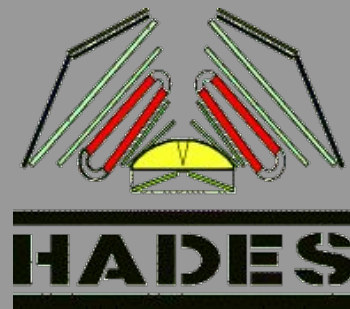


Iterative method to extract Δ resonances in the Ag+Ag data set

HADES Analysis Meeting - 23rd of June 2026

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1. Motivations - $\Delta(1232)$

Why $\Delta(1232)$?

- $\Delta(1232)$ is the first excitation of the proton.
- $\Delta(1232)$ with a lifetime of 10^{-23} s is a witness of the hot and dense stage of the heavy ion collision.
- Precise $\Delta(1232)$ measurements would constrain transport models and simulations.

Questions and challenges :

- How is $\Delta(1232)$ affected by the hadronic medium? Are these effects reproduced by hadronic models?
- How to distinguish correlated $N\pi$ pairs coming from $\Delta(1232)$ decay from uncorrelated ones?

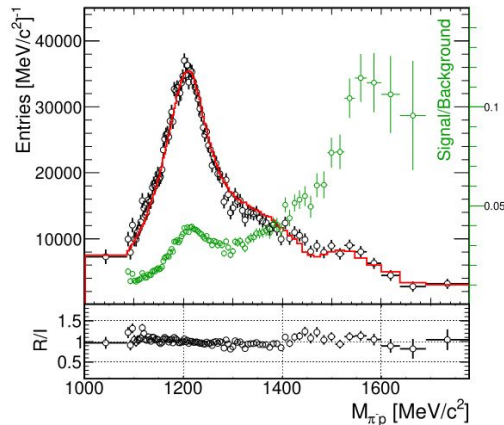
1. Motivations - New iterative method

An iterative method to estimate the combinatorial background

[doi: 10.1140/epja/i2019-12910-4](https://doi.org/10.1140/epja/i2019-12910-4)

Pluto cocktail

	N/Nprot	Channels	Γ/Γ_i
$\Delta(1232)^0$	5 %	$\pi^- p$	1
$N(1440)^0$	2 %	$\pi^- p, p\rho^-, \Delta^+ \pi^-$	0.62/0.02/0.36
$N(1535)^0$	1.5 %	$\pi^- p, p\rho^-, \Delta^+ \pi^-$	0.70/0.06/0.23
$\Delta(1620)^0$	1 %	$\pi^- p, p\rho^-, \Delta^+ \pi^-$	0.18/0.12/0.70
$\Delta(1920)^0$	0.5 %	$\pi^- p, p\rho^-, \Delta^+ \pi^-$	0.7/0.2/0.1
p	20		
π^-	10 %		



Method developed by Georgy Kornakov :

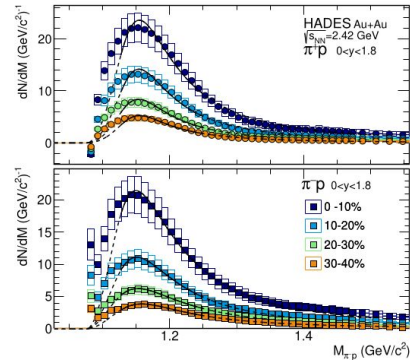
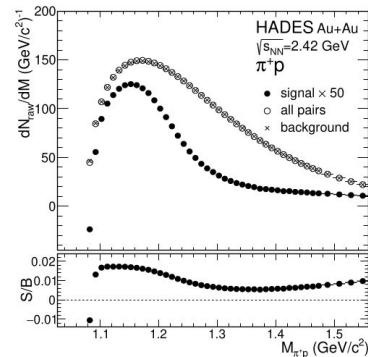
- 2 main publications :

concepts

method applied to experimental data

Correlated pion-proton pair emission off hot and dense QCD matter

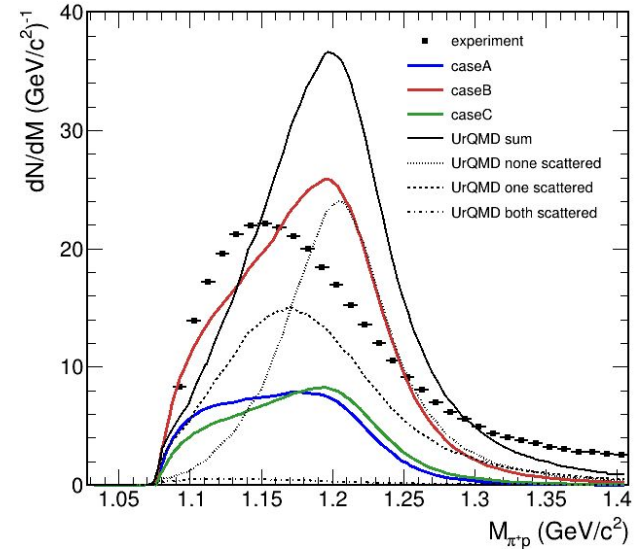
[doi: 0.1016/j.physletb.2021.136421](https://doi.org/0.1016/j.physletb.2021.136421)



1. Motivations - $\Delta(1232)$ with new iterative method

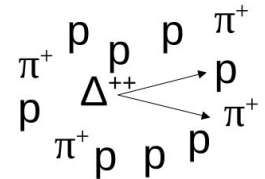
Δ resonances have very different spectra in different simulation data sets and in experimental data.

- need more data to determine which model is closest to experimental data and which mechanisms take place in the collision.
 - Ag+Ag has more statistics, higher signal to background ratio because of smaller collision systems
 - With this new method, we want to test whether the signal can be extracted in different models where signal has different shapes.



Δ resonances decay via $N\pi$ - be able to discriminate $N\pi$ pairs coming from Δ resonances and others.

