Accuracy versus Precision
-
how well do our data agree?

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Joint CATHIE/TECHQM
Workshop
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This talk is not all my own work

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Jinhui Chen (Shanghai), Xin Dong (LBL), Jamie Dunlop (BNL), Jin Fu (SINAP/Shanghai), Sasha Milov (Weizmann), Bedanga Mohanty (VECC), Zebo Tang (BNL), Thomas Ullrich (BNL/Yale), Zhangubu Xu (BNL), Xiaoping Zhang (LBNL), Chen Zhong (SINAP)

for helping me their plots, macros
What we’ve measured

• STAR, PHENIX,
• PHENIX and STAR, all 4 experiments

• $h^\pm, \pi^+, \pi^-, \pi^0, \rho, \bar{\rho}$
• $K^+, K^-, K^0_s$
• $\Lambda, \bar{\Lambda}, \Xi^+, \Xi^-, \Omega^+, \Omega^-$
• $\Phi, K^*, \rho, \eta, \omega, \Lambda(1520), \Sigma^+, \Sigma^-$
• real and virtual $\gamma$
• $D^0, D^*, NPE$
• $J/\Psi, \Upsilon$
• $d, \bar{d}, \text{He}, \lambda H, \bar{\lambda H}$
Where at least 2 results exist

- In p-p, Au-Au, Cu-Cu at $\sqrt{s} = 200$ and 62 GeV
- PHENIX and STAR, all 4 experiments

- $h^\pm, \pi^\pm, \pi^0, p, \bar{p}$
- $K^+, K^-$
- $\Lambda, \bar{\Lambda}$
- $\Phi, \rho$
- real $\gamma$
- NPE
- $J/\Psi, \Upsilon$
- $d, \bar{d}$
And where spectra overlap significantly

- In p-p, Au-Au, at $\sqrt{s} = 200$ GeV
- PHENIX and STAR, all 4 experiments

- $\pi^+$, $\pi^-$, $\pi^0$, $p$, $\bar{p}$
- $K^+$, $K^-$
- $\Phi$
- NPE
How data are compared

- Take the published data points
- Combine in quadrature stat and sys error (realize not strictly correct but sufficient)
- Fit data to formula: 
  \[ \frac{A}{(e^{-ap_T-bp_T^2} + p_T/p_0)^n} \]
  (don’t interpret variables just good fit)
- To compare spectra divide fits, plot 95% confidence band
Data references

STAR $\pi$ and protons  
Phys. Rev. Lett. 97, 152301

STAR low pt $\pi$, K, $p$  
Phys. Rev. Lett. 92, 112301

STAR high pt $\pi$ and $p$ in p-p  
Phys. Lett. B 637, 161

STAR $\pi^0$  

STAR NPE  

STAR $\phi$  

BRAHMS $\pi$ and protons  
Phys. Rev. C 72, 014908

PHENIX charged $\pi$ and protons  
Phys. Rev. C. 69, 034909

PHENIX $\pi^0$  

PHENIX $\pi^0$, 2003  
Phys. Rev. Lett. 91, 072301

PHENIX $\pi^0$ p-p  

PHENIX NPE Au-Au  

PHENIX NPE p-p  

PHENIX $\phi$  
Where problems became evident - $R_{AA}$ of pions

Latest/most precise PHENIX $\pi^0$ data consistently below STAR $\pi^{\pm}$ at high $p_T$

No longer the same “within errors”
Is it just a problem with the p-p?

Calculate $R_{AA}$ using common fit function to PHENIX $\pi^0$ p-p

Not a great fit to the $\pi^0$ but cancels out in comparison

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New STAR data on $\pi^0$ at first glance resolves the issue.

STAR data has large errors

Are STAR data self consistent
Difference between STAR $\pi^0$ and $\pi^\pm R_{CP}$?

Seem to be!

How can that be?

A=B
B=C
C!=A?

Large errors cover a multitude of sins.
Difference between $\pi^0$ and $\pi^\pm$?

- STAR $\pi^0/\pi^\pm$
- STAR $\pi^0/PHENIX \pi^0$

Au+Au at $\sqrt{s_{NN}} = 200$ GeV

- 0-20%
- 20-40%
- 40-80%

Transverse Momentum $p_T$ (GeV/c)

Spectra Ratio

STAR $\pi^0 \lessgtr $ PHENIX $\pi^0$

STAR $\pi^+ > PHENIX \pi^0$

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π in Au-Au 0-10%

**STAR**  
\(\pi^+, \pi^-\)

**PHENIX**  
\(\pi^0, \pi^+, \pi^-\)

**BRAHMS**  
\(\pi^+, \pi^-\)

<table>
<thead>
<tr>
<th>Variable</th>
<th>STAR</th>
<th>PHENIX</th>
<th>BRAHMS</th>
</tr>
</thead>
<tbody>
<tr>
<td>(p_0)</td>
<td>1630±347.2</td>
<td>1126±10.32</td>
<td>766.5±195.3</td>
</tr>
<tr>
<td>(p_1)</td>
<td>0.4527±0.06451</td>
<td>0.2434±0.007378</td>
<td>1.105±0.5401</td>
</tr>
<tr>
<td>(p_2)</td>
<td>0.2055±0.05088</td>
<td>-0.1537±0.002469</td>
<td>-0.6603±0.2923</td>
</tr>
<tr>
<td>(p_3)</td>
<td>0.7647±0.02836</td>
<td>1.032±0.006463</td>
<td>0.5942±0.08748</td>
</tr>
<tr>
<td>(p_4)</td>
<td>8.476±0.08741</td>
<td>7.605±0.04</td>
<td>5.155±0.5237</td>
</tr>
</tbody>
</table>

