Update on Dielectron analysis with MPD

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May 20, 2025

MPD Cross-PWG meeting

Content

- Comparison with Yonghong's analysis
- Curent results after the changes
- Conclusions and outlook

Two dielectron analyses

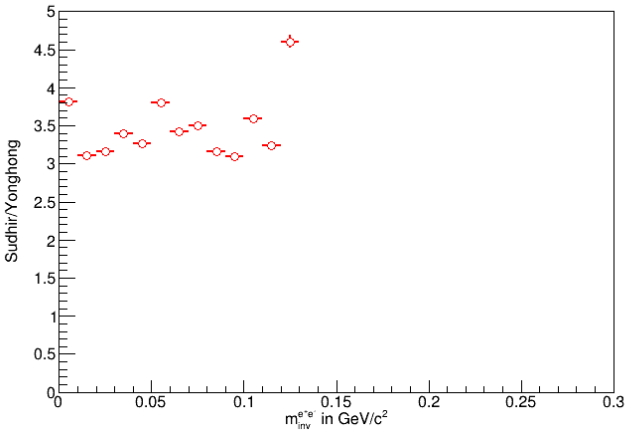
- In last month, Yonghong showed the results of her dielectron analysis.
- Initial comparison shows similar results despite applying different selection cuts.
- Differences:
  - No Fiducial and Veto acceptance $\rightarrow$ rather plain $|\eta| < 1.0$ acceptance.
  - Different pair cuts: Only mass cut in her analysis. We apply cut on opening angle as well[1].
  - She apply PCM for conversion rejection and Mass cut for Dalitz pair rejection. We rely on Close TPC cut i.e mass and opening angle cut.
  - She uses 1D cuts only, however, we also use Machine learning for better eID.
- Thourough comparison was needed to be done: UrQMD to PHSD weights, track and pair selection cuts etc.

[1] In these presetation, "loose cuts" $\rightarrow$ cuts similar to yonghong's analysis; "tight cuts" $\rightarrow$ cuts similar to sudhir's analysis

