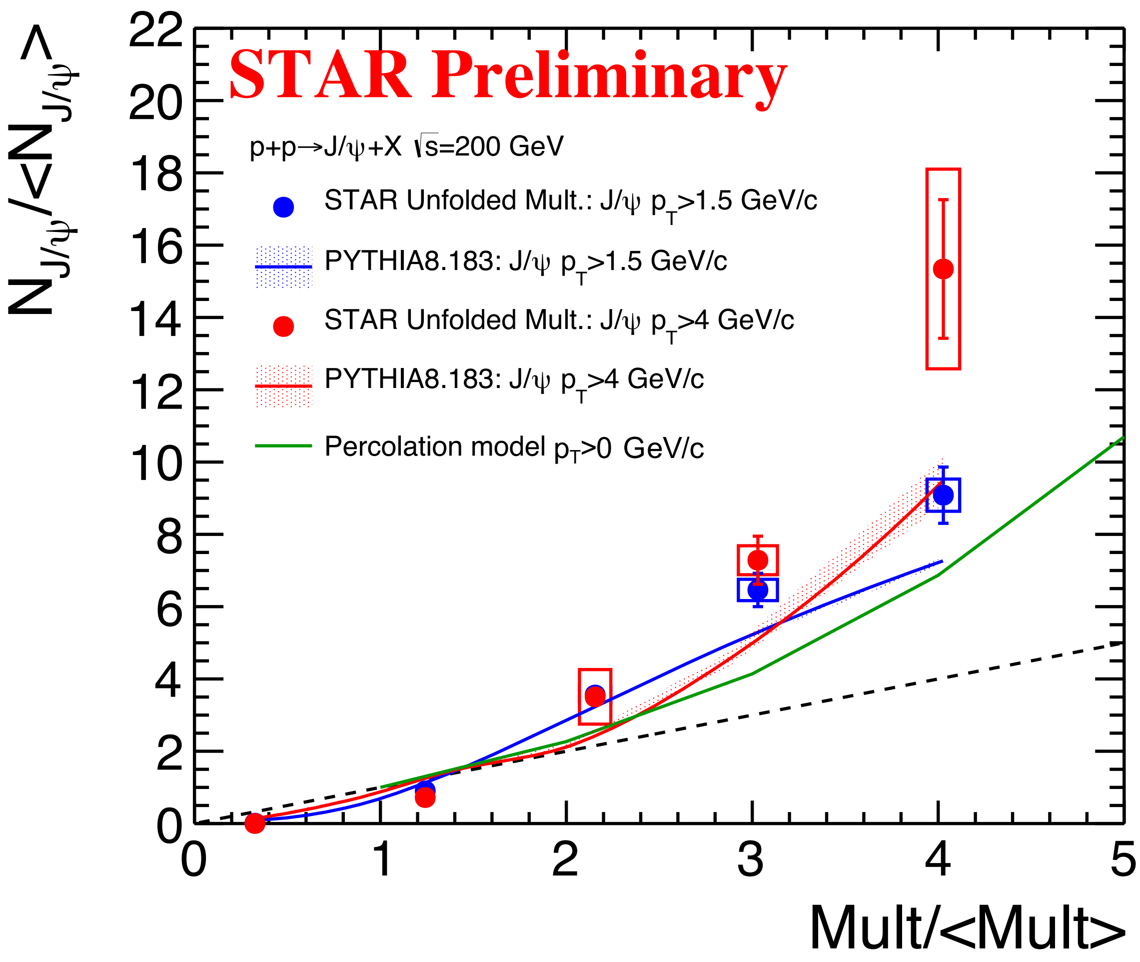