Immediate goal :
Understand the method & Reproduce the results on simulated data



2. Method

total \rightarrow T
 signal \rightarrow S
 background \rightarrow B

$$T = S + B$$

Only the distribution of the signal is affected by the rotation : $B - \hat{U}(B) = 0$; $T - \hat{U}(T) = S - \hat{U}(S)$

1. Break the pair correlation to obtain uncorrelated distribution by applying uncorrelating operator \hat{U} :

Rotation : rotate one of pair's particle (π) in ϕ with random angle and obtain $\hat{U}(T)$.

2. Subtract rotated distribution to non rotated distribution $T - \hat{U}(T)$: Some of the signal is obtained but need to add in the remaining parts.
3. Iterations : $S^{k+1} = \max\{T - (U(T) - U(S^k)), 0\}$
4. Stop at convergence \Rightarrow Reconstruct the signal.

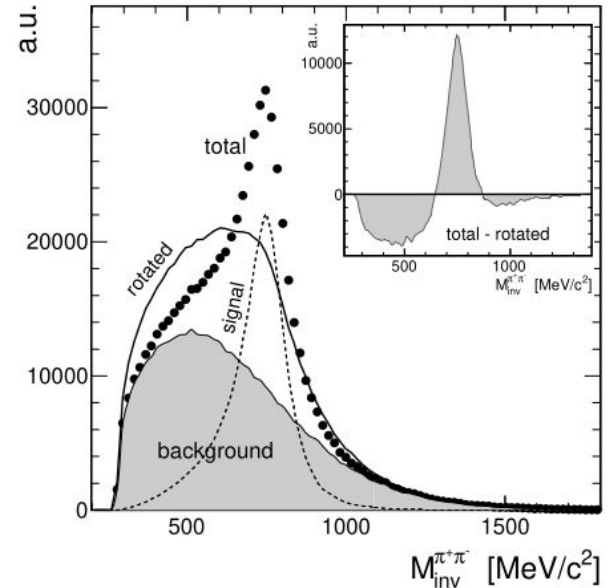


Fig.1 in doi: 10.1140/epja/i2019-12910-4

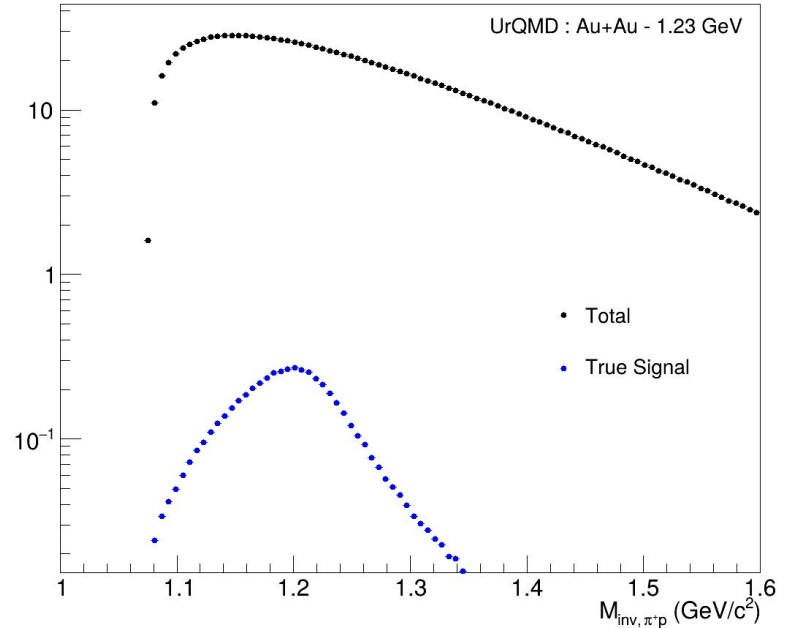
✓ No need for normalization, or model fitting.

3. UrQMD - The simulated data set

- Au+Au collision :
 - Incident beam energy : 1.23 AGeV
 - Impact parameter : [0 - 10] fm
 - EoS 0 / Cascade mode
 - focus only on 0-10% centrality
 - focus only on $\Delta^{++} \rightarrow p\pi^+$

True Signal:

Pair produced by the decay of a resonance (as given by simulation.)



Dimension	Inv. Mass	Pt	Rapidity	Opening Angle
Bins	60	5	5	5

3. UrQMD - The simulated data set

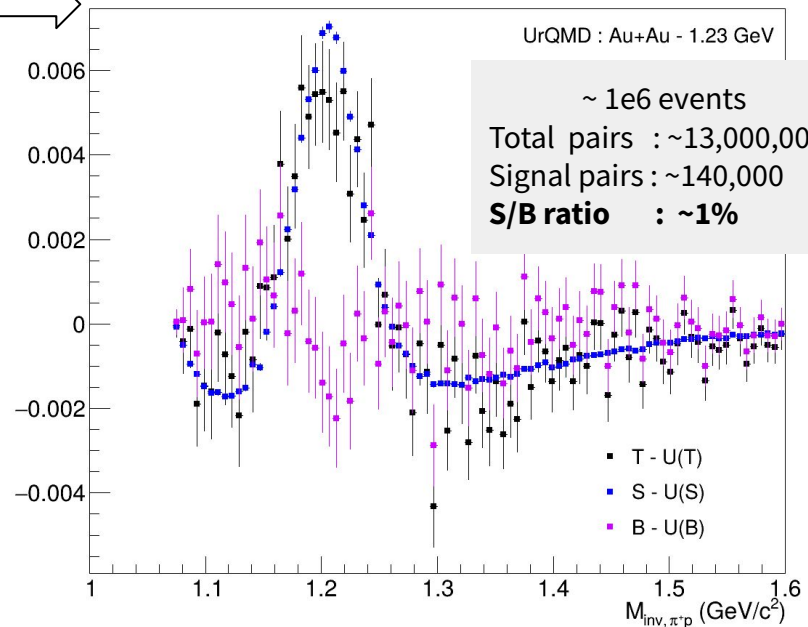
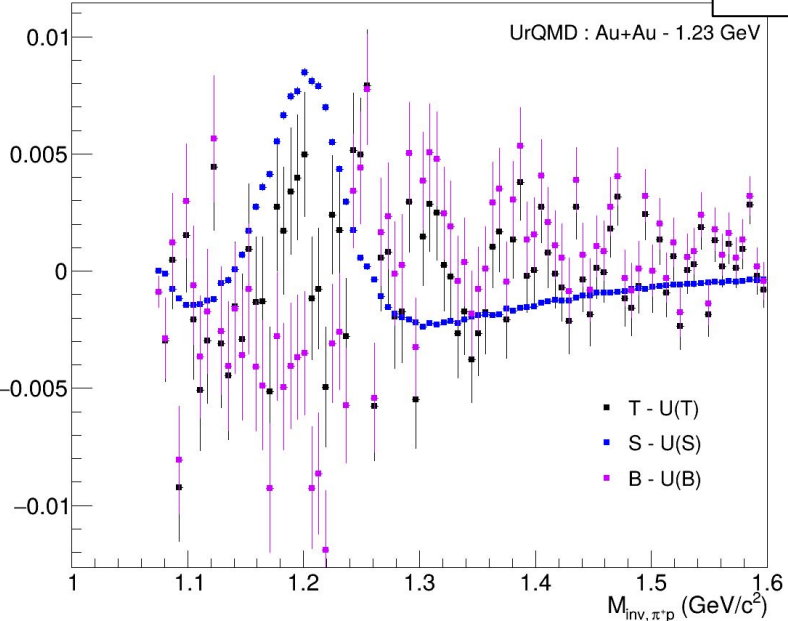
The difference between total distribution and rotated total distribution of the pairs is only due to signal pairs:

