STAR Analysis Meeting 2024

Analysis status of net-proton fluctuations in BES-II

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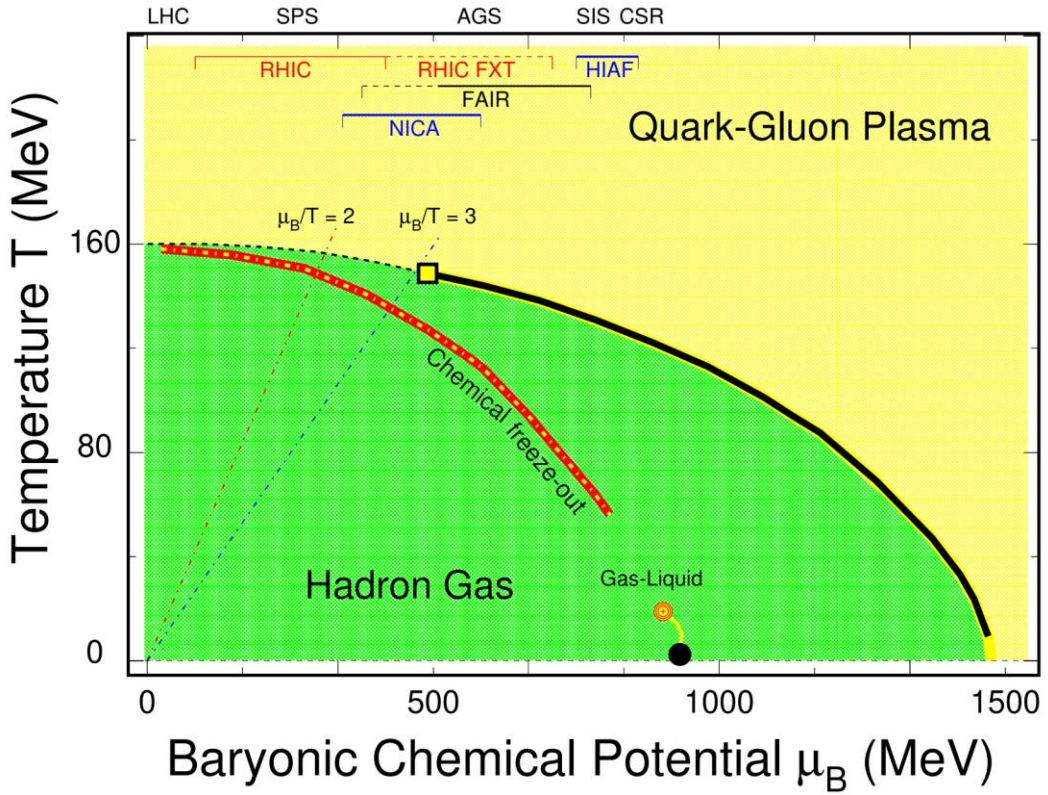
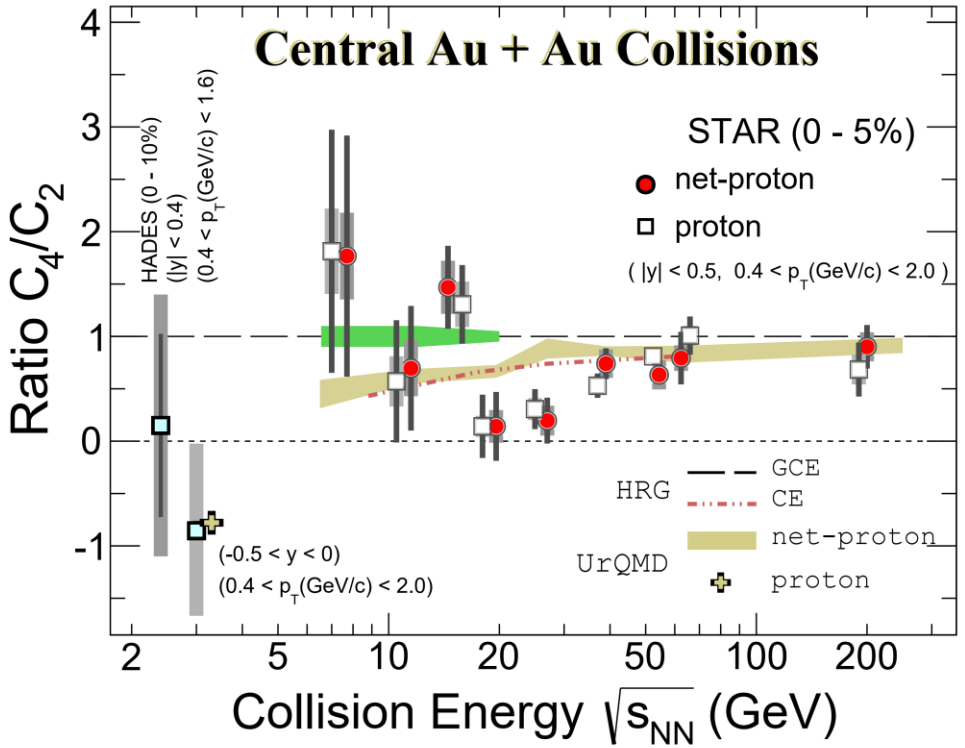
Outline

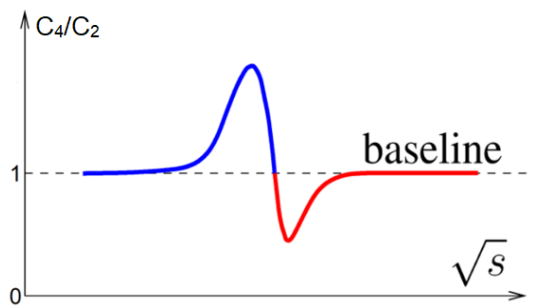
- Introduction
- Collider part
- FXT part (removed)
- Summary