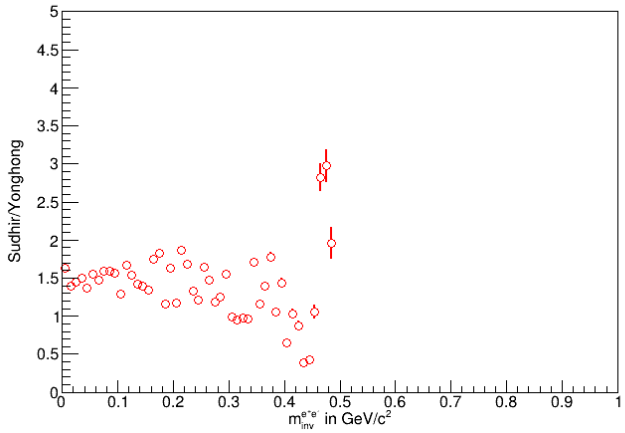
UrQMD to PHSD weights comparison

UrQMD to PHSD weights till collaboration meeting

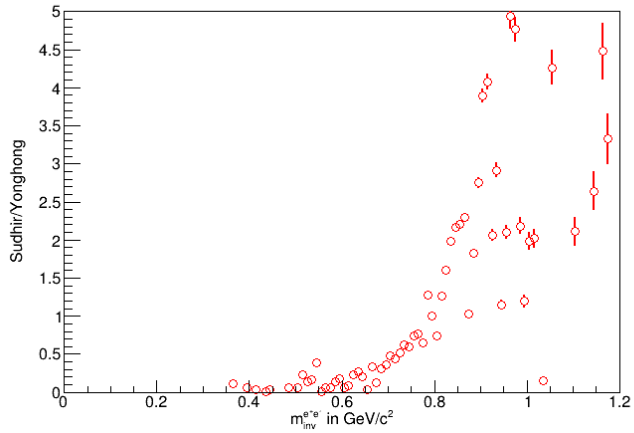
Sudhir: π^0 dalitz



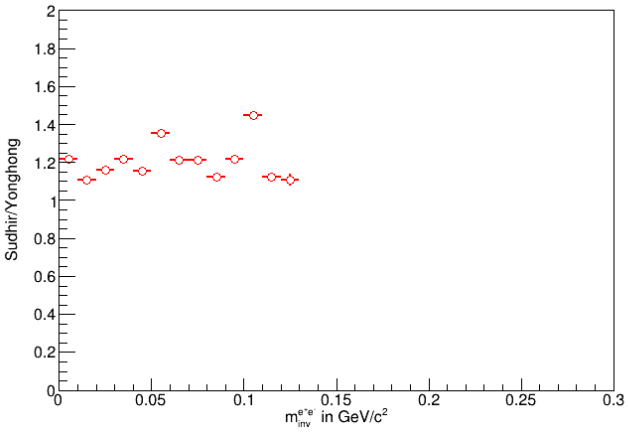
η dalitz



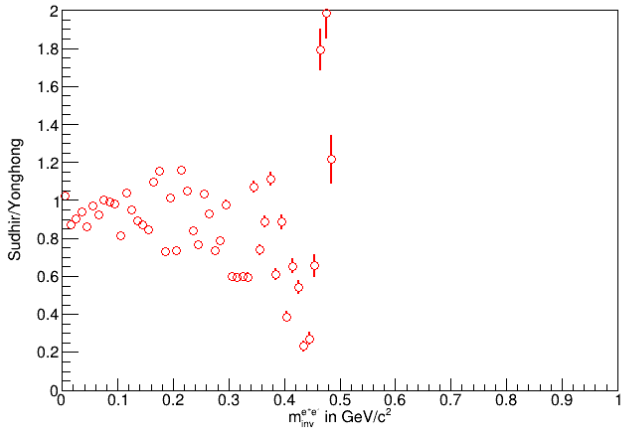
ρ^0



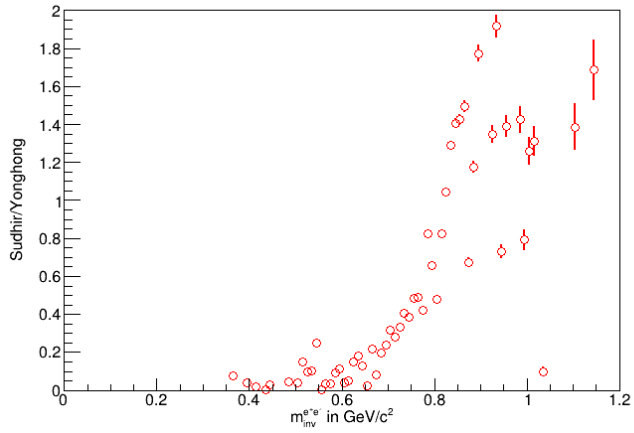
Yonghong: π^0 dalitz



η dalitz

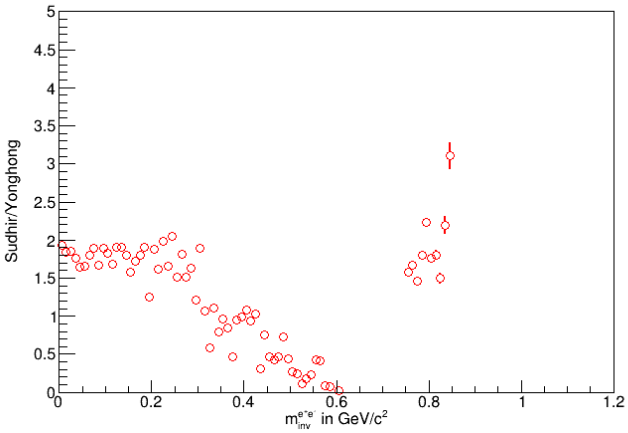


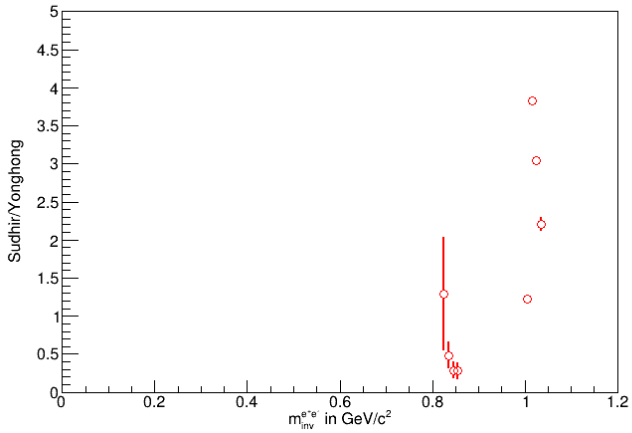
ρ^0

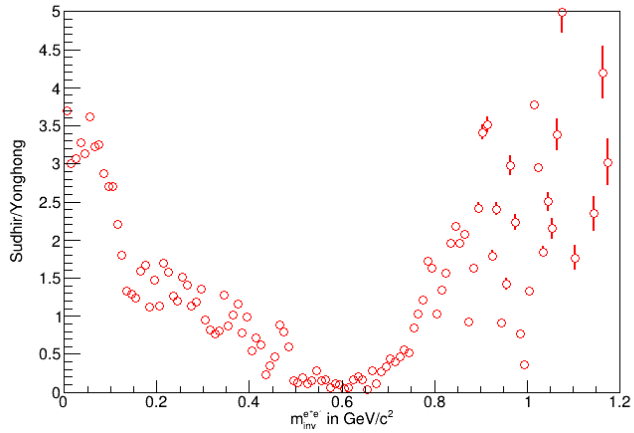


UrQMD to PHSD weights till collaboration meeting

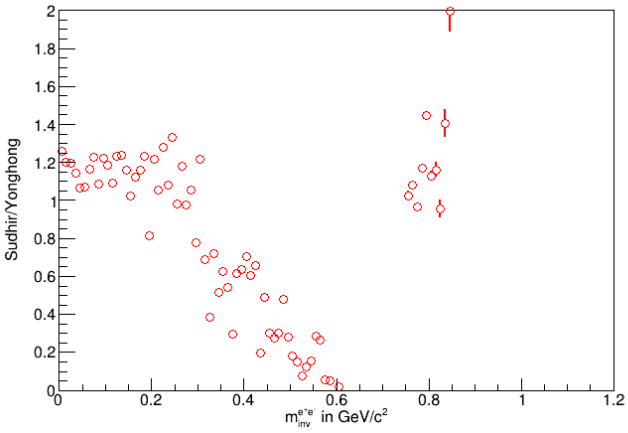
Sudhir: ω ϕ **All**

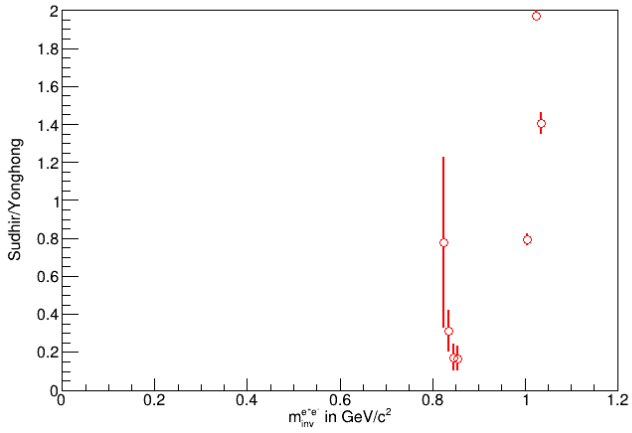


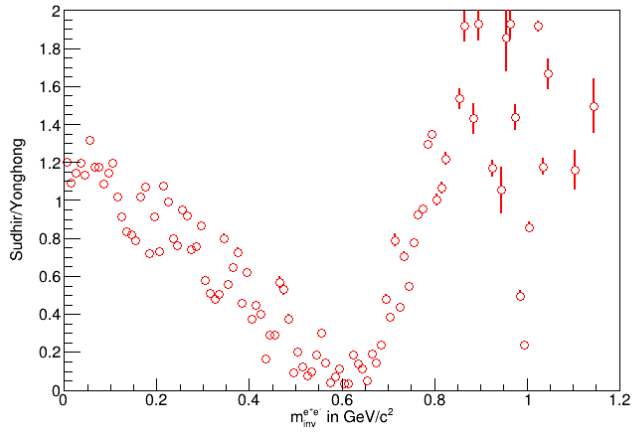




Yonghong: *omega* ϕ **All**





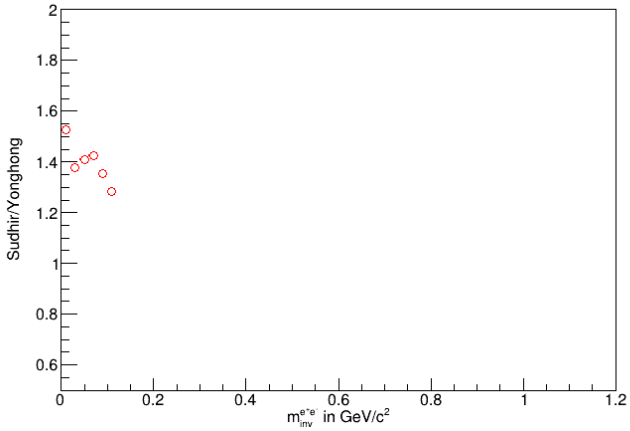


Sources of the difference

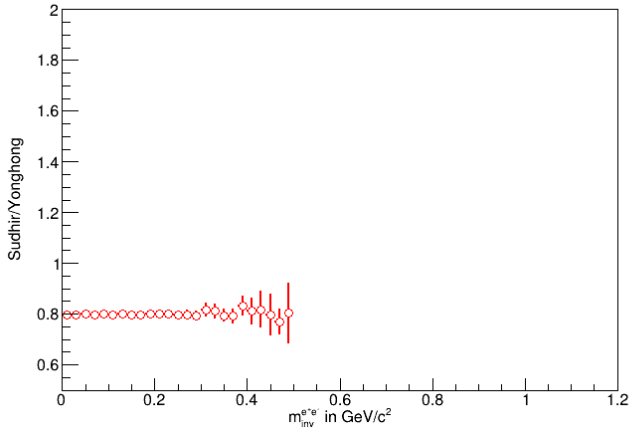
- After a thorough investigation, following differences were found in my weights calculations.
  - PHSD cocktails that I was using (Yonghong uses the same), were assumed to be in $|y_{pair}| < 1.0$, however, in fact they were for $|y_{pair}| < 0.5 \rightarrow$ this is quickly fixed by using factor 2.
  - I used to apply z vertex cut of $|z| < 130$ cm. Yonghong applied 80 cm. Moreover, she removed emply events using $z = 0$ cut.
  - Last change was in primary track identification. Yonghong applies $abs(startvertex_{x,y,z} - MC_{zvrtx}) < 0.1$ selection which I did not.
- All the changes are made in my weights estimation and not in Yonghong's.
- After applying these changes, the UrQMD cocktails were compared. As for PHSD coctails, they are basically same.