$$S - U(S) = T - U(T)$$

Not in agreement:
might be some correlations in what we define as background.

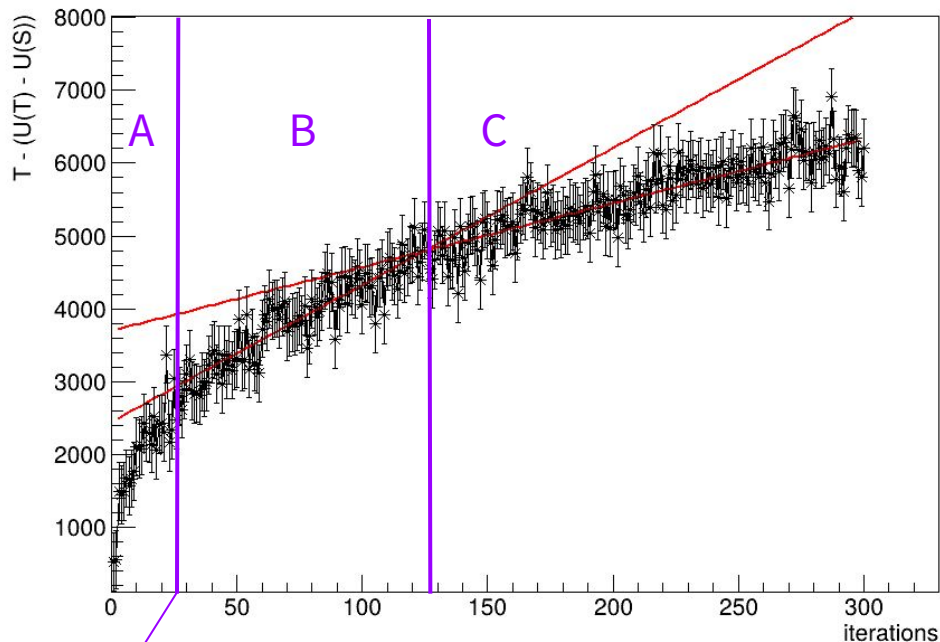
Remove all p & π^+ that after being produced by decay, later scatter

In agreement:
 $T - \hat{U}(T) = S - \hat{U}(S)$



3. UrQMD - The iterations

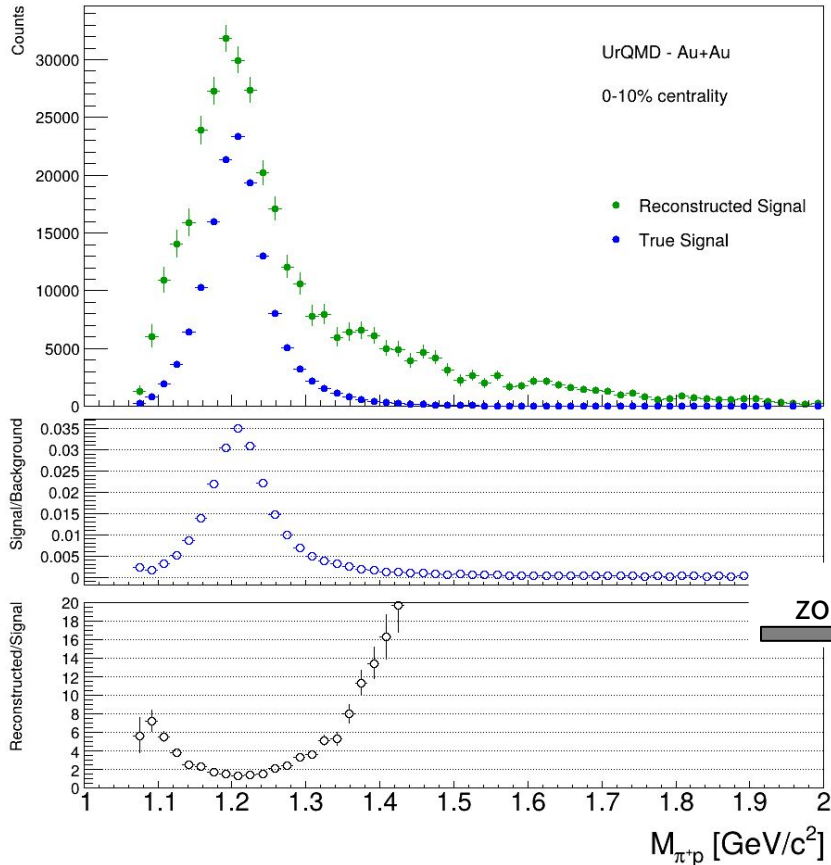
For one bin in $M_{inv.}$, p_t , Rapidity and Opening Angle :



