Dielectron measurements with MPD experiment

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XIV MPD Collaboration meeting

Content

- New production dedicated to di-electrons: Request 34
- Comparison with Request 25 results
- Further improvement in machine learning training
- Current status
- Conclusions and Outlook

Request 34

Request 34: General-purpose, 15M UrQMD BiBi@9.2 (dielectron enhanced)

Monte-Carlo productions

riabovvg Management of Physics Working Groups May 20

UrQMD + Geant-4 based general-purpose simulation project for minbias (b = 0-16 fm) Bi (83/209) +Bi (83/209) collisions at 9.2 GeV, full detector configuration. The basic configuration repeats Request25 with several fixes: vacuum in the beam pipe instead of the air; fixes for cascade decays of strongly decaying particles/resonances; new variables to control track quality.

Please find below the request details:

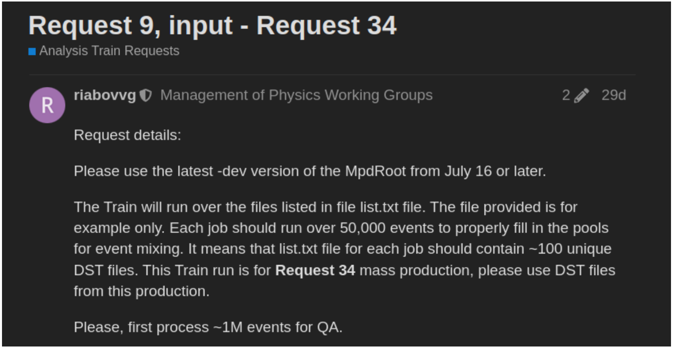
- inputfile (444 Bytes)
- MpdDecayConfig.txt (569 Bytes)
- runMC.C (11.7 KB)
- reco.C (8.8 KB)

- New production dedicated to di-electrons $\rightarrow$ enhanced branching ratios of dielectron sources.

What has changed in 34 with respect to 25?

- Changes in the MPDROOT
  - Beam pipe without air is used.
  - Conversions inside beam pipe due to malfunction with the pythia decayer is fixed.
  - Issue of lost electrons is fixed.
  - New variables are introduced for better track quality, though not applied in the analysis at the moment.
  - The branching ratios of dielectrons 5 decay channels (ρ, ω and ϕ mesons) are enhanced by factor 20.

Train: Request 34



Request 9, input - Request 34

Analysis Train Requests

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Request details:

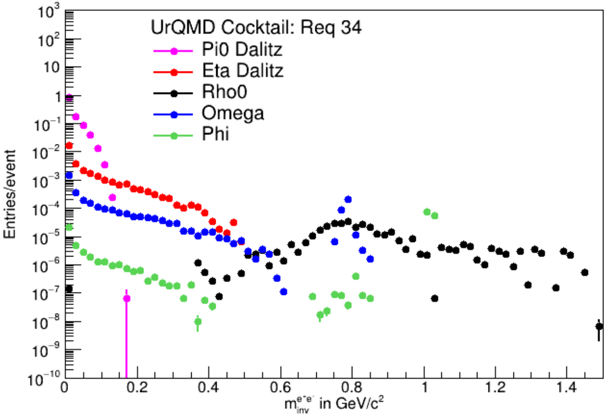
Please use the latest -dev version of the MpdRoot from July 16 or later.

The Train will run over the files listed in file list.txt file. The file provided is for example only. Each job should run over 50,000 events to properly fill in the pools for event mixing. It means that list.txt file for each job should contain ~100 unique DST files. This Train run is for **Request 34** mass production, please use DST files from this production.

Please, first process ~1M events for QA.

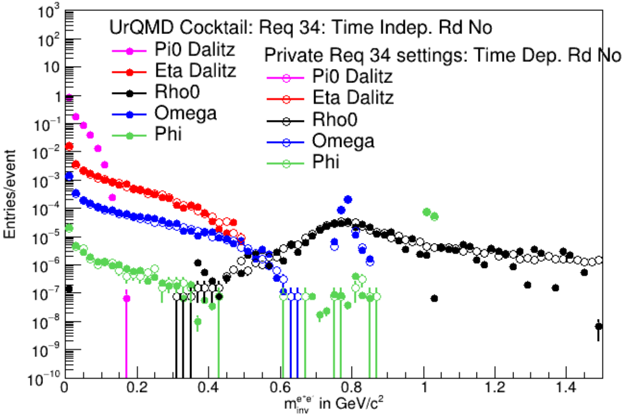
- New official train on Request 34 production → found an issue with dielectron cocktail shape.