UrQMD cocktail comparison before and after

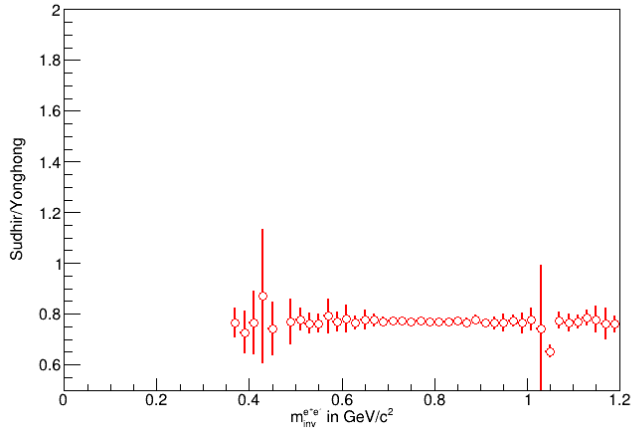
Before: π^0 dalitz



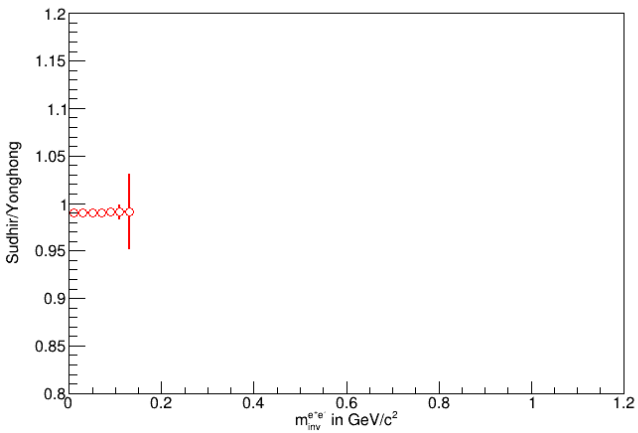
η dalitz



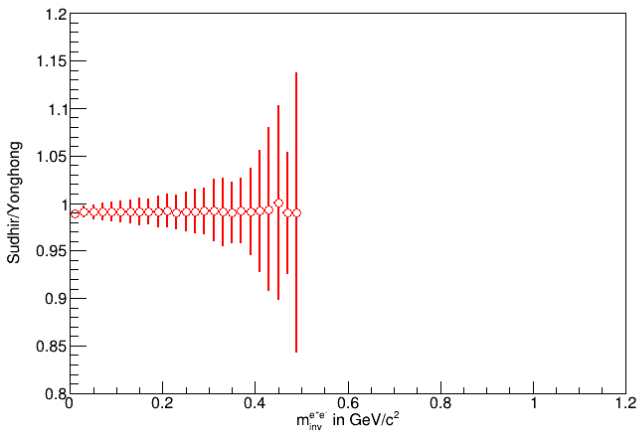
ρ^0



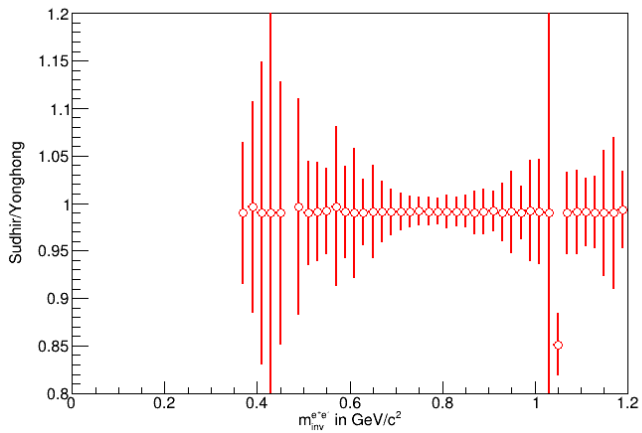
After: π^0 dalitz



η dalitz



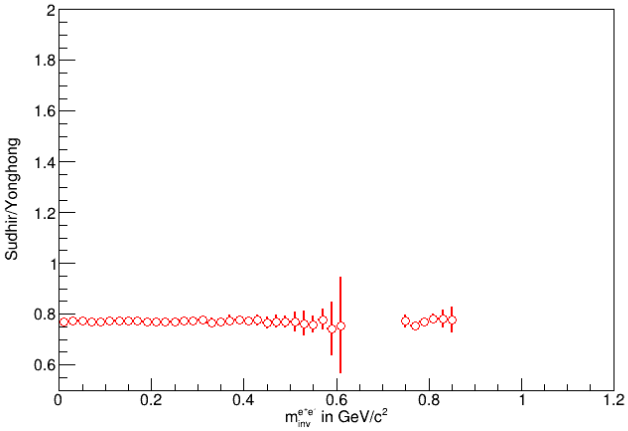
ρ^0



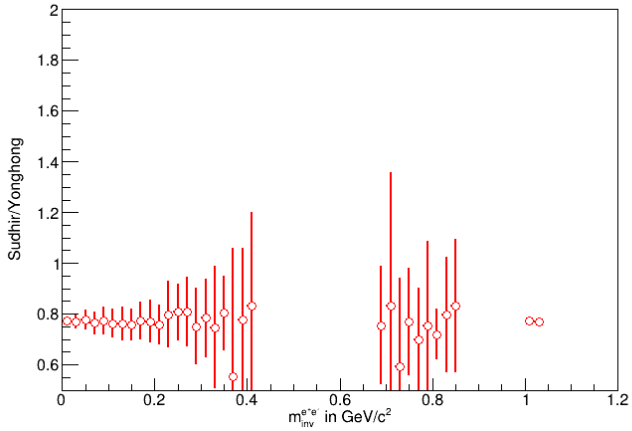
There is still 1% difference in yonghong and my cocktails.
Since the difference is not significant, Yonghong's weights used for my analysis.

UrQMD cocktail comparison before and after

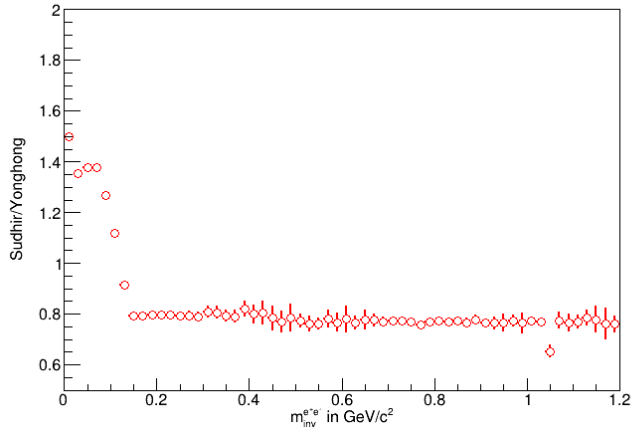
Before: ω



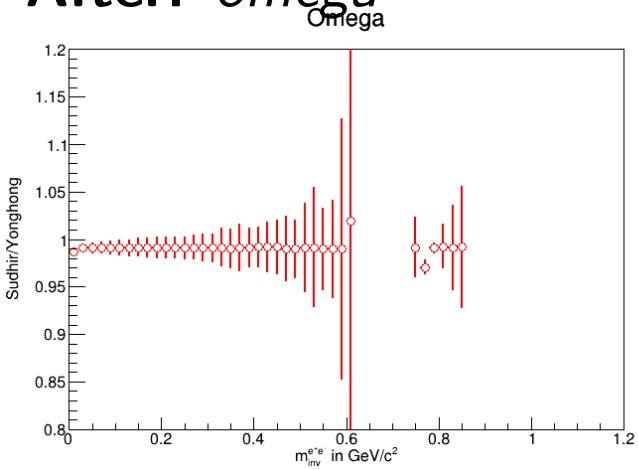
ϕ



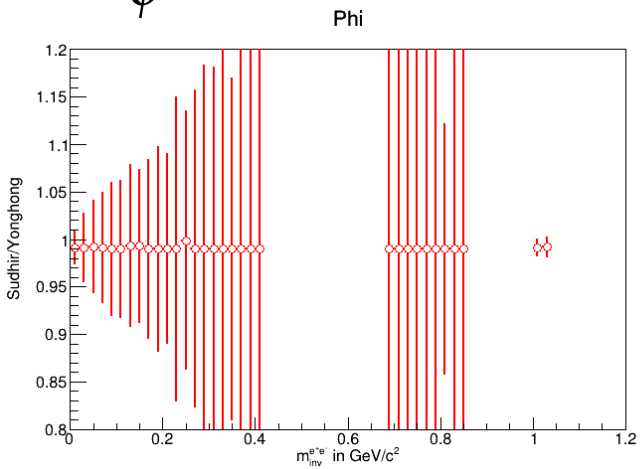
All



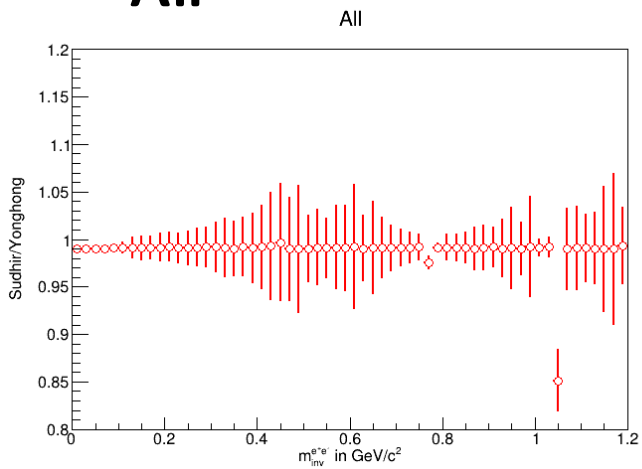
After: *omega*



ϕ



All



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Comparison with Yonghong's analysis (TPC+TOF)

Track selection - 1D cuts TPC+TOF analysis

- For consistent comparison, similar cuts were applied in our analysis as yonghong's analysis:

→ Pool-1: fully reconstructed tracks[2] in $|\eta| < 1.0$

- NHits > 39, DCA $< \mathbf{2.5}\sigma$, **TPC dEdX ($n\sigma_\pi > 2$)**, **TPC dEdX (p dep. (p < 0.7) and -1 to 2σ (p > 0.7))**, TOF Matching (dϕ and dz $<$ **3 (2)**σ), TOF (-2 to 2σ).

→ Pool-2: tracks w/ loose cuts[3].

- ($|\eta| <$2.5, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-2 to 2σ), TOF PID (if matched).

- Mass cut on pairs: $M_{\text{inv}} < 100$ MeV/c^2 and NO restrictions on opening angle.