- A - Exponential rise :
correlated signal
- B - Linear increase :
signal feeding from other bins
- C - Linear increase :
background feeding from other bins

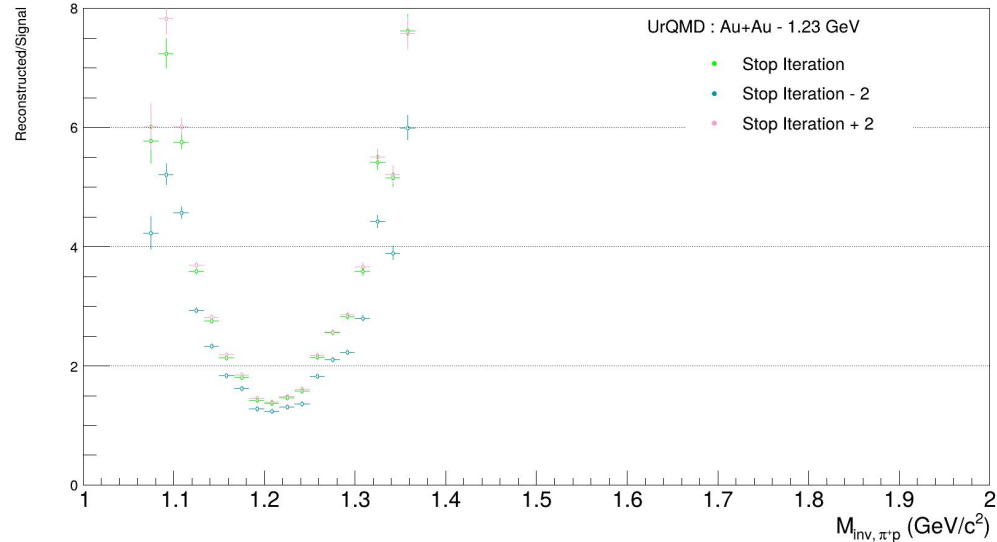
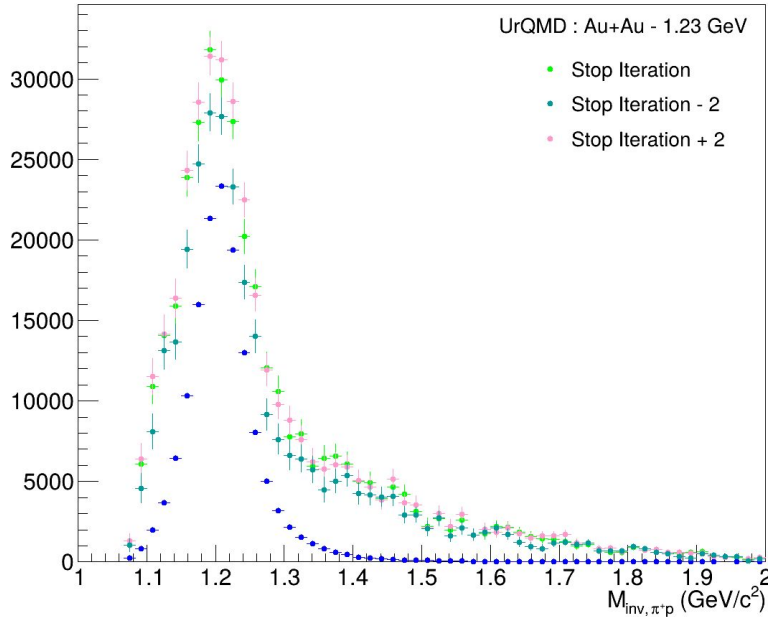
STOP iteration for each bin : identify region A - Two linear fits for the two linear regions. The fits with combined lowest chi-square give stop iteration.

3. UrQMD - Early results



- Reconstructed signal is significantly more important than true signal. ratio > 1
 - Tail has different behaviour
 - Sensitivity to signal / background.
- ⇒ Further investigations needed.

4. Investigations - Robustness of method



For each bin :

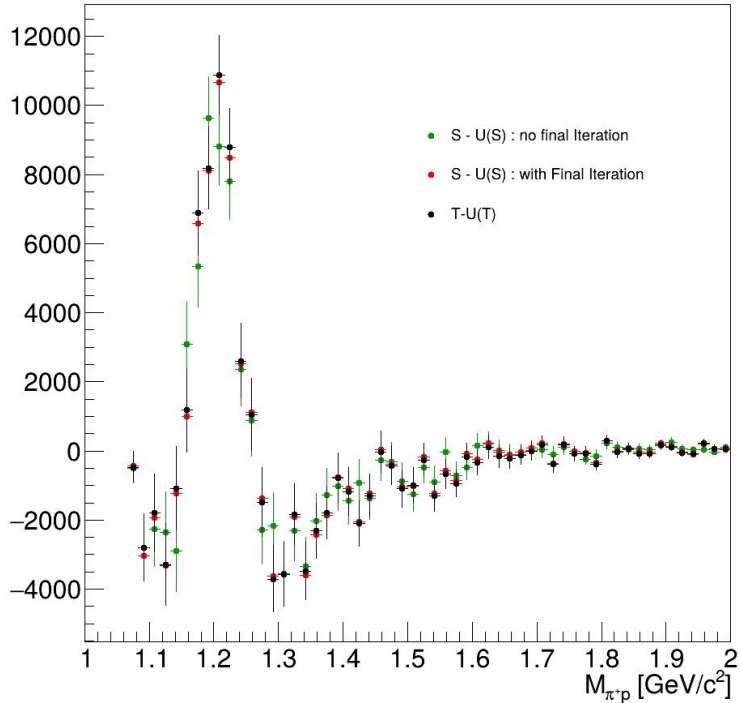
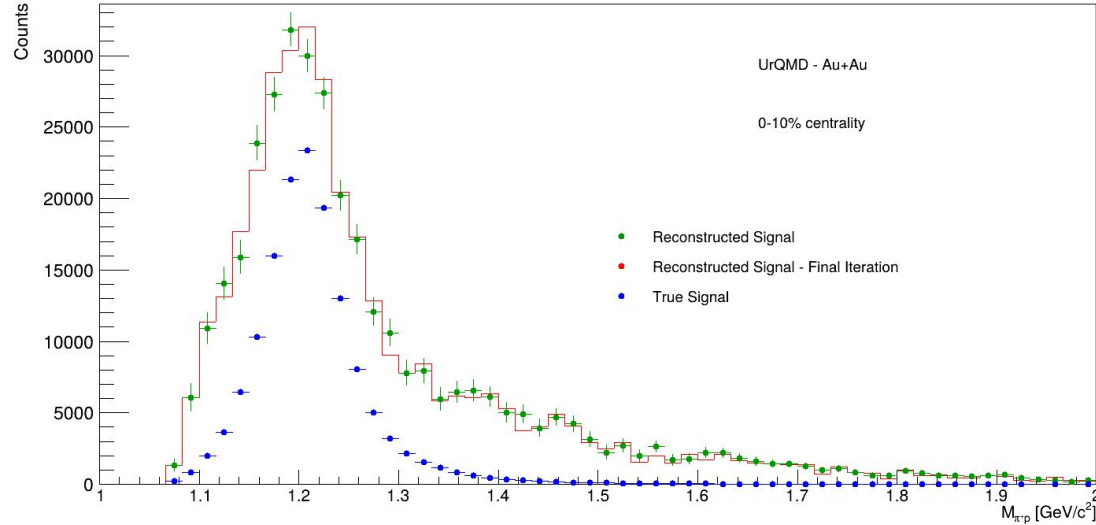
- if we take the stop iteration + 2 we obtain the same results within error bars as stop iteration
⇒ we found the point of inflection
- if we take the stop iteration - 2 we obtain a systematically lower result
⇒ we are still in the exponential rise region