Introduction

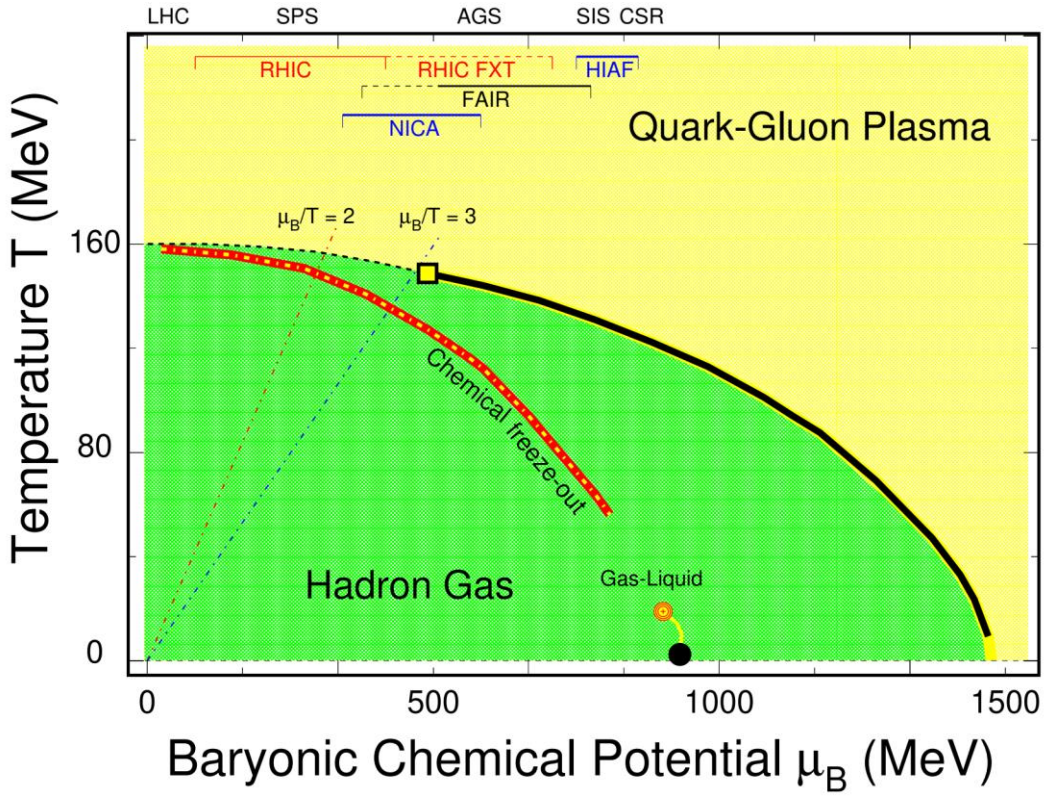


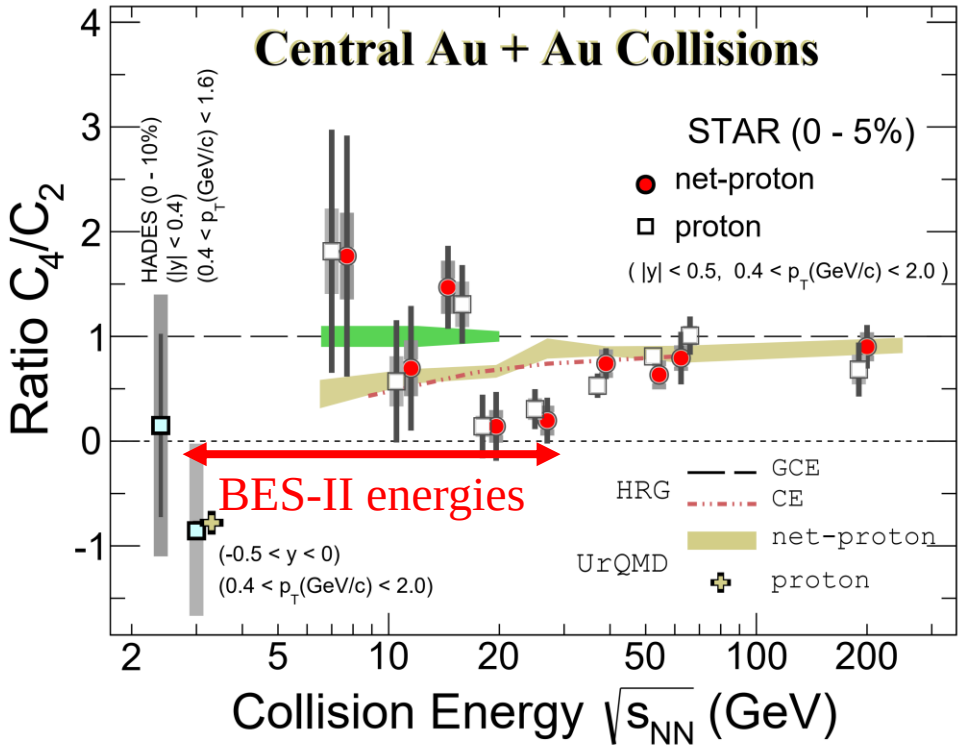


- Search for QCD Critical Point
  - Non-monotonic energy dependence (3.1σ observed in BES-I)

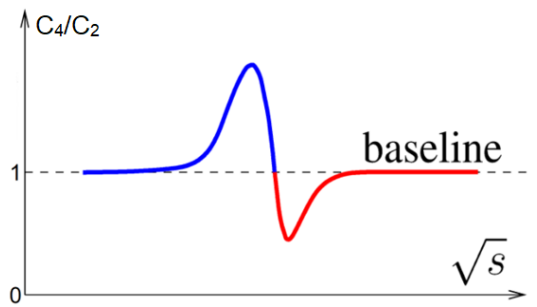


Introduction





- Search for QCD Critical Point
  - Non-monotonic energy dependence (3.1σ observed in BES-I)
- BES-II measurement from $\sqrt{s_{NN}}$ = 3.0 to 27 GeV
  - Crucial for precision observation of energy dependence



Collider part

Overview of datasets

Energy (GeV)	7.7	9.2	11.5	14.6	17.3	19.6	27
Chemical potential μ_B (MeV)	420	373	315	262	230	206	156
Year	2021	2020	2020	2019	2021	2019	2018
Collected events (M)	101	162	235	324	250	582	560
Trigger IDs (min. bias)	8100[1-4]0	7800[1-2]0	7100[0-2]0	650000	870010	6400[0-5]1	6100[0-5]1
Production status	Done	Done	Done	Done	Done	Done	Done
Embedding (normal statistics)	Done	Done	Done	Done	Pending	Done	Done
Embedding (high statistics)	Pending	Pending	Pending	Pending	Pending	Pending	Not needed

Overview of analyses

Energy (GeV)	7.7	9.2	11.5	14.6	17.3	19.6	27
Production	Done	Done	Done	Done	Done	Done	Done
QA	Done	Done	Done	Done	Done	Done	Done
Centrality	Done	Done	Done	Done	Done	Done	Done
Purity	Done	Done	Done	Done	Pending	Done	Done
Embedding (normal statistics)	Done	Done	Done	Done	Pending	Done	Done
Embedding (high statistics)	Pending	Pending	Pending	Pending	Pending	Pending	Not needed
Result	Near com.	Near com.	Near com.	Near com.	Pending	Near com.	Near com.
UrQMD simulation	Near completion (YZ)						
Analyzers	BM/FS/AP	AP/BM	YH/FS	AP/YH	YH/AP	YH/AP	AP/YZ

- At least two independent analyzers required for each dataset

YH: Yige Huang (CCNU)
BM: Bappaditya Mondal (NISER)
AP: Ashish Pandav (LBL)
FS: Fan Si (USTC/Tsukuba)
YZ: Yu Zhang (CCNU)