[2] TOF matched tracks identified in the TPC and TOF

[3] This is corresponding Pool 3 in our analysis

Comparison w/ Yonghong's TPC+TOF results

before applying any pair rejection strategy:

Yonghong → (11.5M)

```
PHSD:
S/B in 0.2-1.5: 0.0119791;S=3660.2;BG=305548
LM    (S/√B 0.2 -0.6 ): 4.3799 ;S=1912.91 ;BG=190748
Omega (S/√B 0.6 -0.85): 5.47688 ;S==1542.1 ;BG=79279.2
Phi   (S/√B 0.85-1.2 ): 1.31316 ;S==237.513 ;BG==32714.6
ALL   (S/√B 0.2-1.5  ): 6.62162 ;S=3660.2 ;BG=305548
```

U-B = 3057±717

Sudhir → (11.6M)

```
================================================================================
S/B (0.2 - 1,5 GeV/c2)  0.0120775
================================================================================
LM      (s/sqrt(b)) (0.20 - 0.60 GeV/c2):4.40873;       S = 1916.96;    B = 189060.3
omega   (s/sqrt(b)) (0.60 - 0.85 GeV/c2):5.49499;       S = 1541.56;    B = 78702.2
phi     (s/sqrt(b)) (0.85 - 1.20 GeV/c2):1.29469;       S = 233.23;     B = 32451.2
All     (s/sqrt(b)) (0.20 - 1.50 GeV/c2):6.64793;       S = 3659.29;    B = 302985.5
================================================================================
```

U-B = 3417±781

after applying respective pair rejection strategies:

Yonghong → (11.5M)

```
PHSD_PCM_Pi0:
S/B in 0.2-1.5: 0.0665213;S=1554.08;BG=23362.1
LM    (S/√B 0.2 -0.6 ): 6.49021 ;S=745.148 ;BG=13181.6
Omega (S/√B 0.6 -0.85): 8.92031 ;S==708.388 ;BG=6306.42
Phi   (S/√B 0.85-1.2 ): 2.01531 ;S==116.563 ;BG==3345.33
ALL   (S/√B 0.2-1.5  ): 10.1676 ;S=1554.08 ;BG=23362.1
```

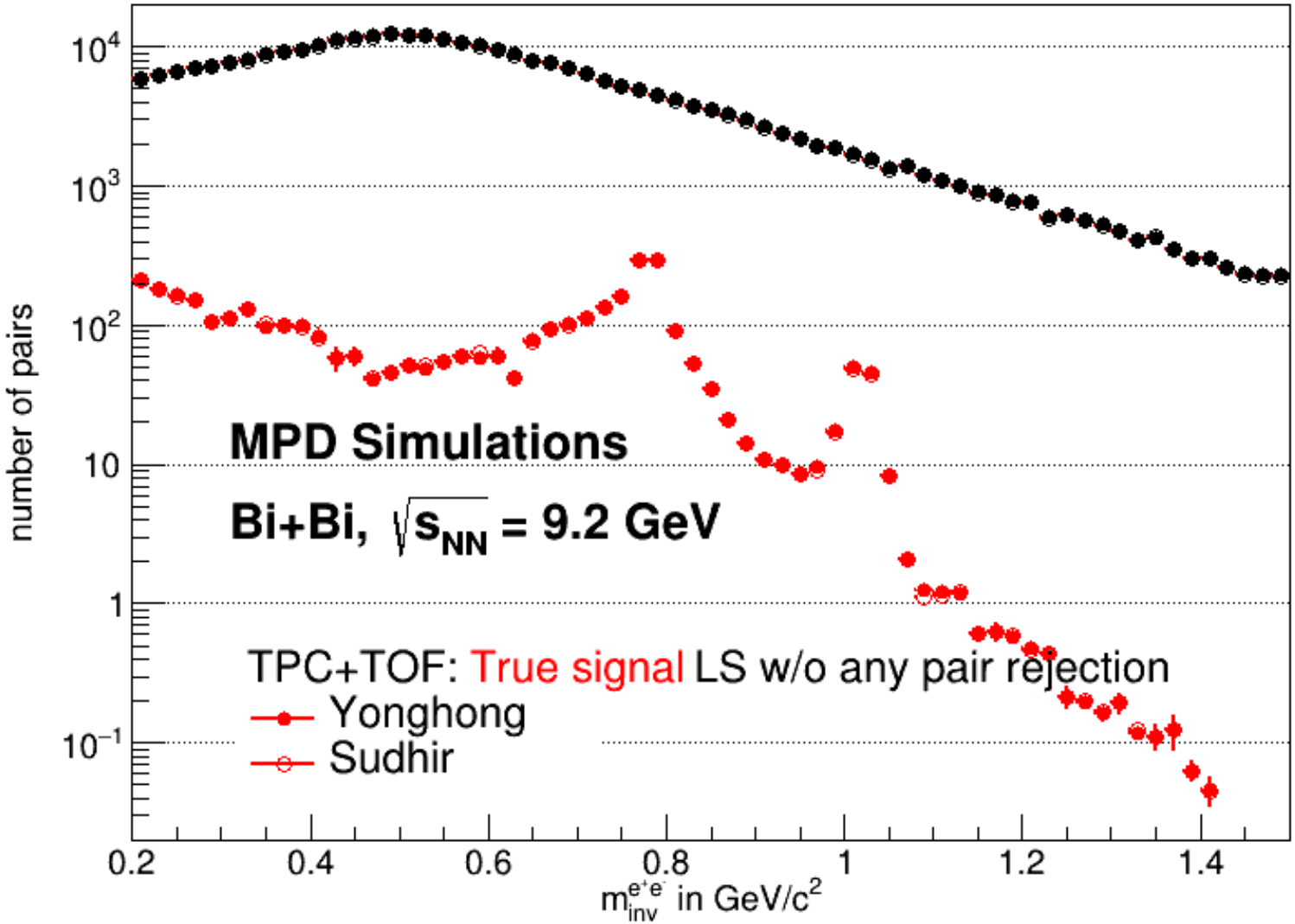
U-B = 1606±220

Sudhir → (11.6M)

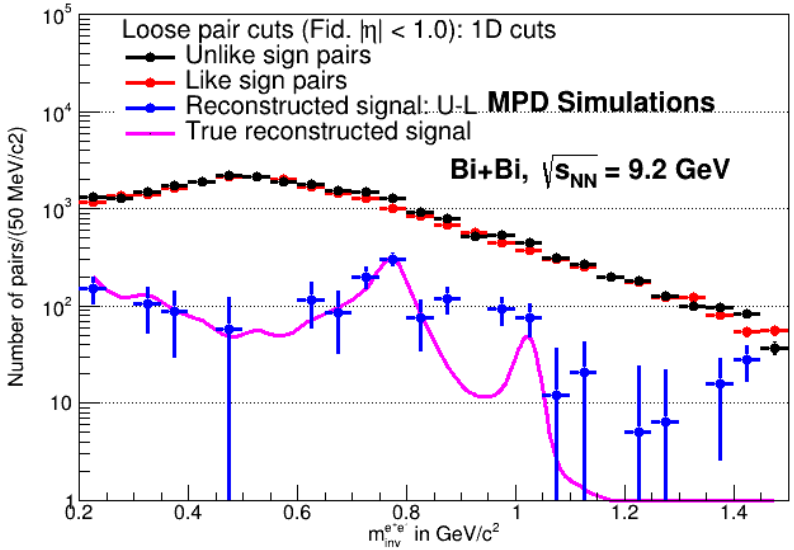
```
================================================================================
S/B (0.2 - 1,5 GeV/c2)  0.0633983
================================================================================
LM      (s/sqrt(b)) (0.20 - 0.60 GeV/c2):6.47626;       S = 769.17;     B = 14105.6
omega   (s/sqrt(b)) (0.60 - 0.85 GeV/c2):8.86687;       S = 728.51;     B = 6750.3
phi     (s/sqrt(b)) (0.85 - 1.20 GeV/c2):1.91563;       S = 117.15;     B = 3739.9
All     (s/sqrt(b)) (0.20 - 1.50 GeV/c2):10.06771;      S = 1598.76;    B = 25217.7
================================================================================
```