- identify the right stop with fits
- varying stop iteration by 2 does not change results drastically

4. Investigations - Final Iteration

Final iteration might be missing.

$$S^{k+1} = T - (U(T) - U(S^k))$$



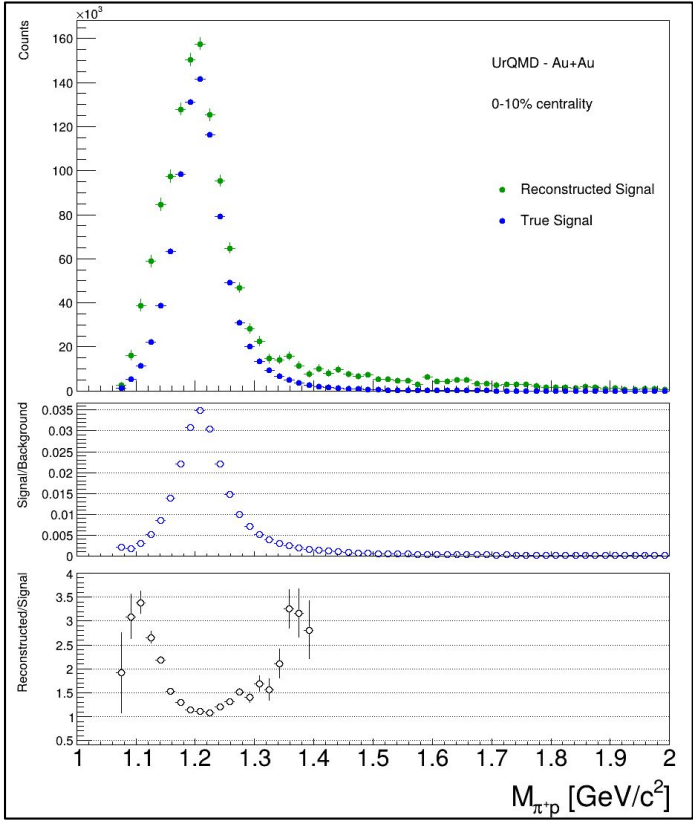
⇒ see small improvement in $S - U(S) = T - U(T)$

⇒ no improvement in the reconstructed signal; not closer to the true signal

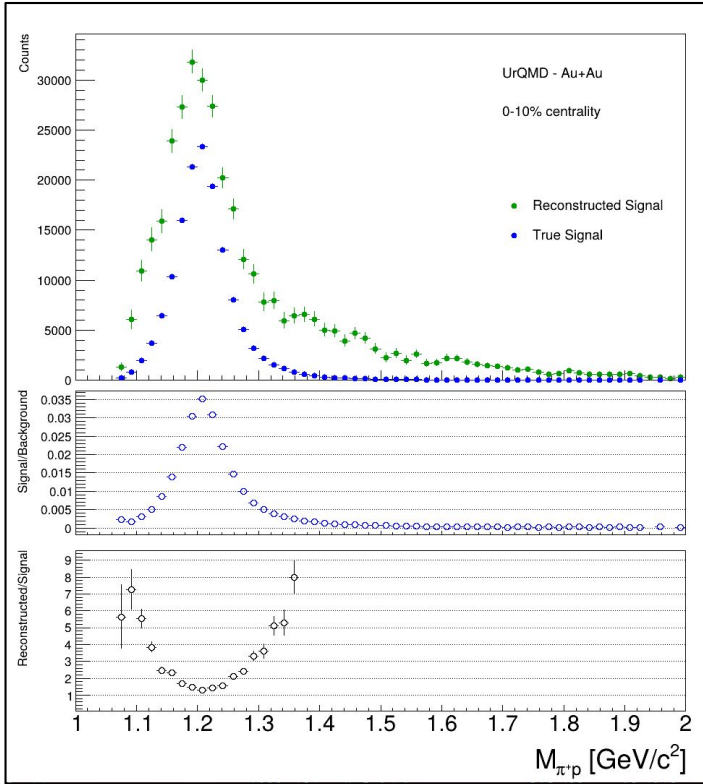
4. Investigations - Statistics

The method is statistics dependent.

for 6e6 events :