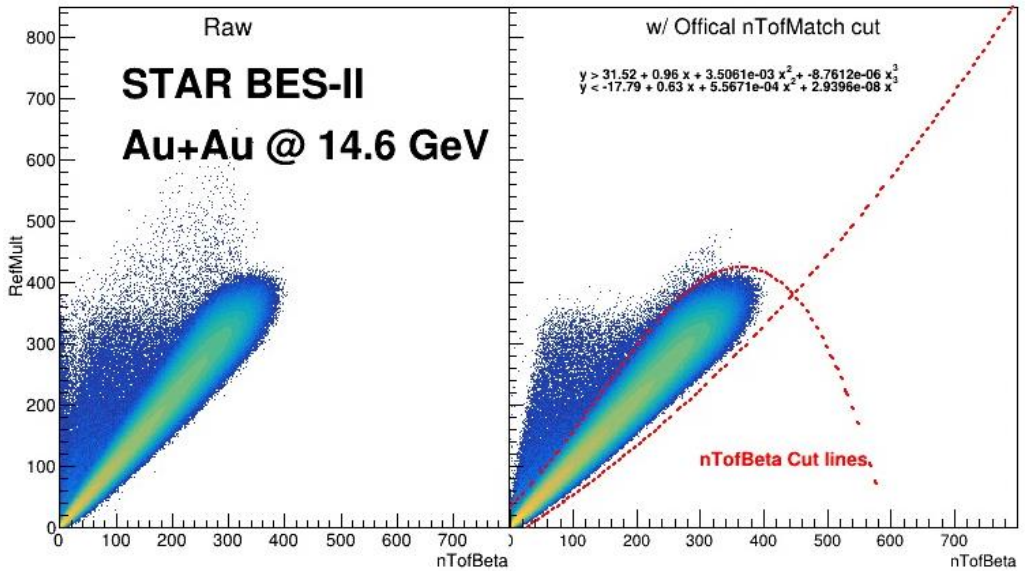
Analysis cuts

Energy (GeV)	7.7	9.2	11.5	14.6	17.3	19.6	27
Trigger IDs (min. bias)	8100[1-4]0	7800[1-2]0	7100[0-2]0	650000	870010	6400[0-5]1	6100[0-5]1
Vz cut	|Vz| < 50 cm						|Vz| < 27 cm
Vr cut	|Vr| < 2 cm						
Good events (M)	45	65	110	172	150	310	220
BES-I good events (M)	3	-	6.6	20	-	15	30

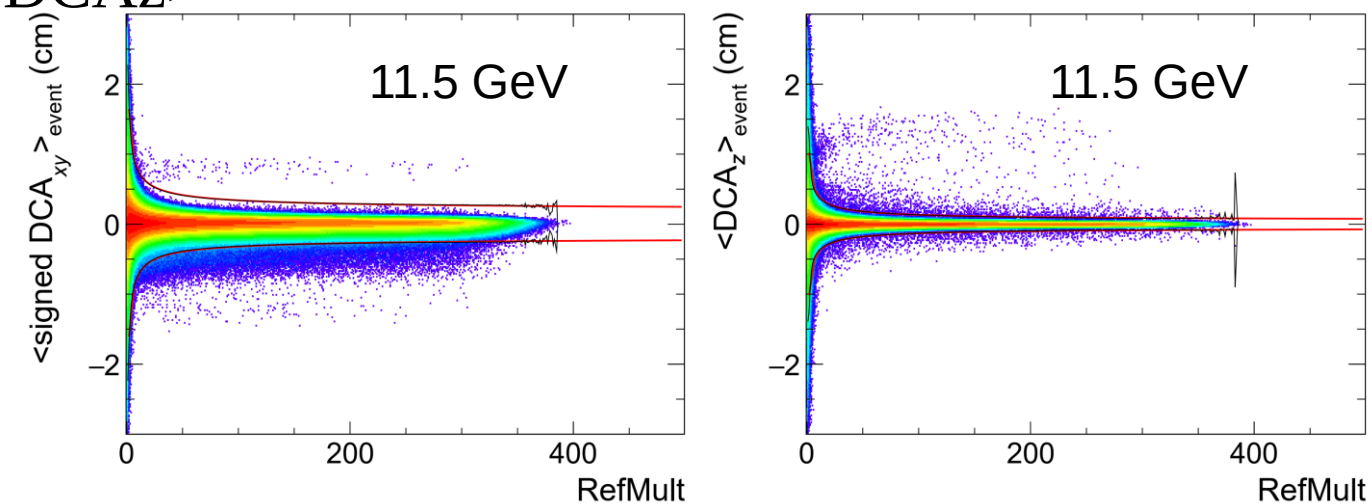
- Track quality cut
  - Primary
  - nHitsFit > 20
  - nHitsFit/nHitsPoss > 0.52
  - nHitsDedx > 5
  - DCA < 1 cm
- Kinematic selection
  - 0.4 GeV/c < p_T < 2 GeV/c
  - $|y_{proton}| < 0.5$
- (Anti)proton identification
  - $|n\sigma_{proton} - \mu| < 2$
  - 0.6 GeV$^2/c^4$ < m^2 < 1.2 GeV$^2/c^4$
    - Only for p_T > 0.8 GeV/c*
    - *Depends on purity (purity > 90% required)

Bad event rejection

- Pileup events
  - TPC multiplicity: RefMult
  - TOF multiplicity: nTofBeta
    - Reasonable β information ($0.1 < \beta < 1.1$) required
  - Official code for pileup identification used