Cocktail shape UrQMD in Request 34



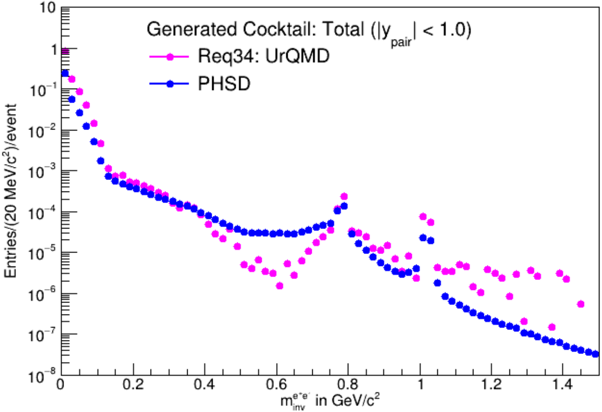
- "Ragged" shape of the di-electron cocktail.
- Random seeds in pythia8 decayer were kept time independent for dubugging → now turned back to time dependent.

Cocktail shape UrQMD in Request 34



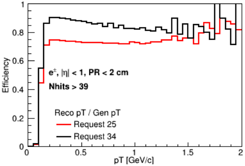
- As a result, "Ragged" shape of the di-electron cocktail can be restored.
- Should it be a huge concern since reweighted to PHSD shape?

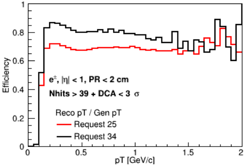
Cocktail shape UrQMD: Request 34

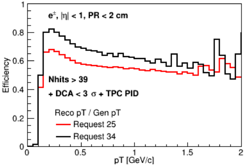


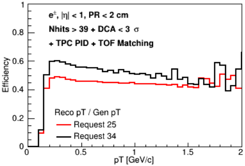
- Yield in 0.4 to 0.6 GeV/c2 in UrQMD significantly differ from PHSD $\rightarrow$ important mass regime in this analysis.
- Ratio of PHSD to UrQMD is used as weights to get PHSD shape.
- Ran my task privately - few changes in my task, so, did not use train output.

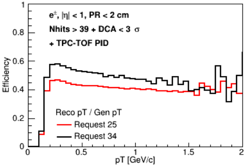
Request 25 and 34: Efficiency using 1D cuts

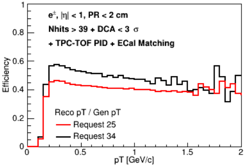


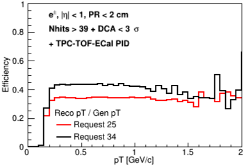












Revised Analysis Strategy

⇒ Three electron pools:

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

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

→ 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.

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

Track selection - 1D cuts analysis

→ Pool-1 - fully reconstructed tracks[2] in fiducial area ($|\eta| < 0.7$)

- NHits > 39, DCA < 3σ, TPC dEdX (p dep. (p < 0.8) and -1 to 2σ (p > 0.8)), TOF Matching ($d\phi$ and dz < 2σ), 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.).

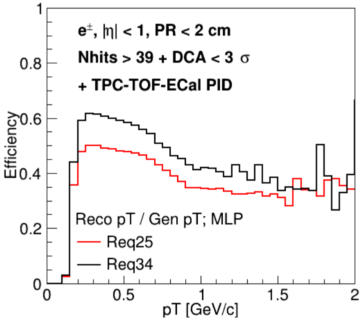
→ Pool-3 with tracks reconstructed in TPC.