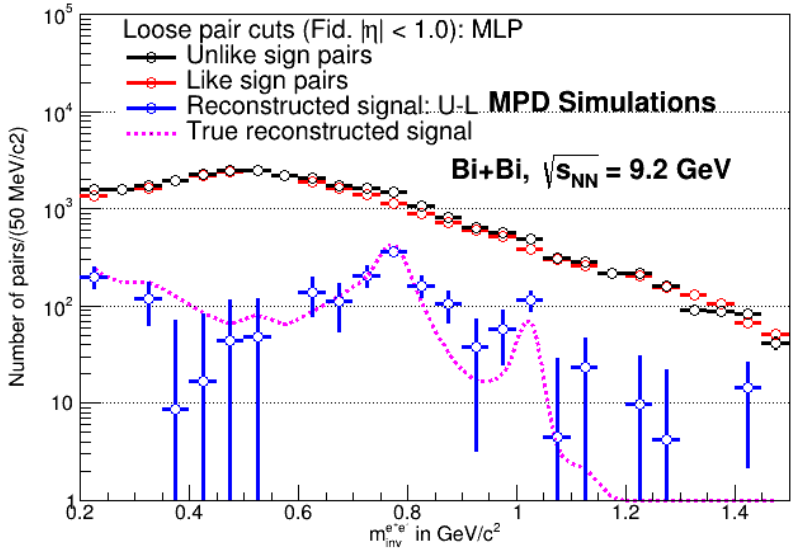
U-B = 1492±228

Comparison w/ Yonghong's TPC+TOF results: Plots

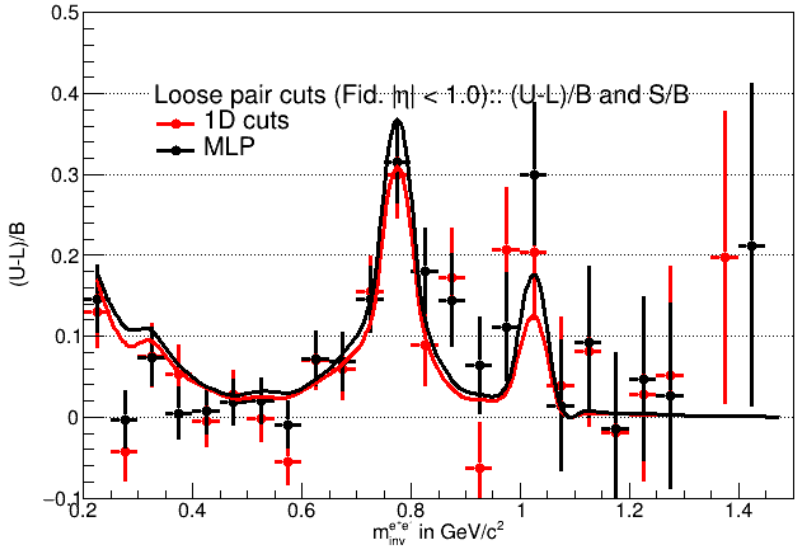


ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (loose cuts) ($|\eta| < 1.0$)





1D cuts: ECal after pT $>$ 0.8 GeV/c



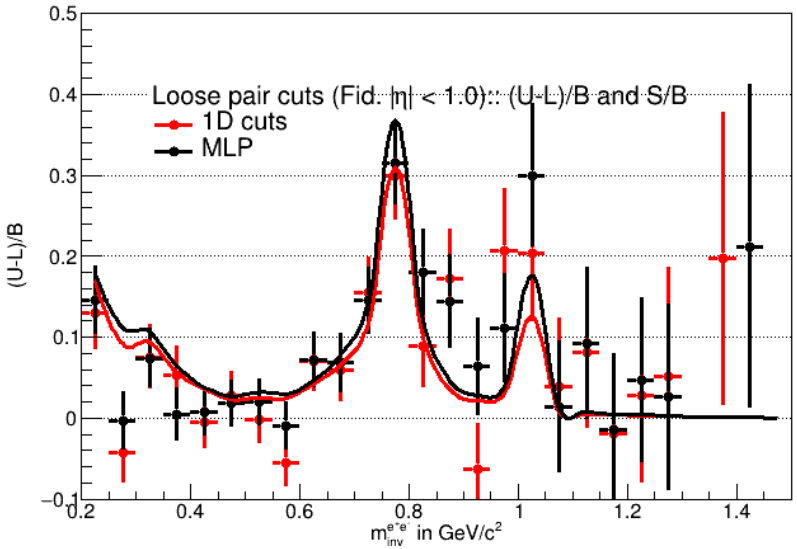
MLP: ECal in whole pT region

ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (loose cuts) ($|\eta| < 1.0$)

	Bef. NFP (1D)	Aft. CTC (1D)	Bef. NFP (MLP)	Aft. CTC (MLP)
Mass	-	100	-	100
U	297314±545	24682±157	362841±602	28246±168
B	294445±543	23394±153	359631±600	26556±163
U-B	2868±769	1288±219	3210±850	1689±234
(U-B)/B (%)	0.97±0.00	5.50±0.05	0.89±0.00	6.36±0.05
BFE	14	34	14	52
S	3618	1578	4761	2112
S/B (%)	1.23	6.74	1.32	7.95
BFE	22	51	31	81
Significance	6.67	10.32	7.94	12.96

1D cuts: ECal after pT $>$ 0.8 GeV/c

Yonghong (1D cuts):
S/B: 7.14%
S/sqrt(B): 10.46
S: 1533; B: 21475
U-B = 1397±211



MLP: ECal in whole pT region

Current status w/ corrected UrQMD/PHSD weights

Current status

- The differences in the analyses are, in Close TPC cut analysis, acceptance is divided into Fiducial and veto regions.
- Moreover, the selection cuts on pair mass and opening angle are dictated by p_{T} of the partner (in contrast to Yonghong's analysis, where flat cut of 100 MeV is applied for all p_{T} and no opening angle cut is applied).
- Howver, best possible results from Close TPC cut need to studied and optimized.
- Events with vertex reconstructed using tracks less than 2 will not be used.
- Similar to Yonghong's analysis, in 1D cuts analysis, ECal will not be used below pT $<$ 0.8 GeV/c.
- In case of Machine learning, ECal information was given for whole pT range, so in this case, ECal is being used in whole range.

Track selection

→ Pool-1 - fully reconstructed tracks[4] in fiducial area ($|\eta| < 0.7$)

- NHits > 39, DCA $< \mathbf{2.5\sigma}$, **TPC dEdX ($\mathbf{n\sigma_\pi > 2}$)**, **TPC dEdX (p dep. ($\mathbf{p < 0.7}$) and -1 to $\mathbf{2\sigma}$ ($\mathbf{p > 0.7}$))**, TOF Matching (dϕ and d$z < \mathbf{3\ (2)}\sigma$), TOF (-2 to 2σ) AND for pT > 0.8 GeV/c: ECal PID (p dep. $<$ E/p < 1.5 and $\mathrm{m}^2 < 2\sigma$) w/ ECal Matching ($< 3\sigma$).

→ Pool-2 - fully reconstructed tracks in veto area ($0.7 < |\eta| < 1.0$) (Same cuts.).

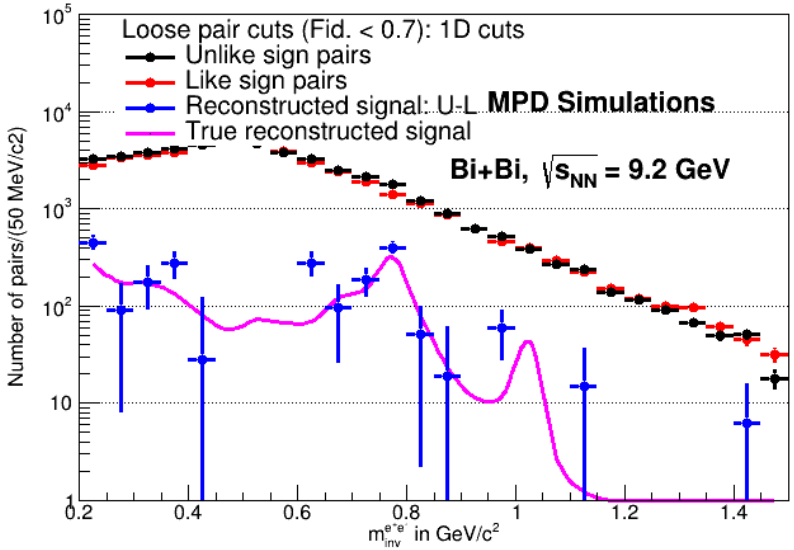
→ Pool-3 with tracks reconstructed in TPC.

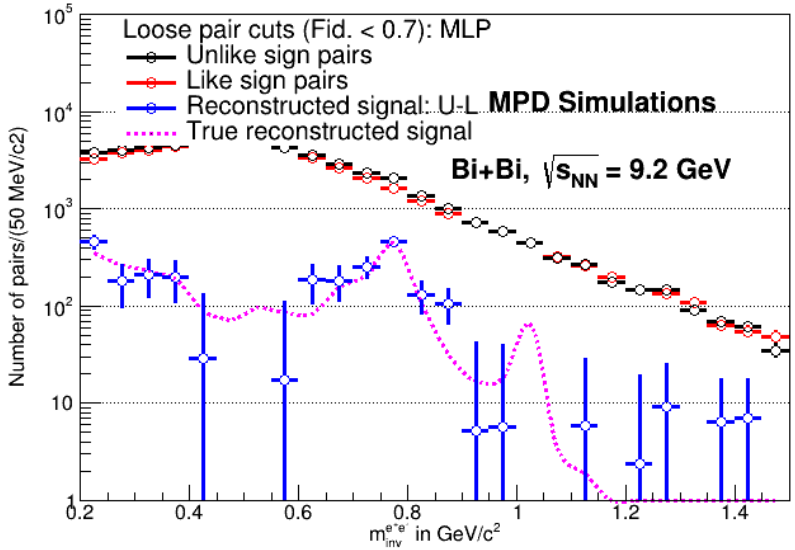
- $p_T <= 110$ MeV/c → not matched in TOF and ECal - ($|\eta| < 2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-4 to 4σ)).
- $p_T > 110$ MeV/c → not matched in TOF but matched in ECal - ($|\eta| < 2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-3 to 3σ), ECal (p dep. $<$ E/p $<$ 1.5 and $\mathrm{m}^2 < 2\sigma$, ECal Matching ($< 3\sigma$)).
- $p_T > 110$ MeV/c → not matched in ECal but may or may not in TOF - ($|\eta| < 2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-1 to 2σ), TOF PID (if matched).