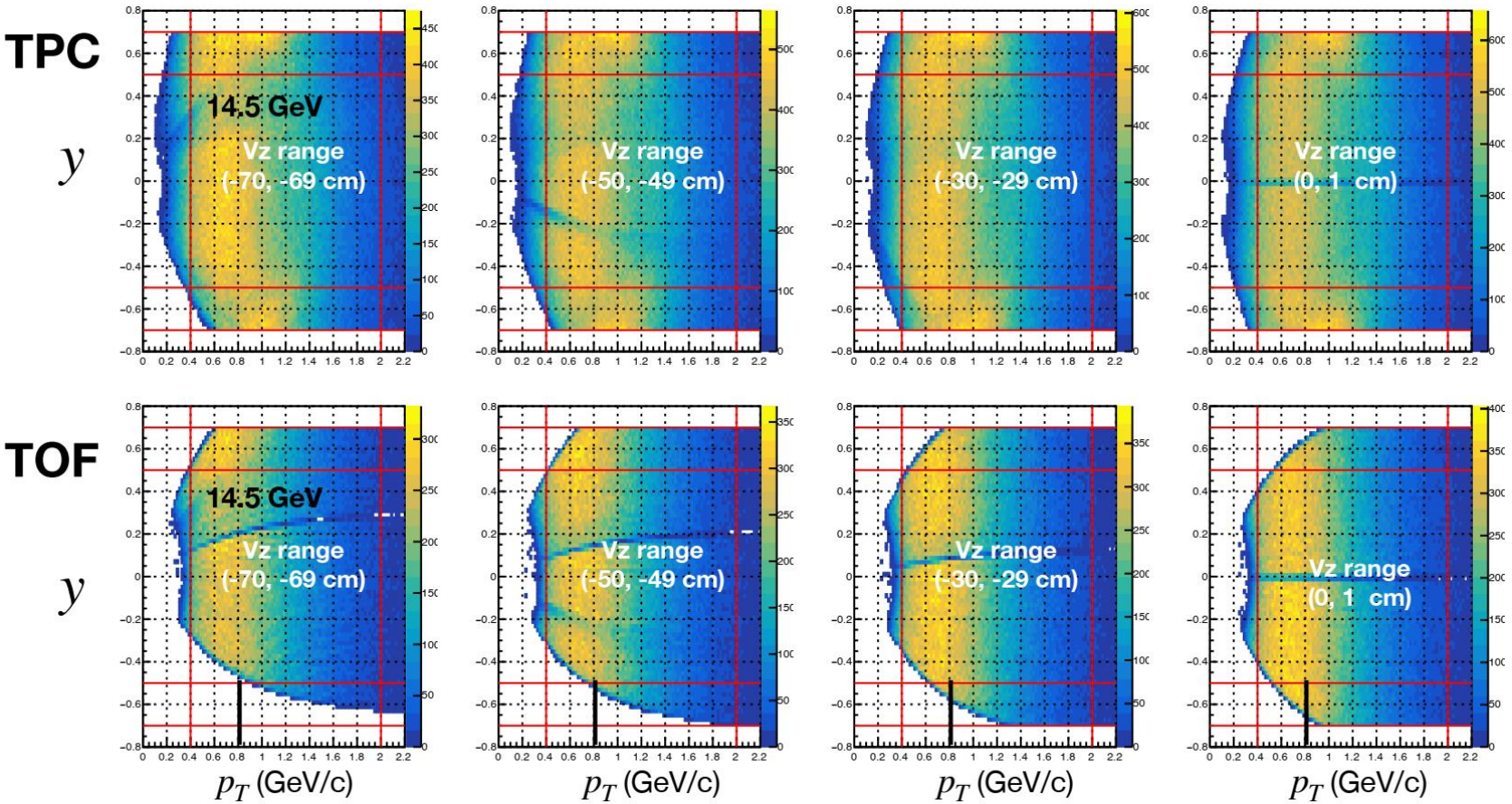


- Events with bad <sDCAxy> and <DCAz>
  - Clear multiplicity dependence
  - 6σ outliers removed



Vz-dependent acceptance

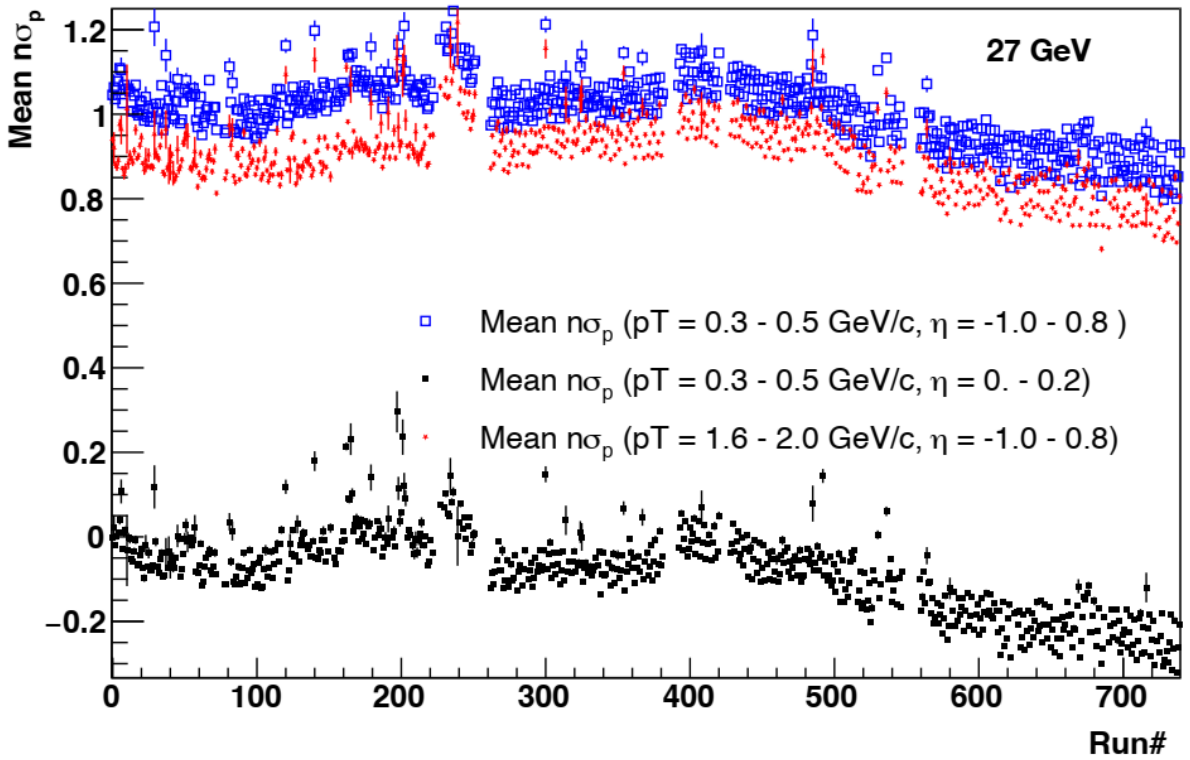
- For events in |Vz| < 50 cm
  - Default phase space (0.4 GeV/c < p_T < 2 GeV/c, $|y_{proton}|$ < 0.5) fully covered by TPC
  - Full TOF acceptance in p_T > 0.8 GeV/c where we require TOF