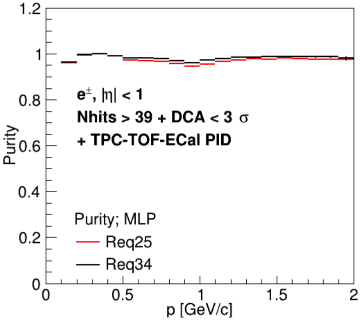
- $p_\mathrm{T} <= 110$ MeV/c → not matched in TOF and ECal - ($|\eta|$ <2.5, NHits > 10, DCA < 5σ, TPC dEdX (-4 to 4σ)).
- $p_\mathrm{T} > 110$ MeV/c → not matched in TOF but matched in ECal - ($|\eta|$ <2.5, NHits > 10, DCA < 5σ, TPC dEdX (-3 to 3σ), ECal (p dep. < E/p < 1.5 and $\mathrm{m}^2 < 2\sigma$,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

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

Request 25 and 34: Efficiency and Purity with MLP





- Efficiency was falling sharply after $p_{\mathrm{T}} > 1$ GeV/c, therefore, 1D cuts were applied after that region.
- Larger efficiency and better purity in case of Request 34.
- Same MLP response cut in both Request 25 and 34.

- Improvements in request 34 with respect to request 25 has significant impact on the analysis.
- Both reconstructed and true signal-to-background has enhanced in request 34.

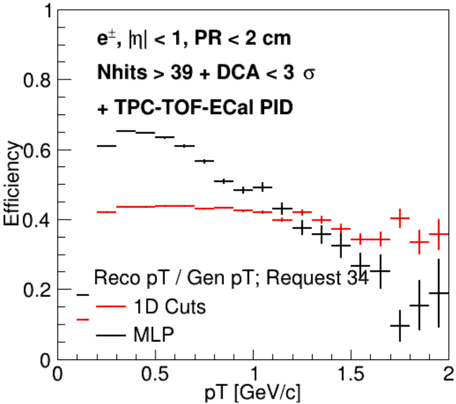
	Aft. CTC[3]	Request 25	Request 34
	Events	31.3M	13M
1D cuts	(U-B)/B(%)	3.39±0.02	6.76±0.09
	S/B(%)	4.53	6.57

- Similar improvement is observed in analysis using MLP for eID.

	Aft. CTC	Request 25	Request 34
	Events	31.3M	12.1M
MLP	(U-B)/B(%)	4.11±0.02	6.26±0.06
	S/B(%)	4.37	6.41

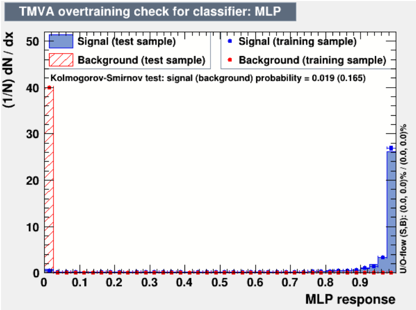
[3] different selection cuts on associated tracks with $p_{\mathrm{T}} <$ and $>$ 110 MeV/c

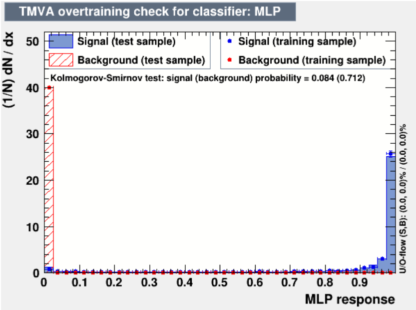
Optimization of Machine learning training: MLP



- Efficiency was falling sharply after $p_{\mathrm{T}} > 1$ GeV/c $\rightarrow$ $p-$integrated training of the sample.
- $p-$differential training may assist in better signal and background separation.