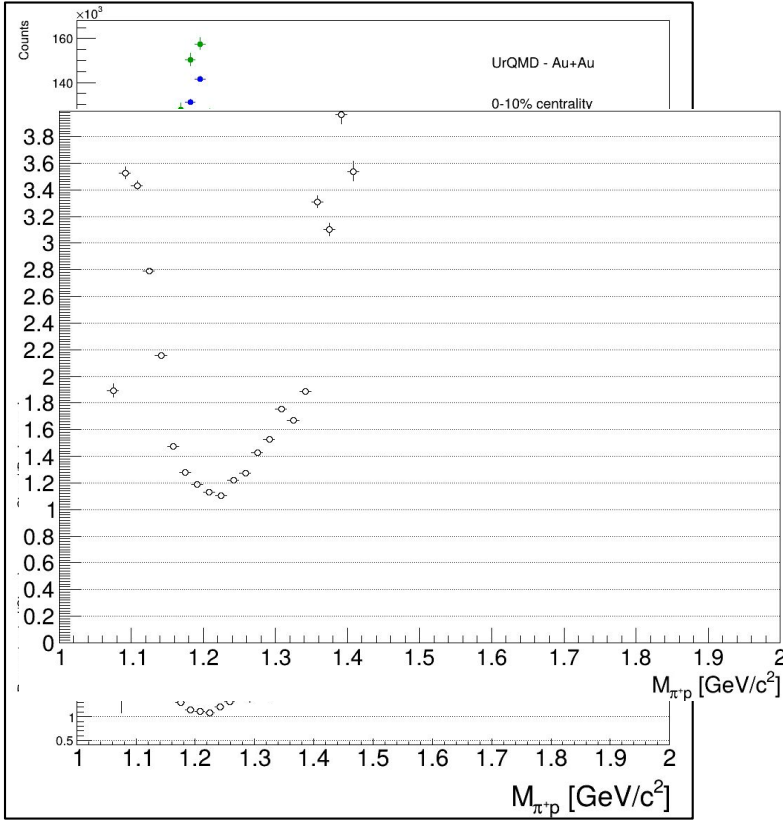
for 1e6 events :



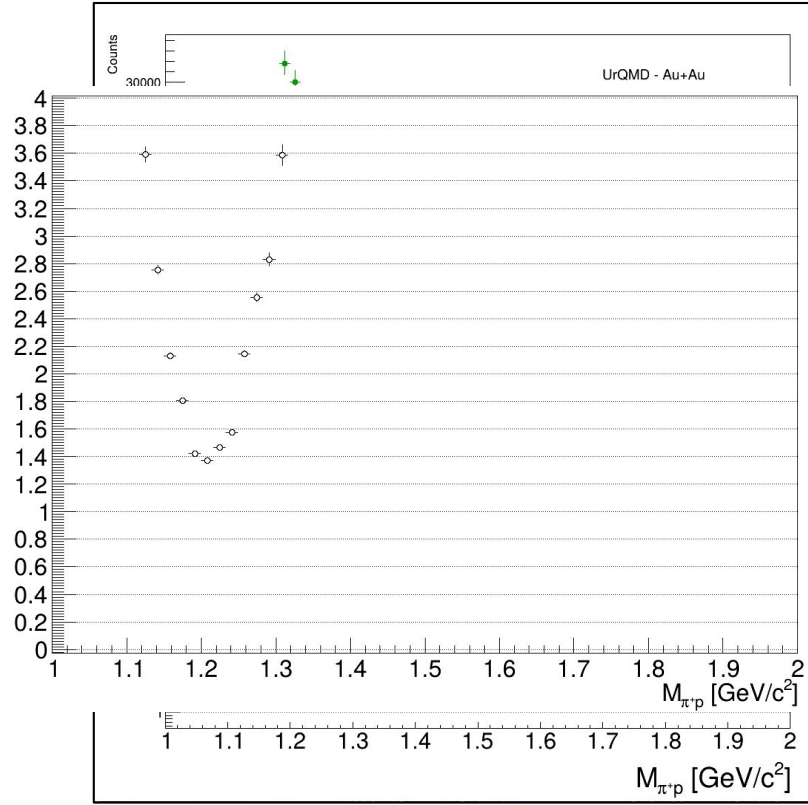
4. Investigations - Statistics

The method is statistics dependent.

for 6e6 events :



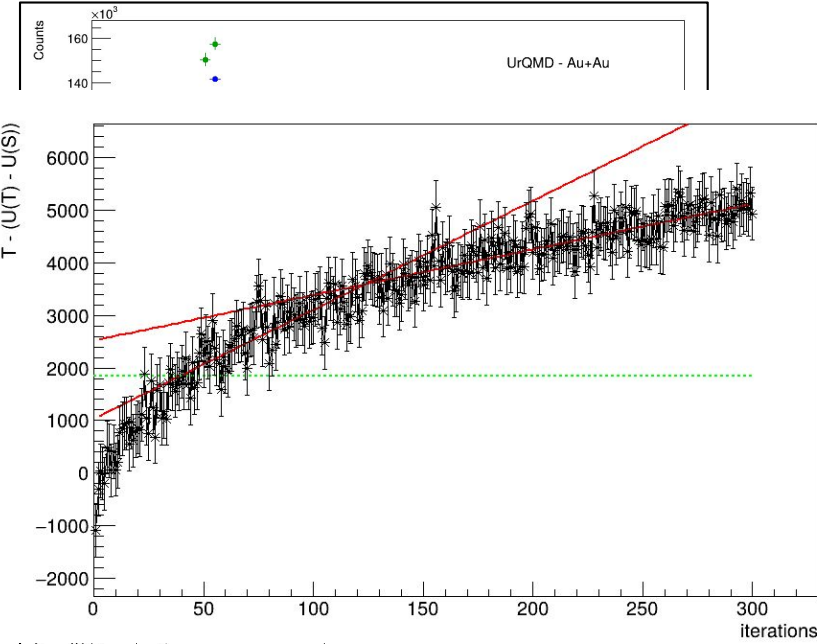
for 1e6 events :