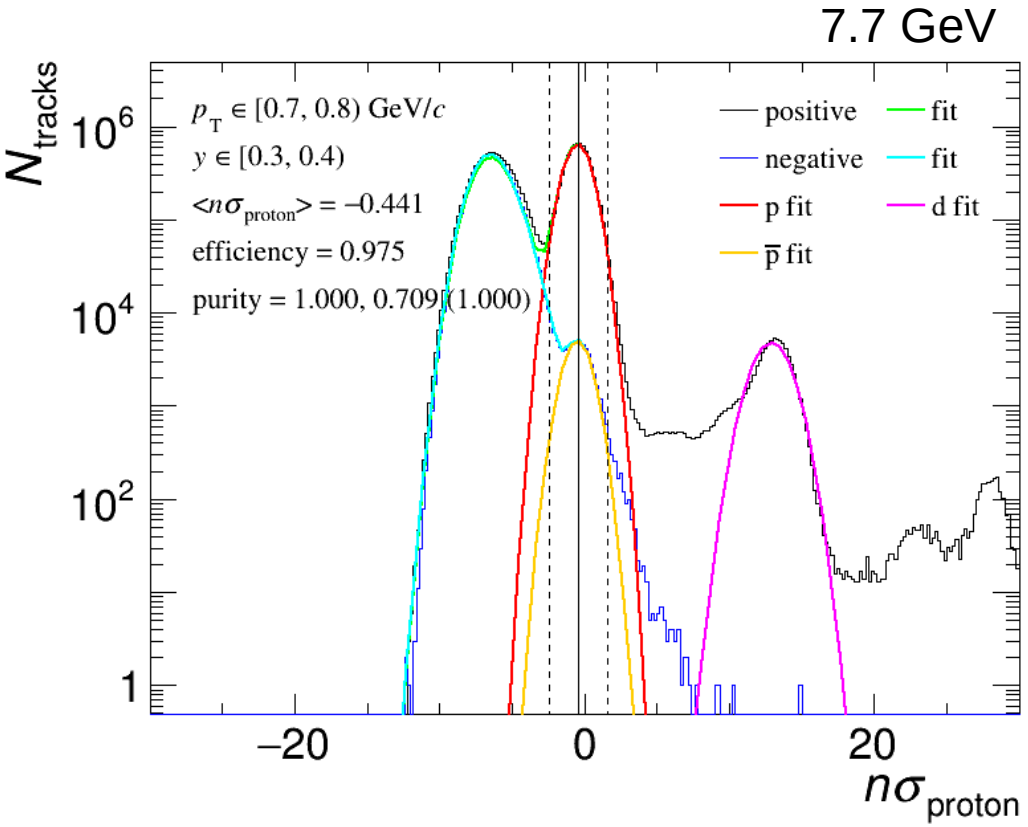


TPC $n\sigma_{\text{proton}}$ recalibration

- 3D dependence: run ID, (pseudo)rapidity , pT

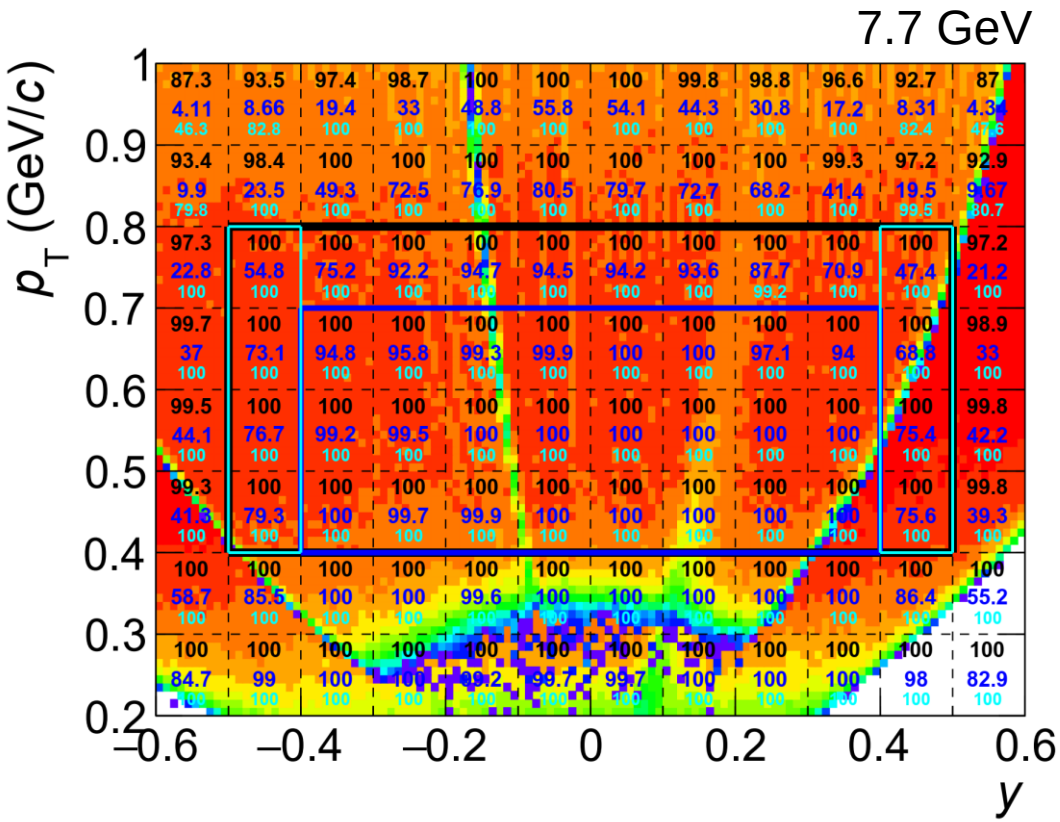
- Shifted $n\sigma_{\text{proton}}$ is used in multiplicity definition and proton number measurement





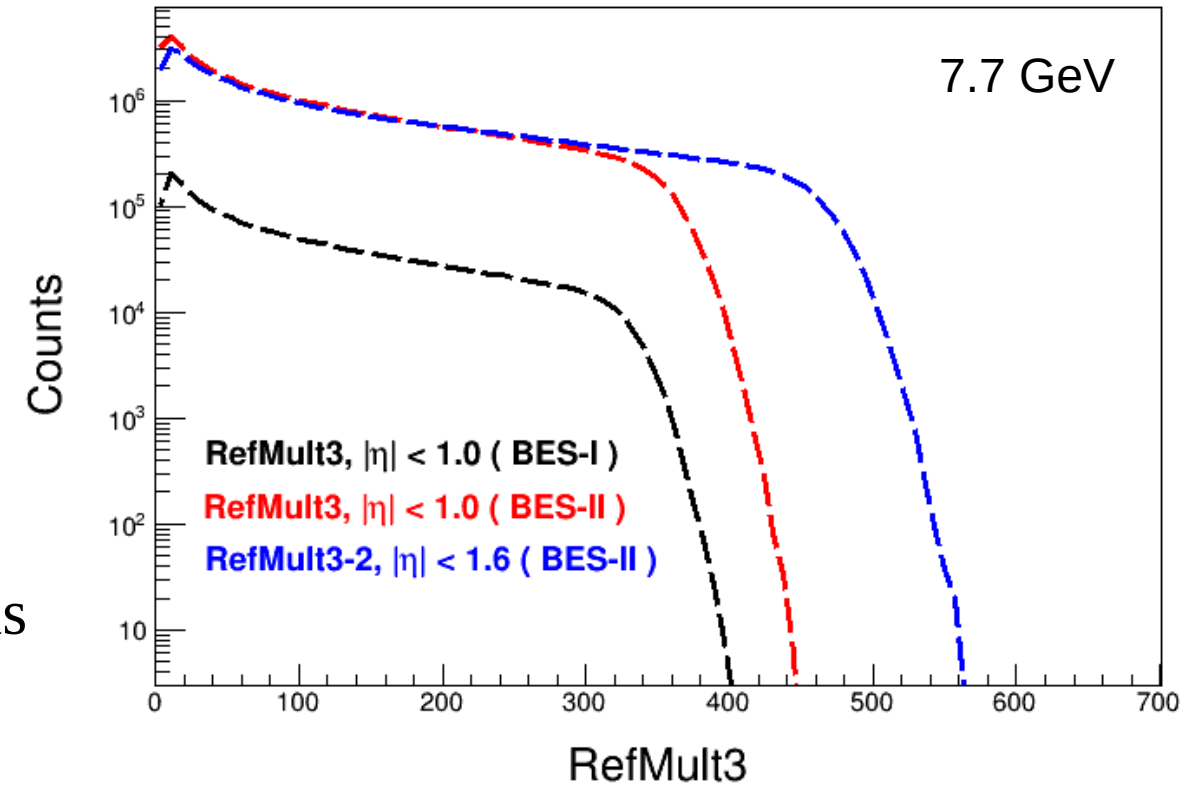
Purity and PID cut

- Purity numbers
  - Black: proton ($|n\sigma_{\text{proton}}-\mu| < 2$)
  - Blue: antiproton ($|n\sigma_{\text{proton}}-\mu| < 2$)
  - Cyan: antiproton (asymmetric, $0 < n\sigma_{\text{proton}}-\mu < 2$)
- High proton purity > 90% at all energies
  - Black square: only TPC PID
- Solution to antiproton purity issue at 7.7 GeV
  - Blue square: only TPC PID
  - Cyan boxes: asymmetric $n\sigma_{\text{proton}}$ cut
    - TPC purity < 90%, not fully covered by TOF
  - Other phase space: TPC+TOF PID
- Acceptance bands
  - TPC (larger) and TOF (smaller)
  - 49 cm < V_z < 50 cm
  - nHitsFit > 25