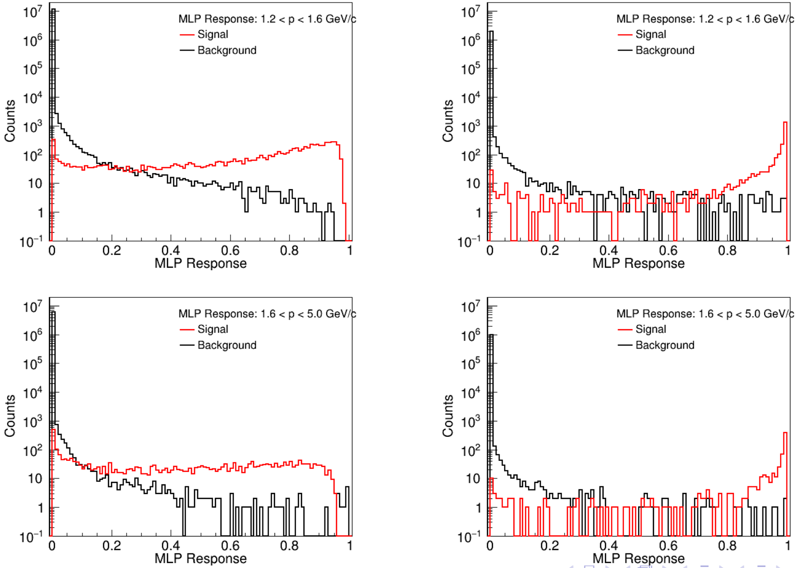
MLP: $p-$differential training



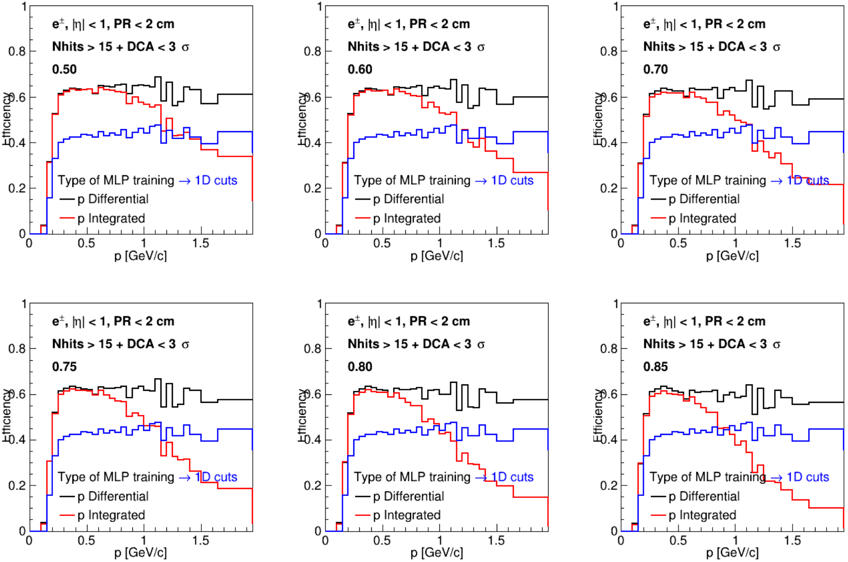


$p < 0.3$ GeV/c $\quad 0.3 < p < 0.6$ GeV/c
$0.6 < p < 0.9$ GeV/c $\quad 0.9 < p < 1.2$ GeV/c
$1.2 < p < 1.6$ GeV/c $\quad 1.6 < p < 5.0$ GeV/c.

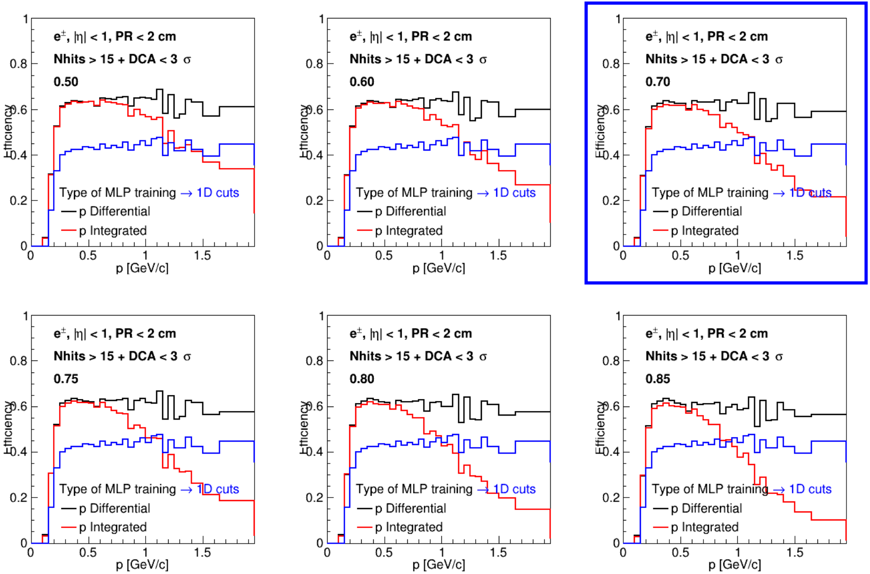
MLP response: $p-$integrated vs $p-$differential training