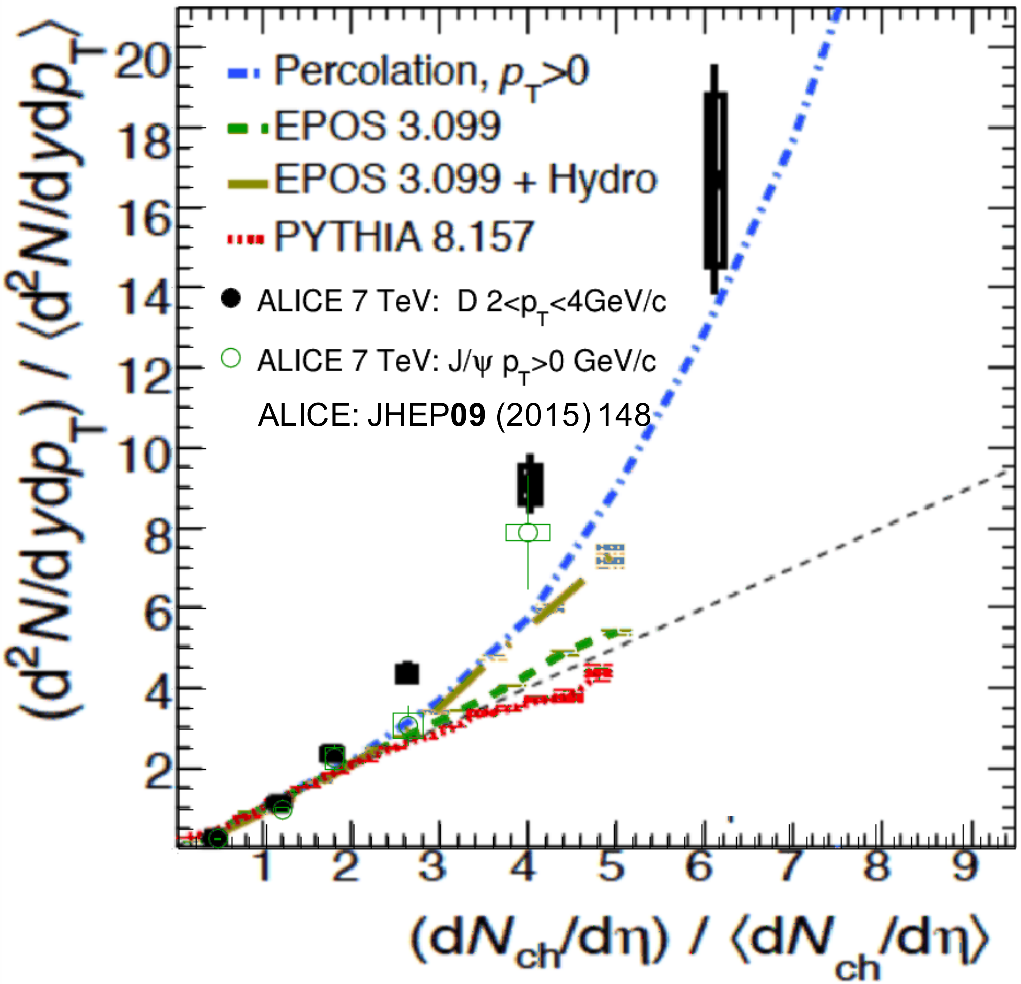
J/ψ Yield vs N_{ch} in p+p @ 200 GeV