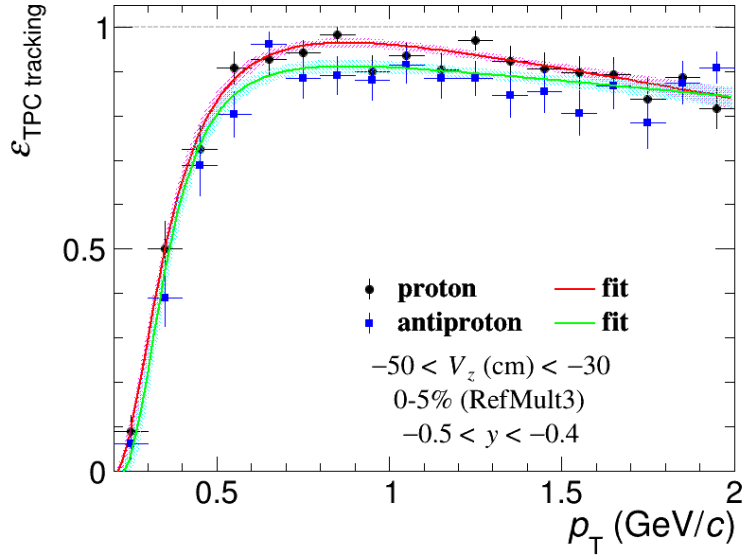
Centrality definition

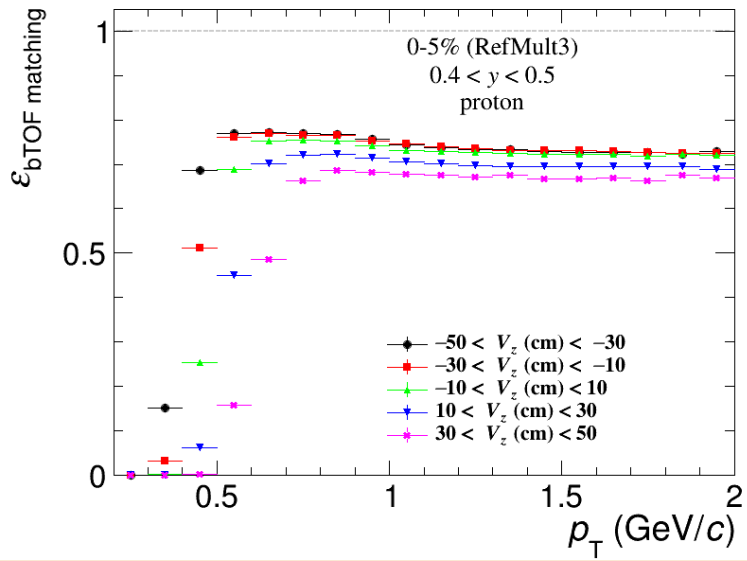
- RefMult3: $\pi^{\pm}$ and $K^{\pm}$ in $|\eta| < 1.0$
  - Better centrality resolution than BES-I
- RefMult3X: $\pi^{\pm}$ and $K^{\pm}$ in $|\eta| < 1.6$
  - NEW in BES-II
  - Even better resolution than BES-I
- Results from different centrality definitions will be compared



Efficiency calculation

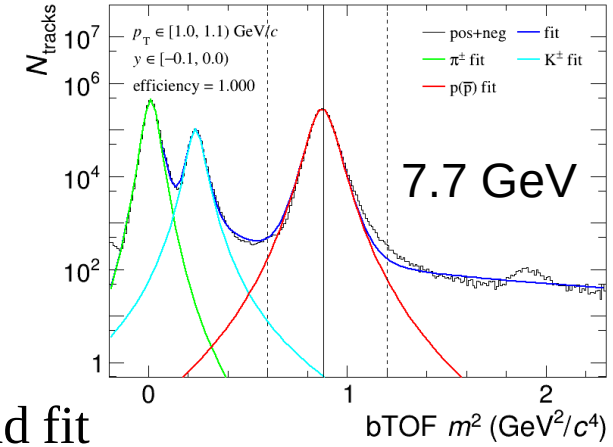
- TPC tracking efficiency and TOF matching efficiency
  - 4D dependence: V_z, centrality, rapidity, p_T
  - Clear Vz dependence
- Large statistical error of TPC tracking efficiency
  - Up to ~10%, due to 4D differential binning
  - pT parameterization to suppress fluctuations
- High statistics of embedding samples needed
  - Statistics are estimated to have 2% error of efficiency
  - Requests have been submitted

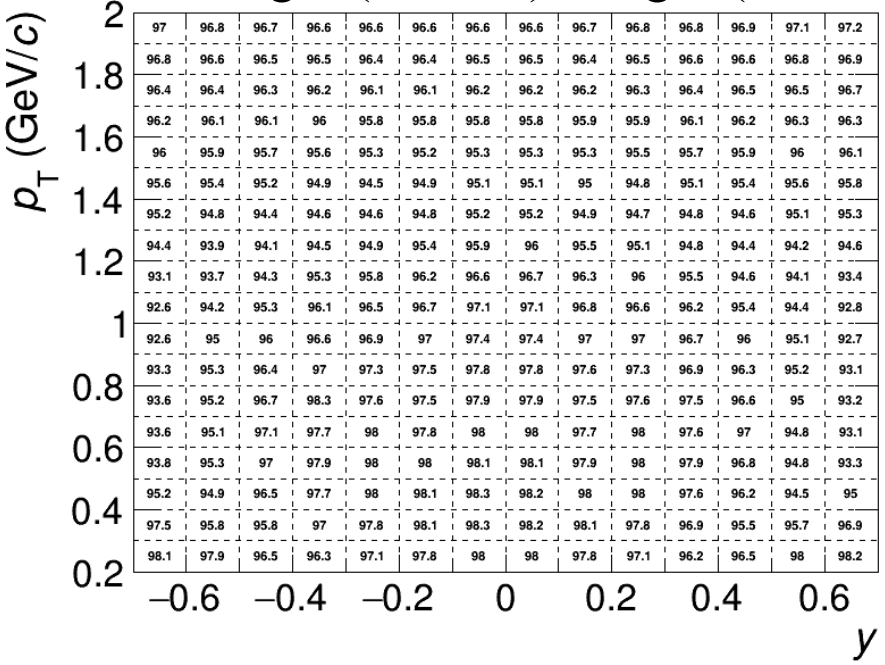




Efficiency calculation

- TPC and TOF PID cut efficiency
  - 2D dependence: y, p_T
  - TPC $n\sigma_{\text{proton}}$: ~ 95%
    - ε = Integral(μ−2, μ+2)/Integral(−∞, +∞) from multi-Gaussian fit
  - TOF m^2: ~100% at low pT, ~95% at pT ~ 2 GeV/c
    - ε = Integral(0.6, 1.2)/Integral(−∞, +∞) from muti-Student's-t + background fit