- No further pairing (NFP): $M_{\mathrm{inv}} < 120$ MeV/c^2 w/ no cut on opening angle.
- Close TPC cut (CTC): $M_{\mathrm{inv}} < 80$ MeV/c^2 and opening angle < 10 or 5^o.

[4] TOF and ECal matched tracks identified in the TPC, TOF and ECal

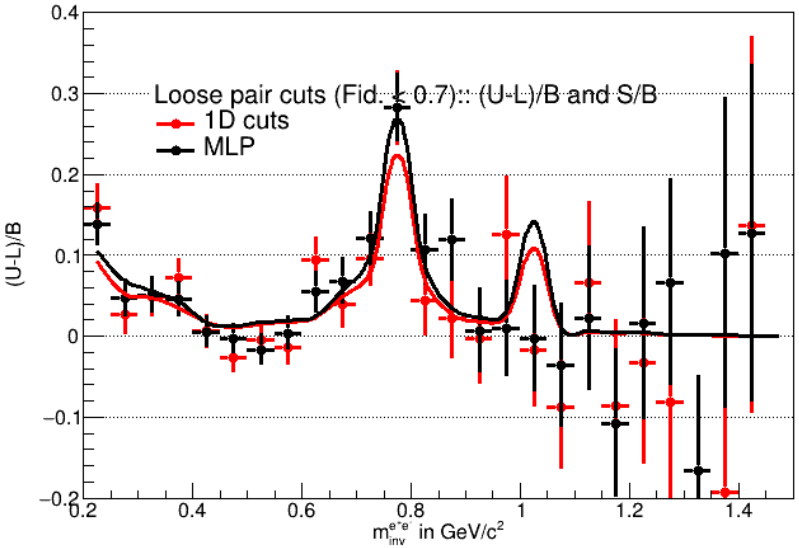
ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (tight cuts) (Fid. < 0.7)





<u>1D cuts</u>:
ECal after pT $>$ 0.8 GeV/c.

<u>MLP</u>:
ECal in whole pT region



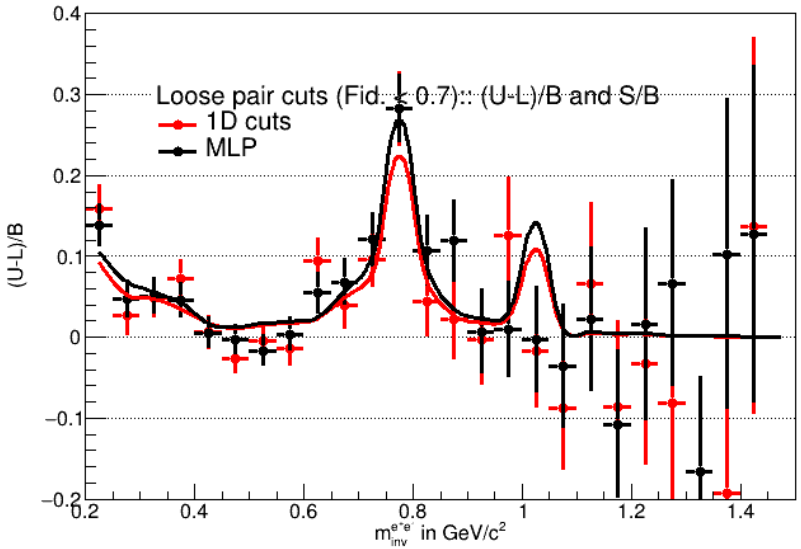
Cuts: pair mass $<$ 120 (80) MeV/c2 and opening angle $<$ 10 (5) deg.

ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (tight cuts) (Fid. < 0.7)

	Bef. NFP (1D)	Aft. CTC (1D)	Bef. NFP (MLP)	Aft. CTC (MLP)
Mass & θ	-	120/80 & 10/5	-	120/80 & 10/5
U	151287±389	47029±217	193895±440	53401±231
B	149055±386	45222±213	191288±437	51114±226
U-B	2231±548	1807±304	2607±621	2287±323
(U-B)/B (%)	1.50±0.01	3.99±0.03	1.36±0.00	4.47±0.03
BFE	17	35	18	50
S	2125	1854	2887	2498
S/B (%)	1.43	4.10	1.51	4.89
BFE	15	37	22	60
Significance	5.50	8.72	6.60	11.05

<u>1D cuts</u>:
ECal after pT $>$ 0.8 GeV/c.

<u>MLP</u>:
ECal in whole pT region



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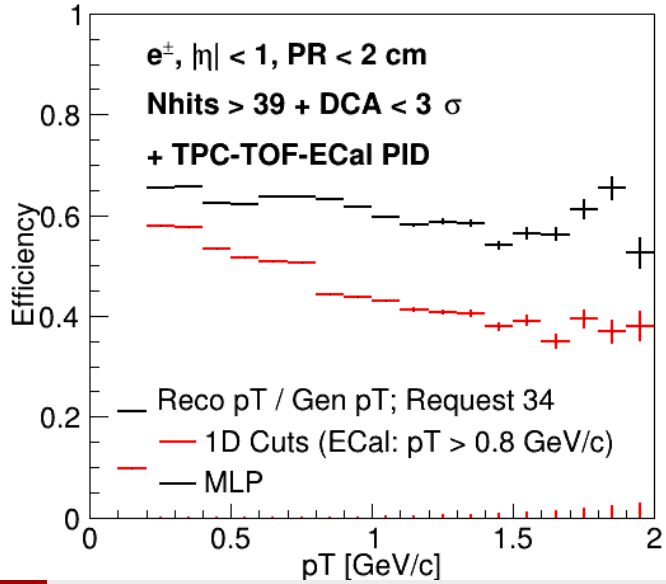
(U-B)/B (%)	1.50±0.01	3.99±0.03	1.36±0.00	4.47±0.03
BFE	17	35	18	50
S	2125	1854	2887	2498
S/B (%)	1.43	4.10	1.51	4.89
BFE	15	37	22	60
Significance	5.50	8.72	6.60	11.05

1D cuts:
ECal after pT > 0.8 GeV/c.

MLP:
ECal in whole pT region



Cuts: pair mass $<$ 120 (80) MeV/c2 and opening angle $<$ 10 (5) deg.

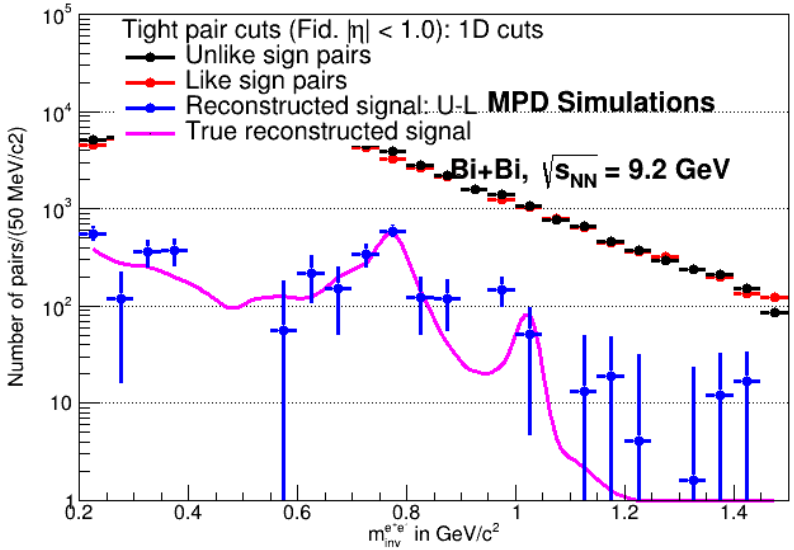
Conclusions and Next steps

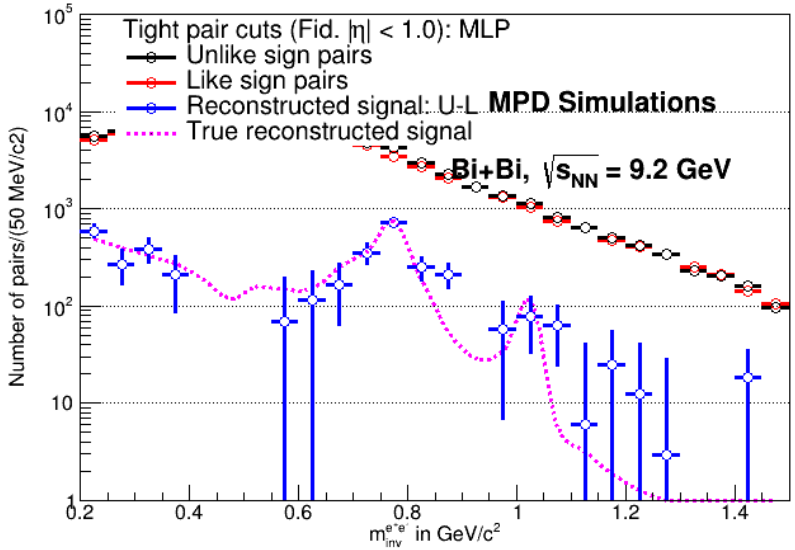
- Two dielectron analyses were compared with similar selection cuts and found consistent with each other.
- Current status of our analysis results with updated weights was shown.
- Strong cuts on pair opening angle and invariant mass reduces the signal loss but less background suppression $\Rightarrow$ yonghong's analysis where no restrictions on the opening angle.
- For visible reconstructed signal, new production is needed: Enhanced η-Dalitz decays (e.g. factor 5) w/ Request 34 like settings and more statsitics.
- Benefit of a veto region is being investigated.