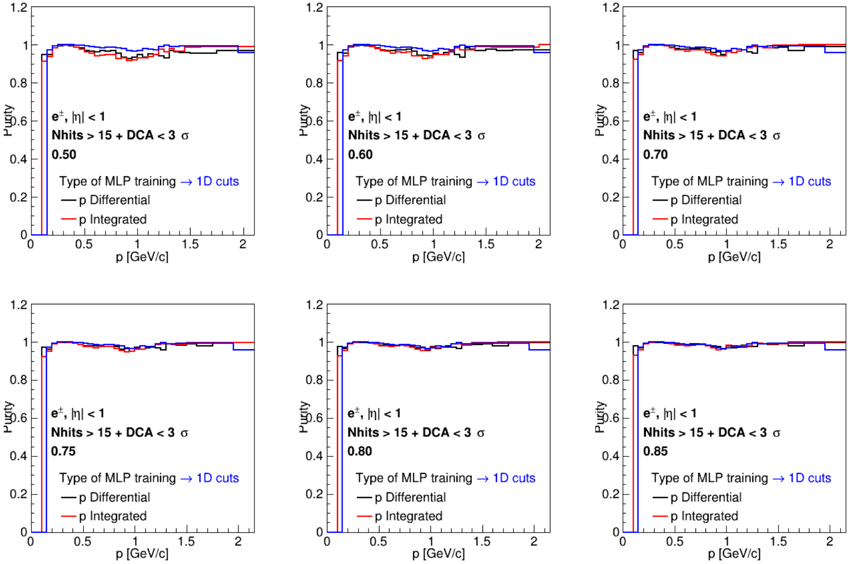


Request 34 Efficiency: p Integrated vs Differential training

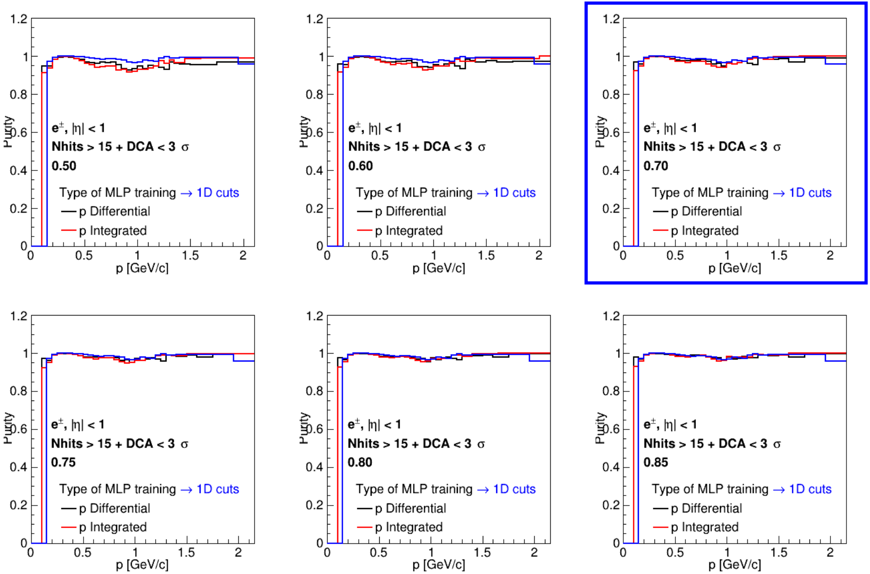


Request 34 Efficiency: p Integrated vs Differential training




Purity
p [GeV/c]
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.50
Type of MLP training → 1D cuts
p Differential
p Integrated
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.60
Type of MLP training → 1D cuts
p Differential
p Integrated
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.70
Type of MLP training → 1D cuts
p Differential
p Integrated
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.75
Type of MLP training → 1D cuts
p Differential
p Integrated
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.80
Type of MLP training → 1D cuts
p Differential
p Integrated
e$^{\pm}$, |η| < 1
Nhits > 15 + DCA < 3 σ
0.85
Type of MLP training → 1D cuts
p Differential
p Integrated

Request 34 Purity: p Integrated vs Differential training



S/B - MLP (Fid. < 0.7) - ML training $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

- Request 34, Number of Events: 12.1M each.
- True values are quoted in parenthesis.
- p-differential training of the MLP → signal is improved by nearly 20%.