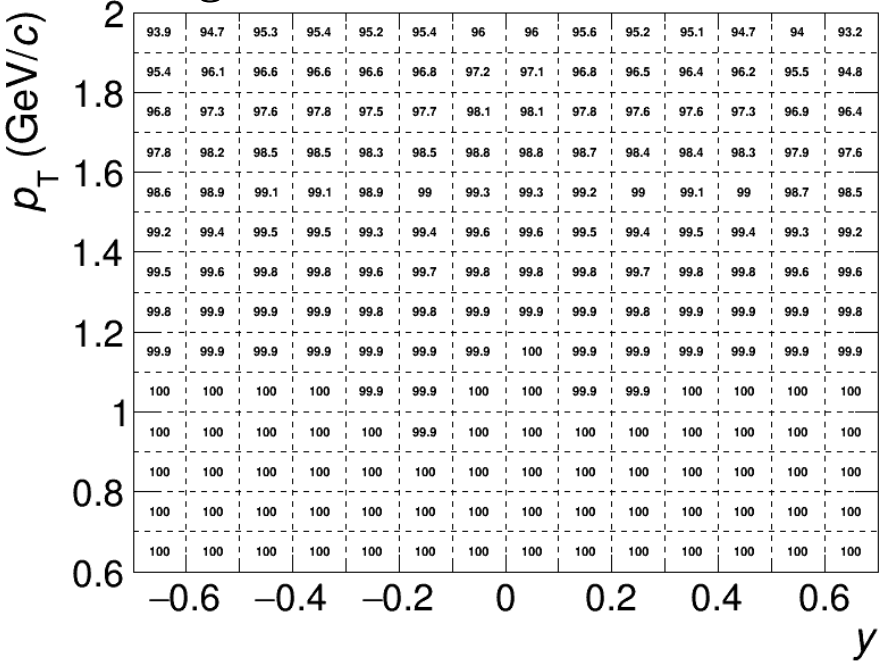




7.7 GeV

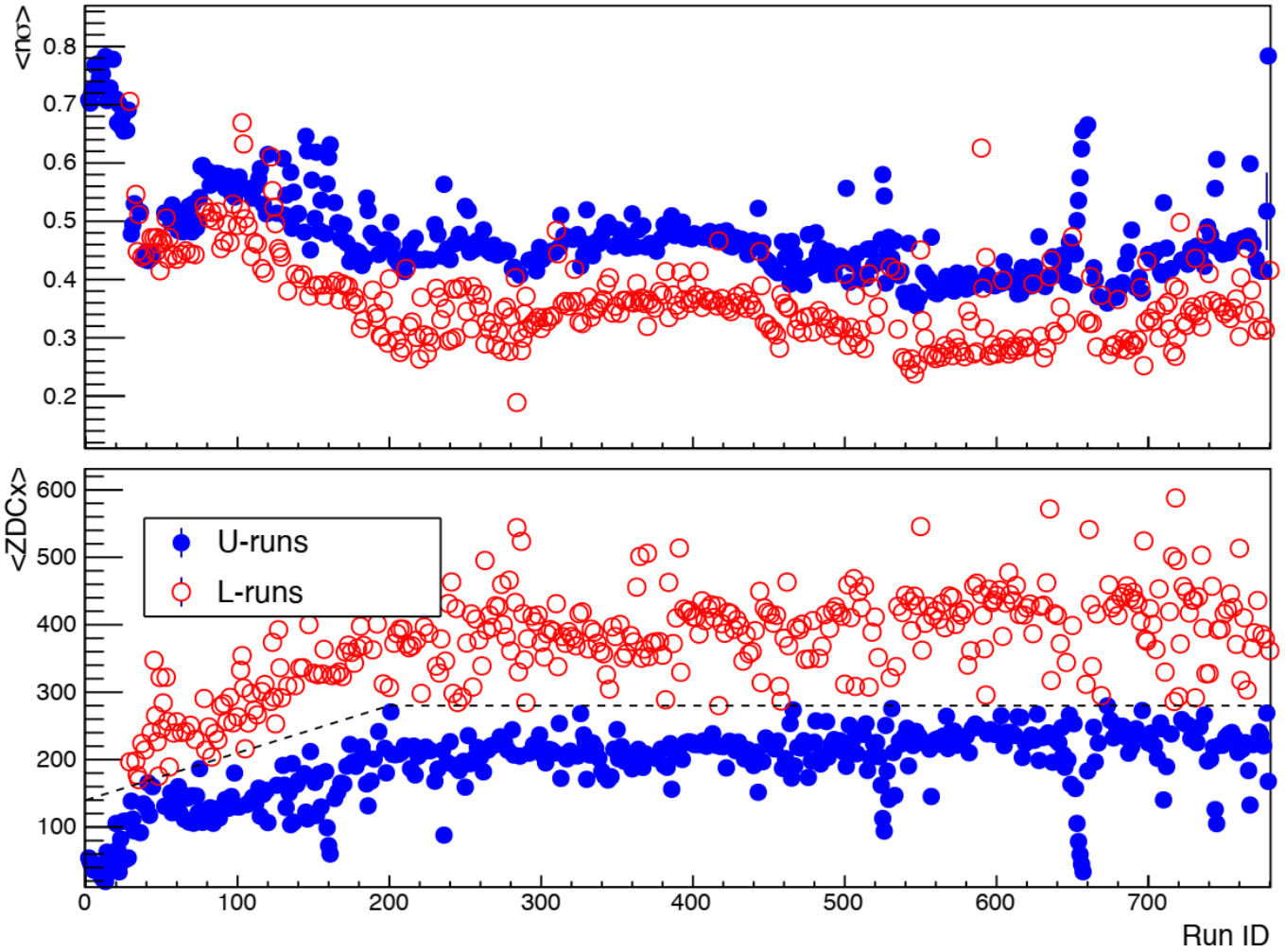
← TPC PID efficiency

TOF PID efficiency →



U/L runs at 19.6 GeV

- Clear separation of two sub-datasets based on luminosity as a function of run ID
- $n\sigma_{\text{proton}}$ shift, centrality, efficiency are obtained individually for U/L runs
- Cumulants for the whole dataset are combined as a weighted average from U/L runs