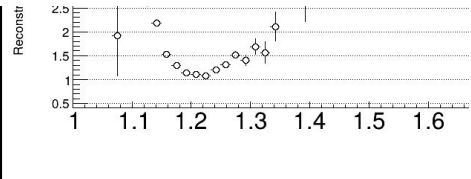
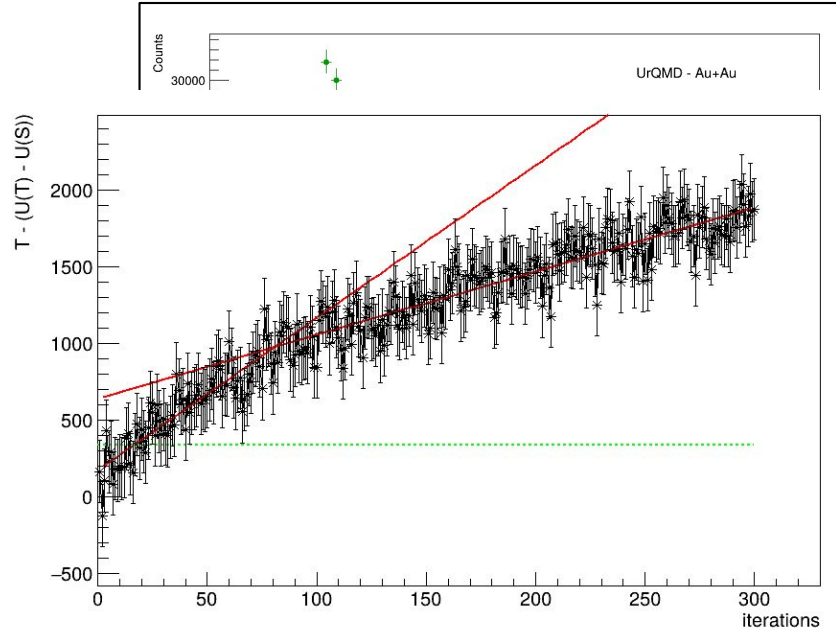
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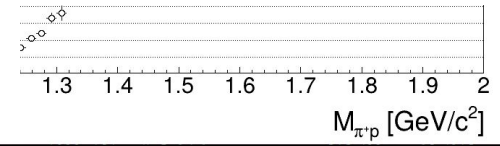
for 6e6 events :



for 1e6 events :

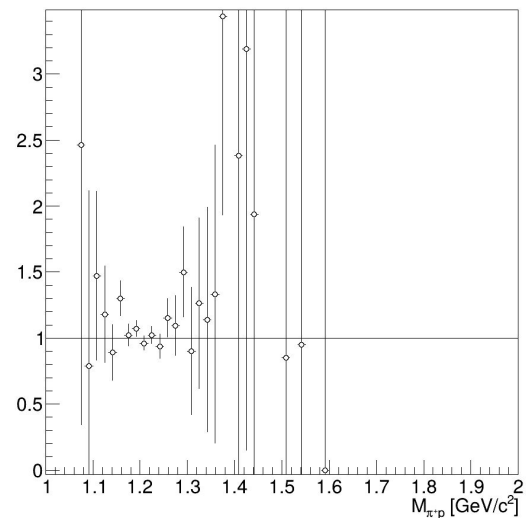
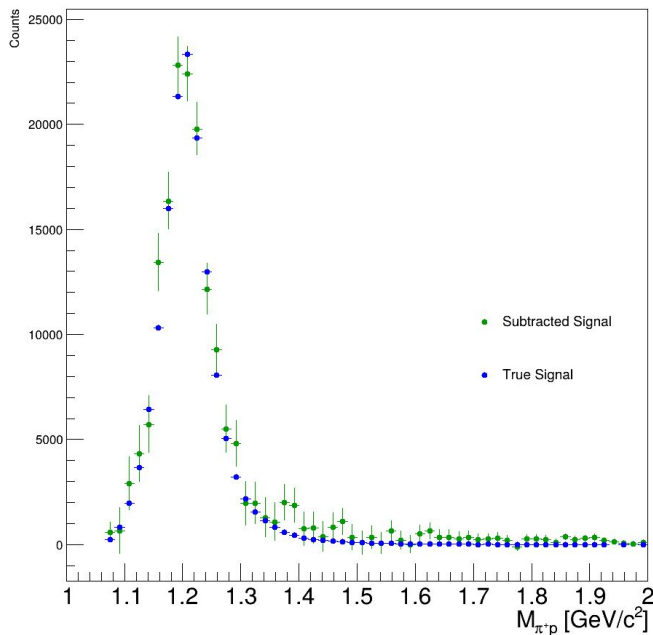
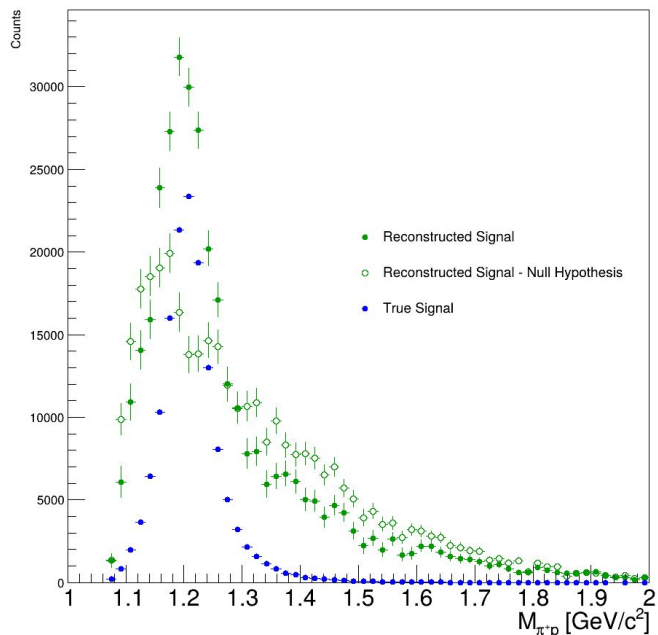


Regions are better defined for more statistics.
Clearer stop iteration.