- Unfolded N_{ch} distribution for J/ψ events can not be described by PYTHIA8. $<N_{ch}>$ in data higher than that in PYTHIA8 for J/ψ production.
- Relative J/ψ yield vs N_{ch} increases faster than linear. Such an increase is qualitatively described by PYTHIA8 and Percolation model but the increase is underestimated.

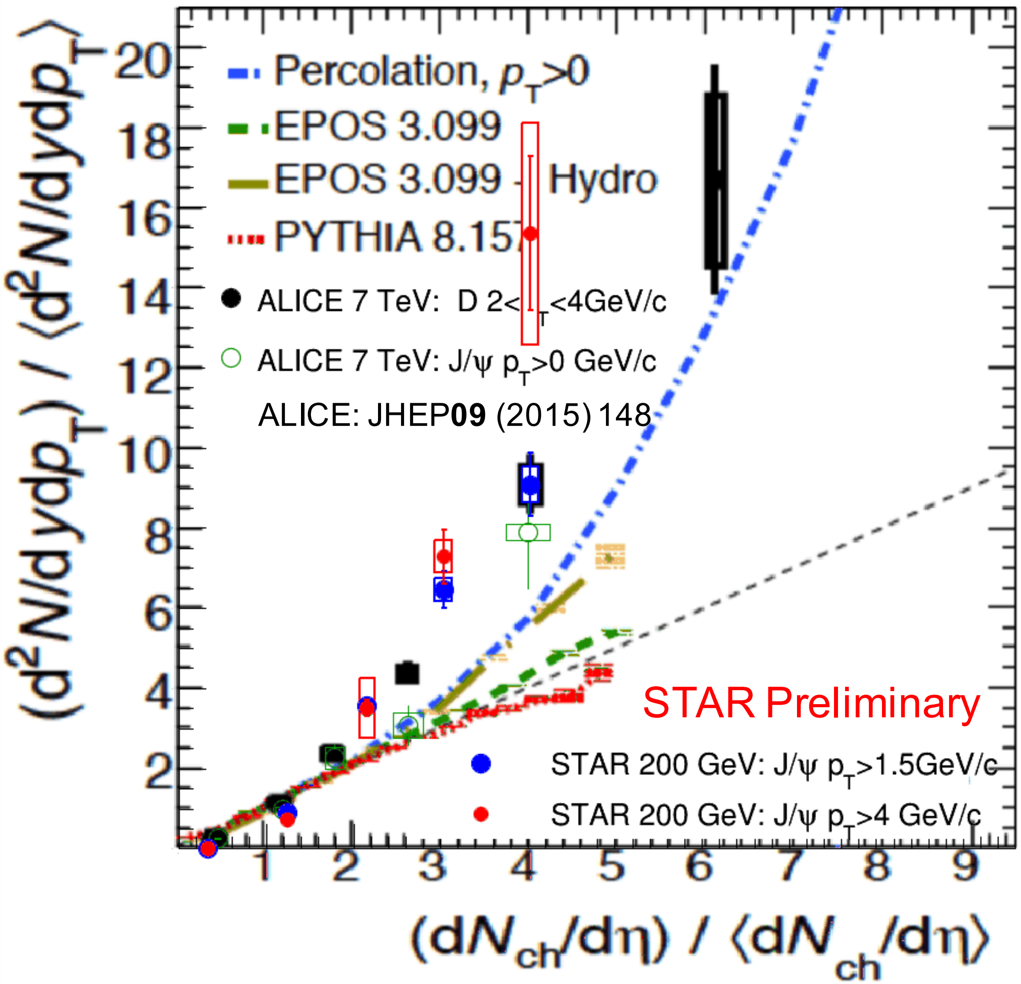
J/ψ Yield vs Event Activity (N_{ch})



Faster-than-linear rise of open charm and J/ψ production vs N_{ch} in p+p @ 7 TeV

- **Percolation model**: exchange color sources in collisions. High energy density suppresses soft processes more than hard processes
  N_{hard} rises faster than N_{ch} at LHC
- **EPOS3+Hydro**: energy density in 7 TeV p+p collisions is high enough to apply hydrodynamic evolution to the core of the collisions
  N_{hard} rises faster than N_{ch} at LHC
- **PYTHIA8 and EPOS3**: with MPI underestimate the increase
  $N_{hard} \propto N_{ch} \propto N_{MPI}$

J/ψ Yield vs Event Activity (N_{ch})



- **Percolation model**: exchange color sources in collisions. High energy density suppresses soft processes more than hard processes
  N_{hard} rises faster than N_{ch} at LHC
  Small collisional energy dependence
  N_{hard} rises faster than N_{ch} at RHIC

- **EPOS3+Hydro**: energy density in 7 TeV p+p collisions is high enough to apply hydrodynamic evolution to the core of the collisions
  N_{hard} rises faster than N_{ch} at LHC
  Strong collision energy dependence
  $\langle dN_{ch}/deta \rangle$ ~ 3 at 200 GeV
  ~ 6 at 7 TeV
  N_{hard} rises linearly as N_{ch} at RHIC

Stronger-than-linear rise following the same trend at 200 GeV and 7 TeV, suggests not a hot medium effect assumed in EPOS3+Hydro for p+p collisions

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Summary and Outlook

J/ψ yield vs event activity (N_{ch}) in p+p collisions at 200 GeV has been studied at STAR and compared to LHC results at 7 TeV

- Strong and similar correlation between J/ψ production and N_{ch} at 0.2 and 7 TeV
- PYTHIA8 qualitatively describes RHIC and LHC data but underestimates at high N_{ch}
- EPOS3 with MPI predicts linear increase and underestimates the data
- EPOS3+Hydro and Percolation model predict faster-than-linear increase, but the former expects strong dependence on $\sqrt{s}$, inconsistent with RHIC data.