Aft. CTC	p-integrated	p-differential
U	22576±150	26978±164
B	21246±146	25573±160
U-B	1330±209 (1361)	1405±229 (1649)
(U-B)/B(%)	6.26±0.06 (6.41)	5.49±0.05 (6.45)
BFE	40 (42)	38 (51)

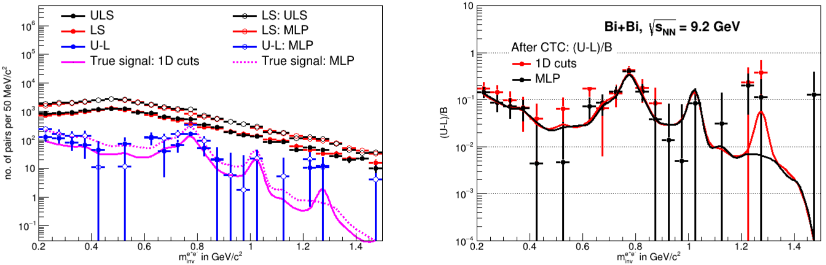
Current status (Fid. < 0.7) $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

- Request 34, Number of Events: 13M ← 1D cuts and 12.1M ← MLP.
- Machine learning improves signal, i.e. Background Free Equivalent signal.
- S/B ratio remains mostly unaffected.
- After close TPC cut strategy, integrated S/B ratio is nearly 6%.
- Measured signal is close to true signal within uncertainties.

Aft. CTC	1D cuts	MLP
U	12340±111	26978±164
B	11559±108	25573±160
U-B	781±155 (759)	1405±229 (1649)
(U-B)/B(%)	6.76±0.09 (6.57)	5.49±0.05 (6.45)
BFE	26 (24)	38 (51)

Current status

$0.2 < m_{inv}^{e^+e^-} < 1.5~\mathrm{GeV}/c^2$



Aft. CTC	1D cuts	MLP
U	12340±111	26978±164
B	11559±108	25573±160
U-B	781±155 (759)	1405±229 (1649)
(U-B)/B(%)	6.76±0.09 (6.57)	5.49±0.05 (6.45)
BFE	26 (24)	38 (51)

1. Signal between 0.4 to 0.6 GeV/c is not reconstructed properly.
2. Cocktail shape in this range in UrQMD differ significantly from PHSD.

Conclusions and Next steps

- New and improved Request 34: changes in production helps in improving signal and S/B, substantially.
- Generated UrQMD cocktail shape has "ragged" features which can be fixed by using time-dependent random seeds in pythia8 decayer $\rightarrow$ currently working with this feature.
- Momentum differential training helps improving the efficiency at high p_{T}.
- Apply machine learning for eID of partially reconstructed tracks $\rightarrow$ Revisit.
- Proper reconstruction of signal in 0.4 to 0.6 GeV/c and ϕ meson peak $\rightarrow$ Need alternative to UrQMD if possible and maybe more statistics.
- Close to exhausting options to further improve the results with current reconstruction algorthm $\rightarrow$ using γ in ECal to identify CB (preliminary tests are not promising) $\rightarrow$ eventually need to improve the low p_{T} reconstruction.

	Total	p_{T} (MeV) 0-30	p_{T} (MeV) 30-110	p_{T} (MeV) 110-
unpaired Pi0 Dalitz e ($p_{\mathrm{T}} > 200$ MeV/c):	241787			
partners in geant:	217906	67485	110944	39477
unpaired conversions ($p_{\mathrm{T}} > 200$ MeV/c)	143330			
partners in geant:	118362	32523	56136	29703

THANK YOU

BACK-UP

S/B - (Fid. < 0.7): Request 25 (34)