THANK YOU

BACK-UP

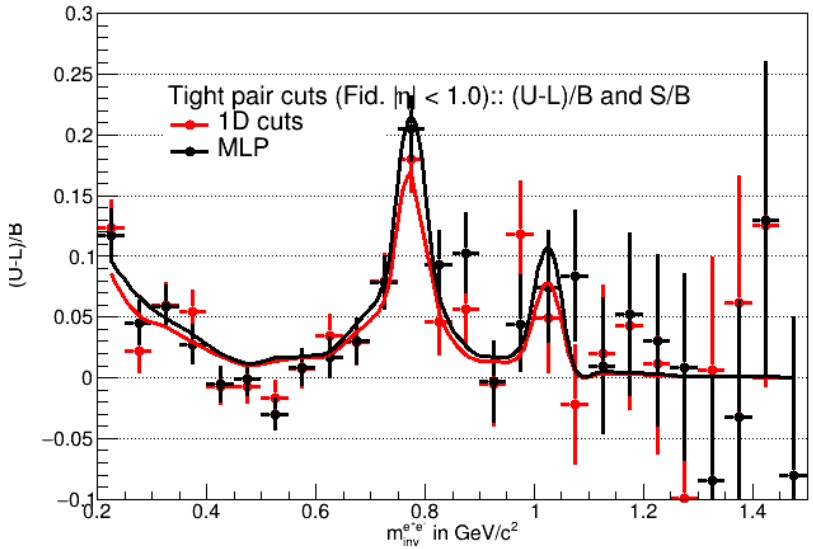
ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (tight cuts) ($|\eta| < 1.0$)





<u>1D cuts</u>:
ECal after pT > 0.8 GeV/c.

<u>MLP</u>:
ECal in whole pT region



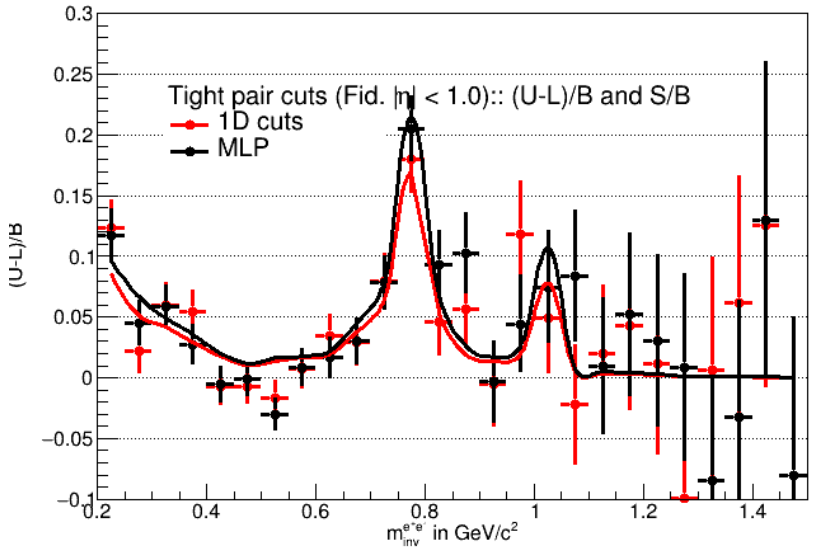
Cuts: pair mass < 120 (80) MeV/c2 and opening angle < 10 (5) deg.

ULS, LS and Signal: 1D cuts (11.4M) and MLP (10.6M) (tight cuts) ($|\eta| < 1$)

	Bef. NFP (1D)	Aft. CTC (1D)	Bef. NFP (MLP)	Aft. CTC (MLP)
Mass & θ	-	120/80 & 10/5	-	120/80 & 10/5
U	297314±545	90313±301	362841±602	98370±314
B	294445±543	87414±296	359631±600	95164±308
U-B	2868±769	2899±422	3210±850	3206±440
(U-B)/B (%)	0.97±0.00	3.32±0.02	0.89±0.00	3.37±0.02
BFE	14	47	14	53
S	3618	3073	4761	4039
S/B (%)	1.23	3.52	1.32	4.24
BFE	22	53	31	84
Significance	6.67	10.39	7.94	13.09

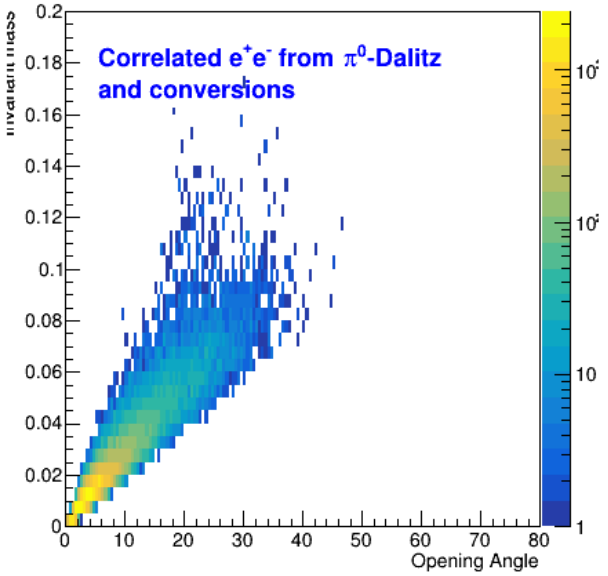
1D cuts:
ECal after pT > 0.8 GeV/c.

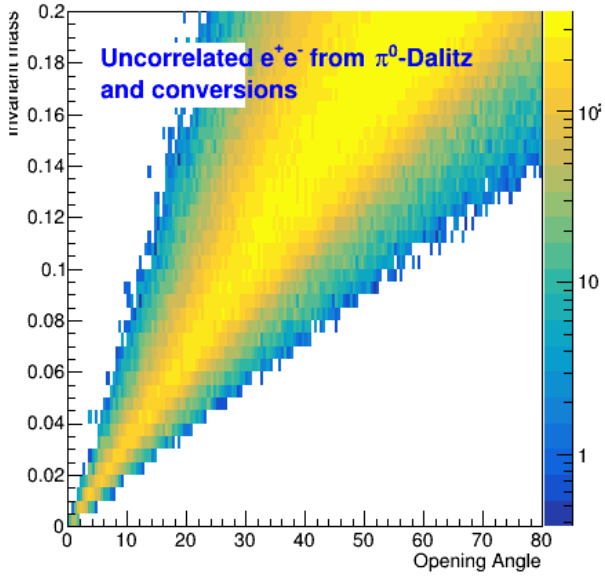
MLP:
ECal in whole pT region

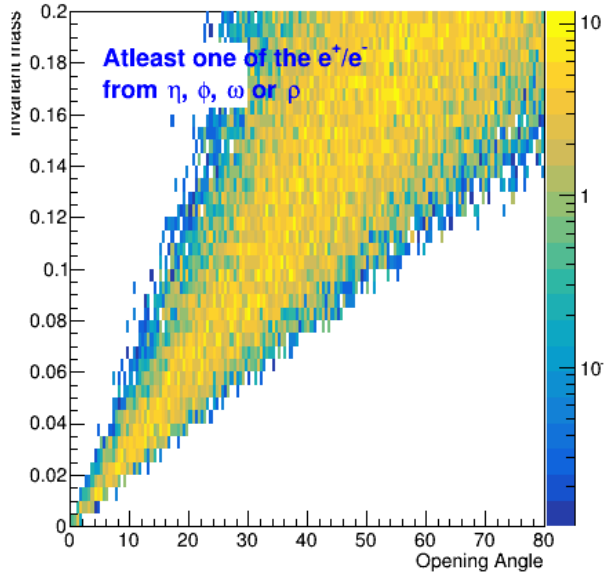


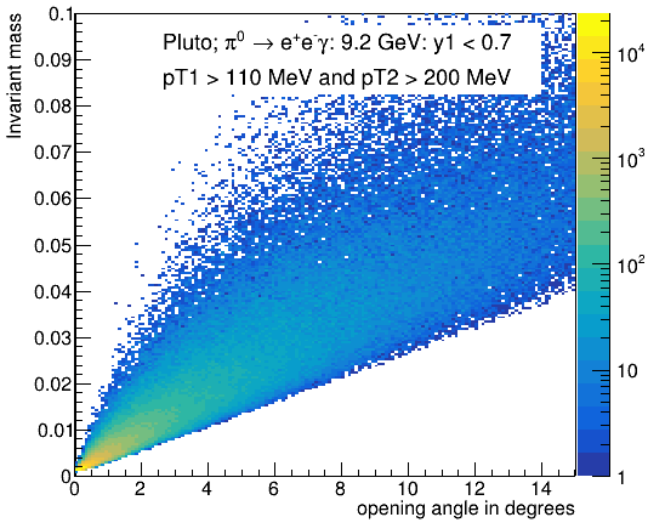
Cuts: pair mass < 120 (80) MeV/c2 and opening angle < 10 (5) deg.