4. Investigations - Correlations / Null Hypothesis

signal pairs removed from T - running the method with no True Signal



- ⇒ other correlations in the data set : already removed the “scattered” but other processes are present.
- ⇒ statistical baseline from the method

Early conclusions on the method

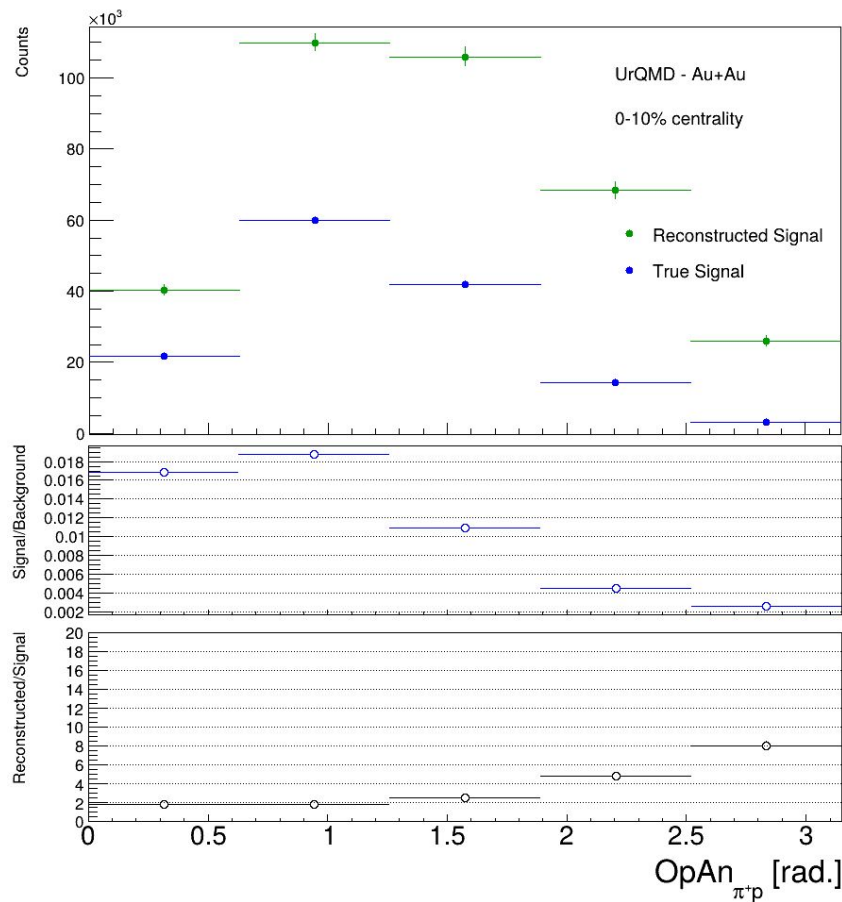
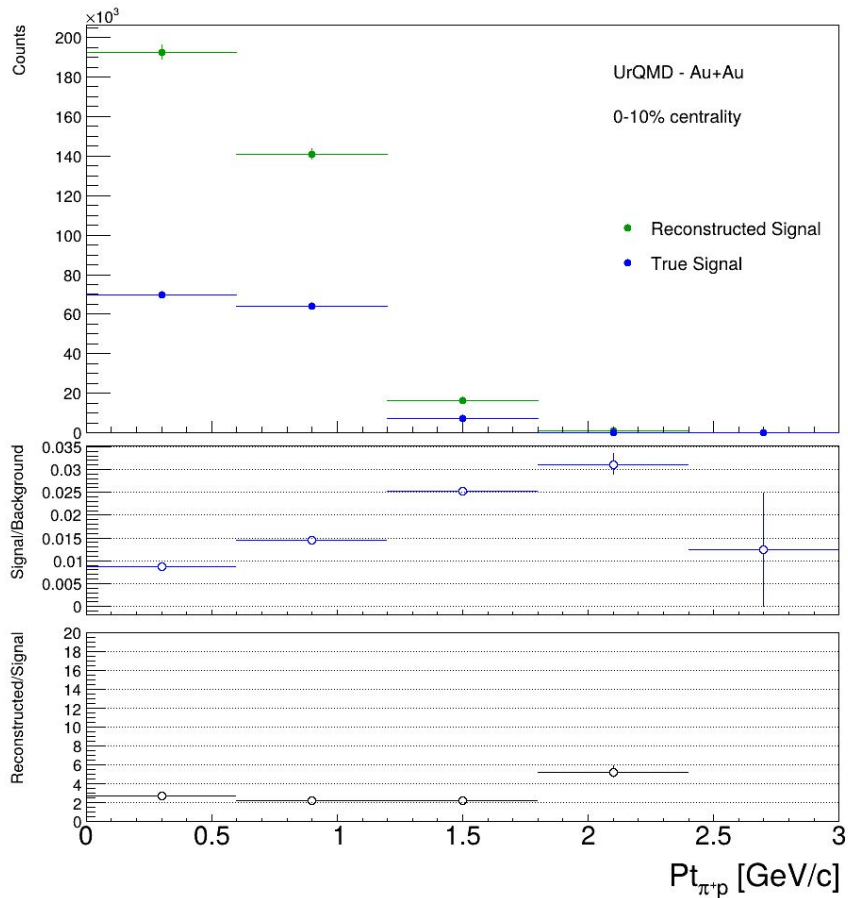
- Working algorithm for iterative method
- limitations of the method : it extracts more than the signal (other correlations / noise).
 - study of simulation model can be done to extract other possible present correlations.
- sensitive to statistics and to S/B

Outlook

- ⇒ Benchmark this method with thermal model ; Compare performance on urqmd and thermal :
 - Find distortion in reconstructed signal (yield, width, position) compared to true signal.
 - Find uncertainties.
- ⇒ Try it on simulated passed through GEANT 3 data
- ⇒ Try it on experimental data (requires experimental analysis first)

BACKUP SLIDES

Other dimensions - Early results



Other dimensions - Early results