\(\chi^2 / \text{ndf} = 8.738 / 25\)
\(\chi^2 / \text{ndf} = 79.3 / 23\)
\(\chi^2 / \text{ndf} = 34.61 / 12\)

Prob: 0.9989
Prob: 4.127e-08
Prob: 0.0005397

Prob

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π in Au-Au 0-10% - Self consistency

**STAR**
π⁺/π⁻

**PHENIX**
π⁰/π⁰

**PHENIX** consistency needs more detailed check

**BRAHMS**
π⁺/π⁻
π in Au-Au 0-10% - Comparison

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\[ \frac{\chi^2}{\text{ndf}} = 7.042 / 18 \]

\[ \text{Prob} = 0.9898 \]

\begin{align*}
\text{p0} & = 12.61 \pm 3.867 \\
\text{p1} & = 0.345 \pm 0.3587 \\
\text{p2} & = -0.04284 \pm 0.05058 \\
\text{p3} & = 0.7536 \pm 0.1875 \\
\text{p4} & = 8.303 \pm 0.9616
\end{align*}

\[ \frac{\chi^2}{\text{ndf}} = 0.598 / 15 \]

\[ \text{Prob} = 1 \]

\begin{align*}
\text{p0} & = 12.84 \pm 12.63 \\
\text{p1} & = 0.3953 \pm 0.1938 \\
\text{p2} & = 0.09746 \pm 0.09905 \\
\text{p3} & = 0.6799 \pm 0.09742 \\
\text{p4} & = 8.17 \pm 0.1364
\end{align*}
π in p-p - Comparison

- STAR π±, PHENIX π0 compared to a Tsallis fit
- New STAR data from run without SVT not published - presented at QM09

\[ \chi^2 / \text{ndf} = 0.598 / 15 \]

\begin{align*}
p_0 &= 12.84 \pm 12.63 \\
p_1 &= 0.3953 \pm 0.1938 \\
p_2 &= 0.09746 \pm 0.09905 \\
p_3 &= 0.6799 \pm 0.09742 \\
p_4 &= 8.17 \pm 0.1364
\end{align*}
Proton spectra - the feed-down correction

• **STAR** - hyperon feed-down of $\Lambda$ and $\Sigma^+$ - use measured $\Lambda$ spectra, $\Sigma^+ / \Lambda = 0.35$ independent of $p_T$

• **PHENIX** - HIJING tunes to measured ratio of $\Lambda / p$, including $p_T$ dependence, in 130 GeV. $\Sigma^+$ correction not applied

• **BRAHMS** - Use $p_T$ independent ratio of $N(\Lambda) = 0.89N(p)$ from 130 GeV data

• From this would expect STAR > PHENIX ~ BRAHMS
Feed-down corrected protons - Au-Au 0-10%

STAR

PHENIX

BRAHMS

PHOBOS

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Feed-down corrected protons - Au-Au 0-10%
Feed-down corrected protons - Au-Au

Clear centrality trend difference

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Comparison restricted by limited mtm coverage.

New data on high $p_T$ $K^\pm$ but not compared here. Starts at $p_T > \text{PHENIX}$.
$K^\pm$ in Au-Au - STAR/PHENIX

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$\phi$ in p-p - STAR/PHENIX

\[ \frac{\chi^2}{\text{ndf}} = 6.355 / 8 \]
\[ \text{Prob} = 0.6076 \]

\[ A = 0.0008087 \pm 0.001036 \]
\[ a = 2.305 \pm 0.797 \]
\[ b = -0.5926 \pm 0.2145 \]
\[ p_0 = 1.326 \pm 0.2513 \]
\[ n = 5.005 \pm 0.3887 \]

\[ \frac{\chi^2}{\text{ndf}} = 3.92 / 10 \]
\[ \text{Prob} = 0.9509 \]

\[ A = 0.03295 \pm 0.2413 \]
\[ a = 0.287 \pm 0.9942 \]
\[ b = 0.1445 \pm 0.3474 \]
\[ p_0 = 1.133 \pm 1.093 \]
\[ n = 8.436 \pm 0.9034 \]
In Min-bias d-Au - STAR/PHENIX