More precise results from significantly increased data size and upgraded STAR detectors are expected.

- Improved low p_T J/ψ precision by Muon Telescope Detector
- Open heavy flavor and Upsilon production, p+p at 500 GeV

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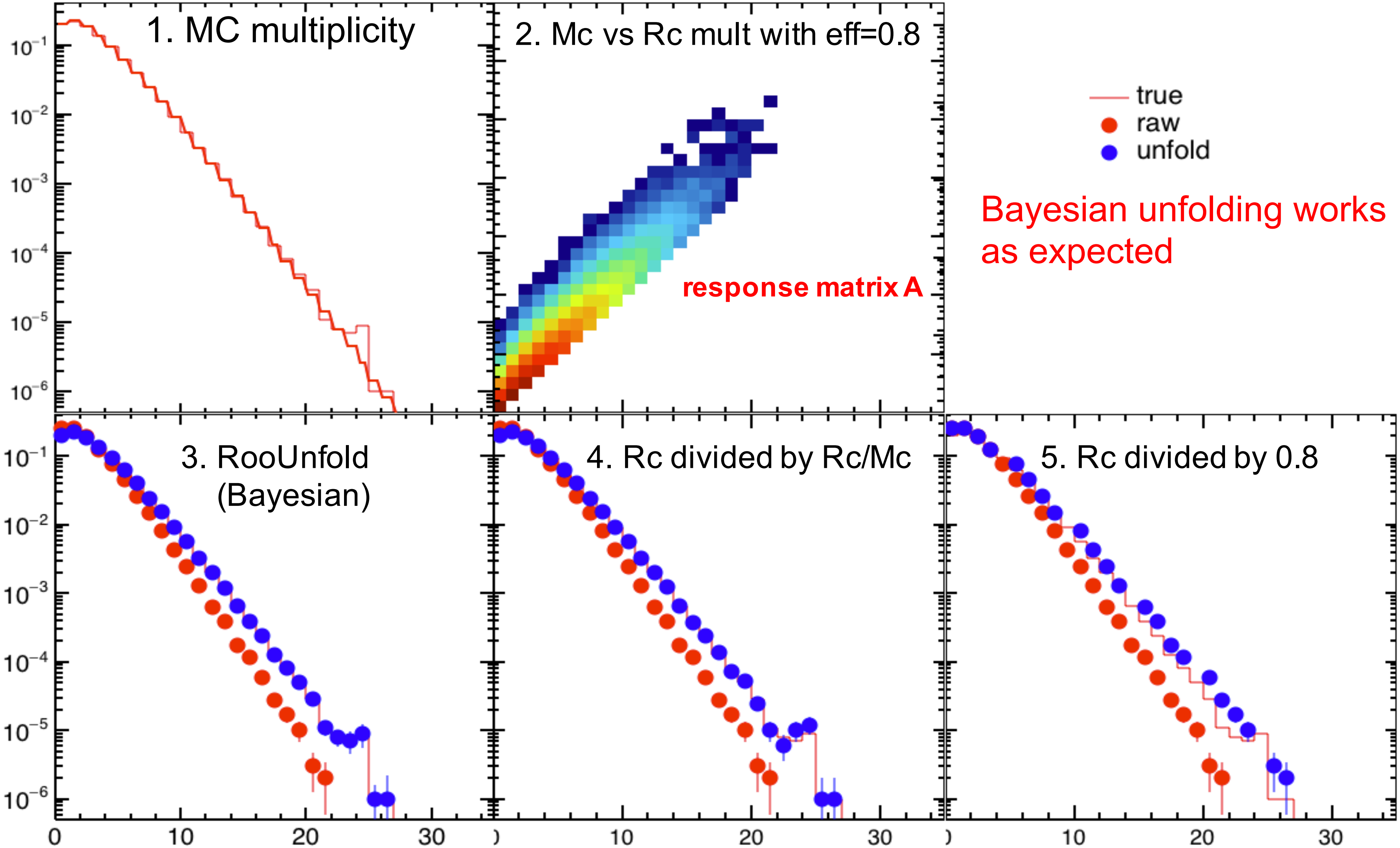
Backup