Request 34: Pairing with partner pT $<$ 110 MeV/c



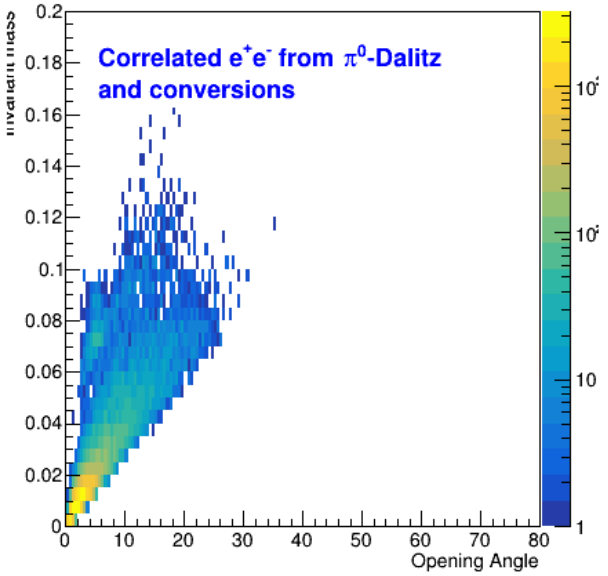


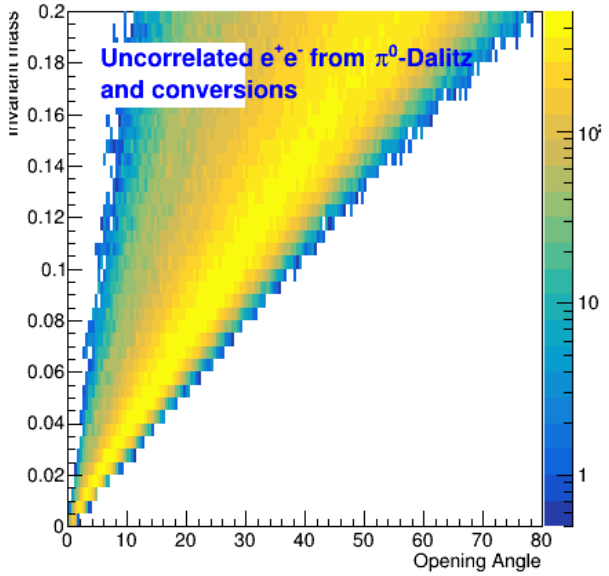


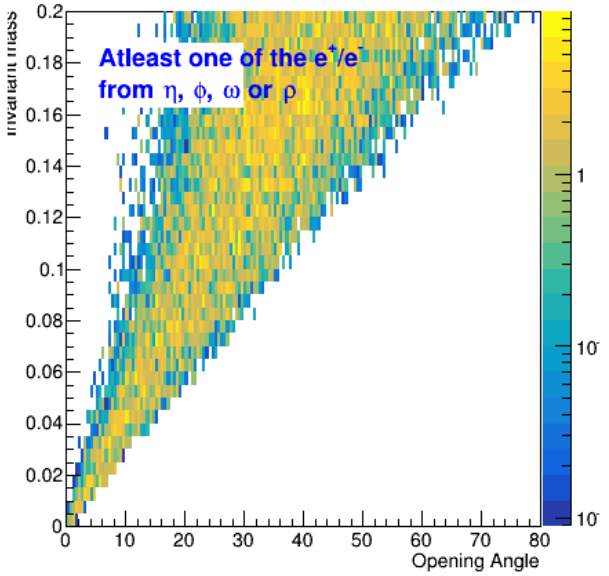


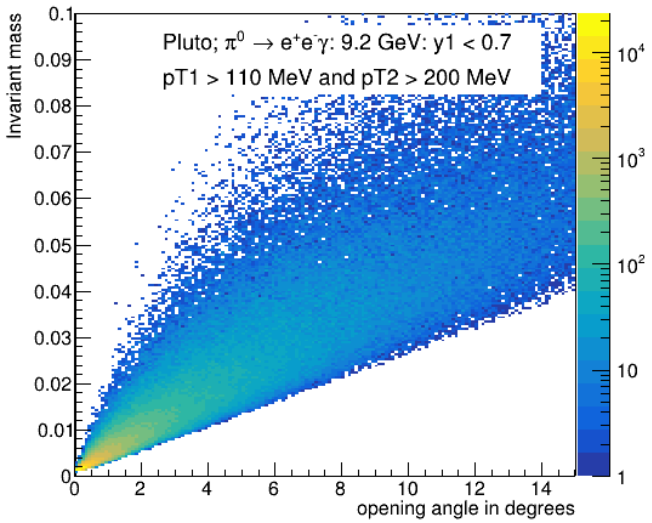
- Track1 is matched and fully reconstructed in TOF and ECal.
- Correlation between invariant mass and opening angle weakens at higher values.

Request 34: Pairing with partner pT $>$ 110 MeV/c









- Track1 is matched and fully reconstructed in TOF and ECal.
- Correlation between invariant mass and opening angle weakens at higher values.

Revised Analysis Strategy

$\Rightarrow$ Three electron pools:

$\rightarrow$ Pool-1 - fully reconstructed tracks[5] in fiducial area ($|\eta| < 0.7$) - $p_{\mathrm{T}} \gtrapprox 110$ MeV/c

$\rightarrow$ Pool-2 - fully reconstructed tracks in veto area $0.7 < |\eta| < 1.0$ - $p_{\mathrm{T}} \gtrapprox 110$ MeV/c.

$\rightarrow$ Pool-3 with tracks reconstructed in TPC.

- $p_{\mathrm{T}} <= 110$ MeV/c $\rightarrow$ not reaching the TOF.
- $p_{\mathrm{T}} > 110$ MeV/c $\rightarrow$ reaching the TOF.

- Step 1 - No further pairing (NFP): Tagging between Pool 1 and Pool 2.
- Step 2 - Close TPC cut (CTC): Tagging between Pool 1 and 3, and pairs within certain M_{inv} and opening angle are removed.
- Step 3: Rest of the tracks with $p_{\mathrm{T}} > 200$ MeV from Pool-1 are paired among themselves to build ULS and LS pair spectra.

[5] TOF and ECal matched tracks identified in the TPC, TOF and ECal

Track selection - 1D cuts analysis

→ Pool-1 - fully reconstructed tracks[6] in fiducial area ($|\eta| < 0.7$)

- NHits > 39, DCA $< 3\sigma$, TPC dEdX (p dep. (p < 0.8) and -1 to 2σ (p > 0.8)), TOF Matching (dϕ and d$z < \mathbf{3}\sigma$), TOF (-2 to 2σ), ECal PID (p dep. $<$ E/p < 1.5 and $\mathrm{m}^2 < 2\sigma$), ECal Matching ($< 3\sigma$).

→ Pool-2 - fully reconstructed tracks in veto area ($0.7 < |\eta| < 1.0$) (Same cuts.).

→ Pool-3 with tracks reconstructed in TPC.

- $p_{\mathrm{T}} <= 110$ MeV/c → not matched in TOF and ECal - ($|\eta| <2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-4 to 4σ)).
- $p_{\mathrm{T}} > 110$ MeV/c → not matched in TOF but matched in ECal - ($|\eta| <2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-3 to 3σ), ECal (p dep. $<$ E/p $<$ 1.5 and $\mathrm{m}^2 < 2\sigma$, ECal Matching ($< 3\sigma$)).
- $p_{\mathrm{T}} > 110$ MeV/c → not matched in ECal but may or may not in TOF - ($|\eta| <2.5$, NHits > 10, DCA $< 5\sigma$, TPC dEdX (-1 to 2σ), TOF PID (if matched).

- No further pairing (NFP): $M_{\mathrm{inv}} < 120$ MeV/c^2.
- Close TPC cut (CTC): $M_{\mathrm{inv}} < 80$ MeV/c^2 and opening angle < 10 or 5^o.

[6] TOF and ECal matched tracks identified in the TPC, TOF and ECal