Net-proton distributions

- Efficiency-uncorrected
- 7.7 9.2 11.5 14.6 19.6 27

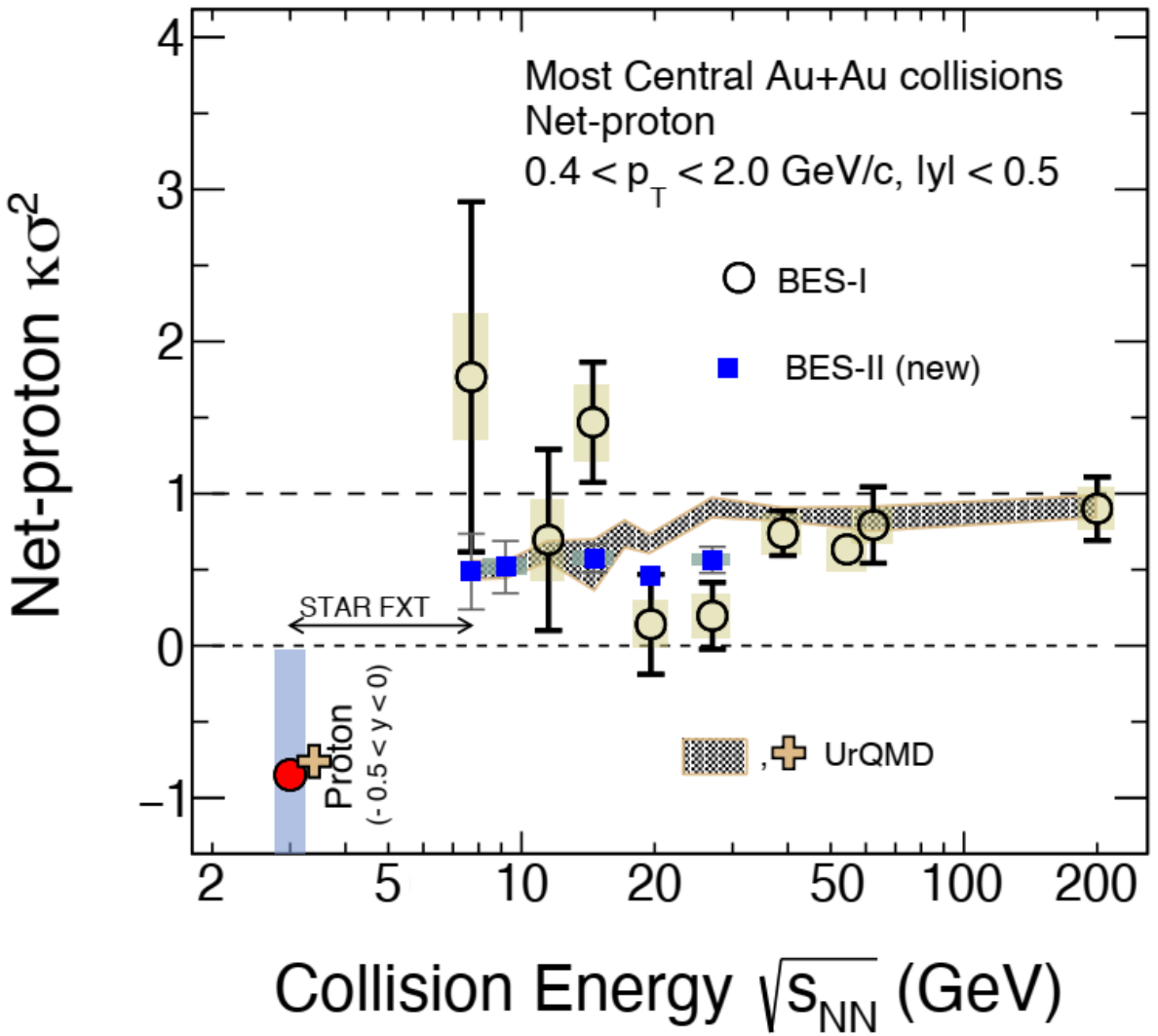
Net-proton cumulants

- Centrality dependence (7.7, 9.2, 11.5, 14.6, 19.6, 27)
- Comparison b/w analyzers, BES-I/II, centrality definitions
- 6 pages

- Since BES-I was not corrected by PID efficiency, C1 is systematically lower than BES-II

Energy dependence of C4

- Latest result will be updated
- 3.2 GeV, 11.5 GeV will be added



Summary

Backup or removed pages

UrQMD simulation

- Centrality resolution dependence of cumulants

FXT part

Overview of datasets

Energy (GeV)	3.0	3.2	3.5	3.9	4.5	5.2	6.2	7.2	7.7
Beam energy (AGeV)	3.85	4.59	5.75	7.3	9.8	13.5	19.5	26.5	31.2
μ_B (MeV)	720	699	666	633	589	541	487	440	420
Year	2021	2019	2020	2020	2020	2020	2020	2020	2020
Collected events (M)	2307	200	115	117	108	103	118	317	112
Trigger IDs	820007 820017	680001	720007	730007	740007 740017	750007	760007	790007	770007
eTOF calibration status	Pending	Not needed	Near com.	Near com.	Near com.	Pending	Pending	Pending	Pending
Production status	Pending	Done	Reproduction pending	Reproduction pending	Reproduction pending	Reproduction pending	Pending	Pending	Pending
Embedding status	Pending	First sample done	Pending	Pending	Pending	Pending	Pending	Pending	Pending

Overview of datasets

Energy (GeV)	3.0	3.2	3.5	3.9	4.5	5.2	6.2	7.2	7.7
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Production status	Pending	Done	Reproduction pending	Reproduction pending	Reproduction pending	Reproduction pending	Pending	Pending	Pending
Embedding status	Pending	First sample done	Pending	Pending	Pending	Pending	Pending	Pending	Pending

Priority

Overview of analyses

Energy (GeV)	3.2	3.5	3.9	4.5
eTOF calibration	Near com.	Near com.	Near com.	Near com.
Production	Done	Reproduction pending	Reproduction pending	Reproduction pending
QA	Done	Done	Done	Done
Purity	Done	Done	Done	Done
Centrality	Done	Done	Done	Done
Embedding	First sample done	Pending	Pending	Pending
Result	Near com.	Pending	Pending	Pending
UrQMD simulation	Near completion (YZ)			
Analyzers	XZ/ZS	ZS/YX	ZS/FS	ZS/YZ

FS: Fan Si (USTC/Tsukuba)
ZS: Zachary Sweger (UC Davis)
YX: Yongcong Xu (CCNU)
XZ: Xin Zhang (IMP, CAS)
YZ: Yu Zhang (CCNU)

- At least two independent analyzers required for each dataset

Analysis cuts

- Bad run rejection
- Event cut
  - V_z ~ 200 cm (depends on dataset)
  - $|V_r| < 2$ cm, with center $(0, -2)$ cm
  - Bad event rejection
- Track quality cut
  - Primary
  - nHitsFit > 10
  - nHitsFit/nHitsPoss > 0.51
  - nHitsDedx > 10
  - DCA < 3 cm
- Kinematic selection
  - $0.4\ \text{GeV}/c < p_T < 2\ \text{GeV}/c$
  - $-0.5 < y_{\text{proton}} < 0$
- Proton identification
  - $|n\sigma_{\text{proton}} - \mu| < 3$
  - $0.6\ \text{GeV}^2/c^4 < m^2 < 1.2\ \text{GeV}^2/c^4$
    - If TPC purity < 90%

TPC $n\sigma_{\text{proton}}$ recalibration and purity

Acceptance and TOF gap

eTOF issue

- Counter-by-counter timing shift

- How to have stable eTOF performance
  - Run/counter QA and mask bad runs and counters (in all runs)
    - Also, mask counter with GeomID 55 and 97
    - To have stable performance across runs
  - Mask events with low fraction of good event flags
    - To have stable performance across events
  - For track
    - Require good event flag for the counter (stable efficiency)
    - Cluster size < 100 (stable timing)
    - ΔX and ΔY cut (stable matching with TPC track)

Summary

- A figure for C4/C2 at 3.2, 7.7, 9.2, 11.5, 14.6, 19.6, 27 GeV?