N_{ch} Unfolding



Bayesian unfolding works as expected

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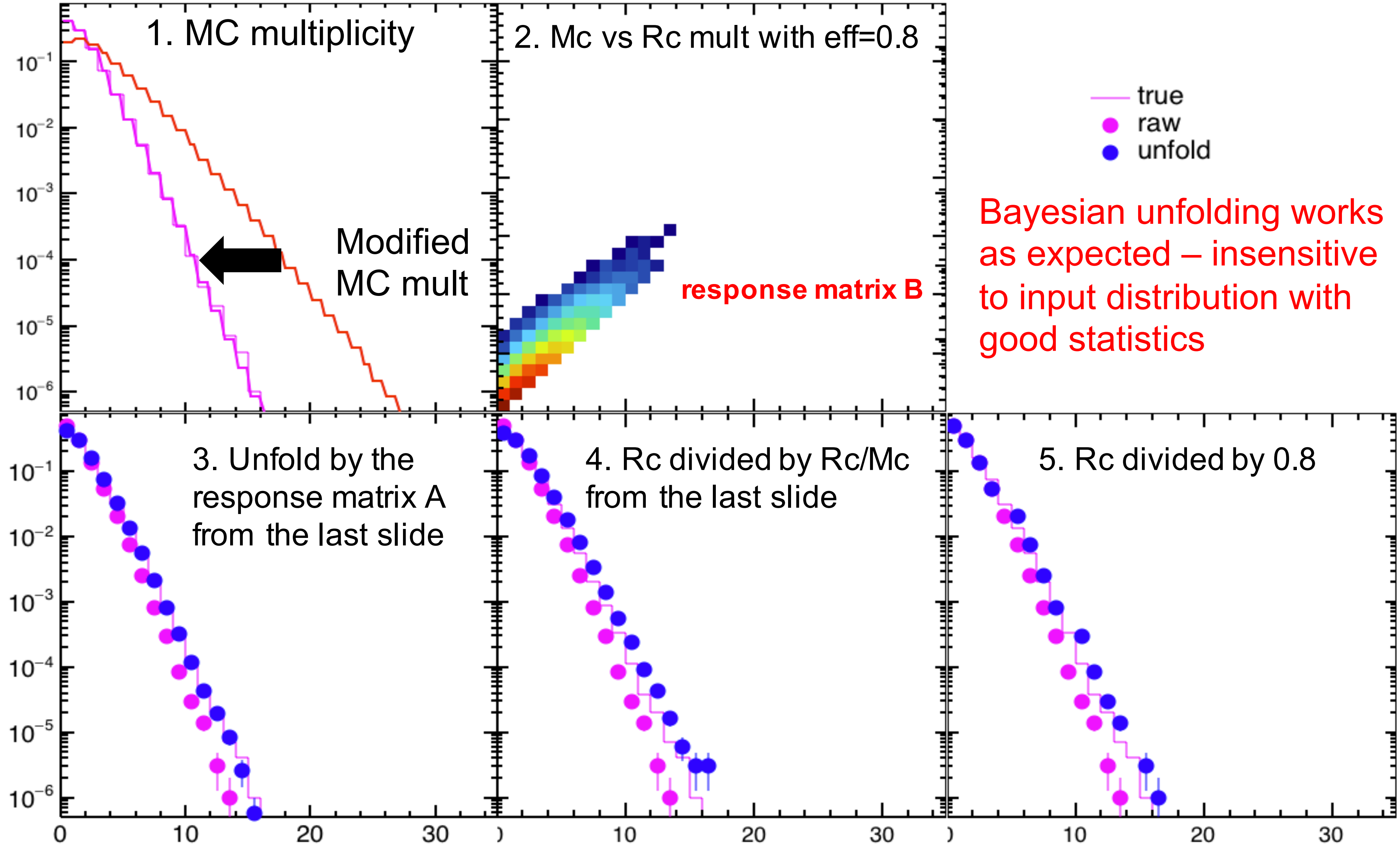
N_{ch} Unfolding



Bayesian unfolding works as expected – insensitive to input distribution with good statistics

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