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\( \phi \) in 0-10% Au-Au - STAR/PHENIX

\[ \chi^2 / \text{ndf} \quad 7.838 / 9 \]
\[ \text{Prob} \quad 0.5506 \]
\[ A \quad 2.034 \pm 0.8523 \]
\[ a \quad 0.5161 \pm 0.2827 \]
\[ b \quad -0.1116 \pm 0.07897 \]
\[ p_0 \quad 2.231 \pm 0.6054 \]
\[ n \quad 8.711 \pm 2.676 \]

\[ \chi^2 / \text{ndf} \quad 4.099 / 8 \]
\[ \text{Prob} \quad 0.8481 \]
\[ A \quad 5.56 \pm 2.547 \]
\[ a \quad 0.01401 \pm 0.2226 \]
\[ b \quad -2.655 \times 10^{-5} \]
\[ p_0 \quad 15.76 \pm 214.6 \]
\[ n \quad 52.66 \pm 685.6 \]

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φ in Au-Au - STAR/PHENIX

- Factor 2 difference for all centralities
- flat as $f^n p_T$

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Issues checked

Significant offset only Au-Au data:
BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR
Issues checked

Significant offset only Au-Au data:
BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR

Effic.?
\[ \phi \text{ effi calculations} \]

\[ \text{PHENIX} \]

\[ \text{STAR: } \sim \text{single } \varepsilon^2 X \text{ accept} \]
- can’t be factor 2 higher

\[ \text{PHENIX: steep } f^n \text{ of } p_T \]
- surprising if make flat offset

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Issues checked

Significant offset only Au-Au data:
BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR

STAR effic.? 
Seems unlikely
Issues checked

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BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR

STAR effic.? 
Seems unlikely

Mass peak fit functions?
Issues checked

Significant offset only Au-Au data:
BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR

STAR effic.?  
Seems unlikely

Mass peak fit functions?
Issues checked

Significant offset only Au-Au data:
BG estimate? - STAR and PHENIX checked STAR data, levels what you would estimate from single particle yields + PID range of STAR

STAR effic.?
Seems unlikely

Mass peak fit functions?
Only minor effect
npe Au-Au 0-10% Central -

\[ \chi^2 / \text{ndf} = 0.8285 / 7 \]
Prob = 0.9971
A = 2.476 ± 1.809
a = -0.03982 ± 0.0183
b = 0.01317 ± 0.003081
p0 = 4.769 ± 0.4586
n = 22.99 ± 1.85

\[ \chi^2 / \text{ndf} = 27.95 / 23 \]
Prob = 0.2178
A = 3.271 ± 1.541
a = -0.2999 ± 0.6462
b = 0.01014 ± 0.04284
p0 = 1.591 ± 0.5017
n = 8.634 ± 5.388

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npe min-bias p-p - STAR/PHENIX

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Summary

- Clearly issues with compatibility of data now (stat.) errors are small

- At best our data is 20% accuracy if you assume all experiments are correct

- Not one overarching issue

- $\phi$ in Au-Au as big a problem as the NPE
Summary

- Clearly issues with compatibility of data now (stat.) errors are small

- At best our data is 20% accuracy if you assume all experiments are correct

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- $\phi$ in Au-Au as big a problem as the NPE

Can we **PLEASE** try and come up with a common format for our data tables.

We want people to use our data!! Found essentially all possible variations including root files, + missing data

Getting almost impossible to find in the long lists of publications
Feed-down corrected protons - Au-Au 10-20%
Feed-down corrected protons - Au-Au 20-40%

$\chi^2$/ndf \quad 4.488 / 22

Prob \quad 1

- $p_0 = 1.02 \pm 2.07$
- $p_1 = 0.7942 \pm 0.4594$
- $p_2 = 0.1345 \pm 0.2716$
- $p_3 = 1.619 \pm 0.4227$
- $p_4 = 8.917 \pm 0.4425$

$\chi^2$/ndf \quad 7.303 / 17

Prob \quad 0.9793

- $p_0 = 1.501 \pm 0.9657$
- $p_1 = 0.6969 \pm 0.08251$
- $p_2 = 0.09043 \pm 0.1905$
- $p_3 = 1.559 \pm 0.3732$
- $p_4 = 8.688 \pm 1.522$

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Feed-down corrected protons - Au-Au 40-60%

STAR p / PHENIX p

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Feed-down corrected protons - Au-Au 60-80%

\[ \frac{\chi^2}{\text{ndf}} = 1.889 \, / \, 21 \]

\[ \text{Prob} = 1 \]

\begin{align*}
p0 & \quad 0.1385 \pm 0.4576 \\
p1 & \quad 1.111 \pm 0.8989 \\
p2 & \quad 0.06283 \pm 0.7268 \\
p3 & \quad 1.426 \pm 0.7346 \\
p4 & \quad 8.08 \pm 0.8448 \\
\end{align*}

\[ \frac{\chi^2}{\text{ndf}} = 2.538 \, / \, 17 \]

\[ \text{Prob} = 1 \]

\begin{align*}
p0 & \quad 0.363 \pm 0.05938 \\
p1 & \quad 0.788 \pm 0.05668 \\
p2 & \quad 0.09011 \pm 0.04537 \\
p3 & \quad 1.197 \pm 0.04223 \\
p4 & \quad 7.956 \pm 0.2971 \\
\end{align*}
Feed-down corrected protons - Au-Au 60-80%

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$R_{AA}$ published vs $R_{AA}$ from fit

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