Mass range: $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

	Bef. NFP	Aft. NFP	Aft. CTC[4]	
Mass	-	120	80	← 1D cuts
Angle	-	-	10 or 5	
B	113089±336	86928±295	36329±191	← Req 25 (31.3M)
B	32972±182	25591±160	11559±108	← Req 34 (13M)
U-B	879±477	838±418	1232±272 (1647)	← True reconstructed values
U-B	876±258	893±228	781±155 (759)	
(U-B)/B(%)	0.78±0.00	0.96±0.00	3.39±0.02 (4.53)	
(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)	
BFE	3	4	21 (37)	
BFE	11	15	26 (24)	

← MLP

B	263803±514	170385±413	76174±276	
B	66065±257	44441±211	21246±146	
U-B	3210±729	2972±586	3130±394 (3291)	← Req 25 (31.3M)
U-B	1248±365	1329±300	1330±209 (1361)	← Req 34 (12.1M)
(U-B)/B(%)	1.22±0.00	1.74±0.01	4.11±0.02 (4.37)	
(U-B)/B(%)	1.89±0.01	2.99±0.02	6.26±0.06 (6.41)	
BFE	19	26	63 (70)	
BFE	12	20	40 (42)	

- B - Combinatorial background approximated by like sign pairs.

[4] different selection cuts on associated tracks with $p_T <$ and $>$ 110 MeV/c

S/B - 1D cuts and MLP (Fid. < 0.7)

Mass range: $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

	Bef. NFP	Aft. NFP	Aft. CTC	
Mass	-	120	80	
Angle	-	-	10 or 5	
B	32972±182	25591±160	11559±108	← 1D cuts
B	66065±257	44441±211	21246±146	← MLP
U-B	876±258	893±228	781±155 (759)	
U-B	1248±365	1329±300	1330±209 (1361)	
(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)	
(U-B)/B(%)	1.89±0.01	2.99±0.02	6.26±0.06 (6.41)	
BFE	11	15	26 (24)	
BFE	12	20	40 (42)	

- Request 34, Number of Events: 13M ← 1D cuts and 12.1M ← MLP.
- B - Combinatorial background approximated by like sign pairs.
- Use Machine learning improves the signal, i.e. Background Free Equivalent signal.
- S/B ratio is expected to stay unaffected.

S/B - 1D cuts and MLP (Fid. < 0.7)

$0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV$/c^2$

		Bef. NFP	Aft. NFP	Aft. CTC
	Mass	-	120	80
	Angle	-	-	10 or 5
1D cuts	B	32972±182	25591±160	11559±108
MLP	B	66065±257	44441±211	21246±146
	U-B	876±258	893±228	781±155 (759)
	U-B	1248±365	1329±300	1330±209 (1361)
	(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)
	(U-B)/B(%)	1.89±0.01	2.99±0.02	6.26±0.06 (6.41)
	BFE	11	15	26 (24)
	BFE	12	20	40 (42)

- Request 34, Number of Events: 13M ← 1D cuts and 12.1M ← MLP.
- B - Combinatorial background approximated by like sign pairs.
- Use Machine learning improves the signal, i.e. Background Free Equivalent signal.
- S/B ratio is expected to stay unaffected.

S/B - MLP (Fid. < 0.7) - ML training $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

- Request 34, Number of Events: 12.1M each.
- p-differential training of the MLP → signal is improved.

	Bef. NFP	Aft. NFP	Aft. CTC	
U	67313±259	45770±214	22576±150	
U	80823±284	53548±231	26978±164	
B	66065±257	44441±211	21246±146	
B	79534±282	52225±229	25573±160	
U-B	1248±365	1329±300	1330±209 (1361)	← p-integrated
U-B	1289±400	1324±325	1405±229 (1649)	← p-differential
(U-B)/B(%)	1.89±0.01	2.99±0.02	6.26±0.06 (6.41)	
(U-B)/B (%)	1.62±0.01	2.53±0.02	5.49±0.05 (6.45)	
BFE	12	20	40 (42)	
BFE	10	17	38 (51)	

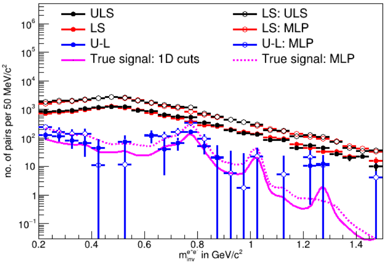
S/B - 1D cuts and MLP (Fid. < 0.7) $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

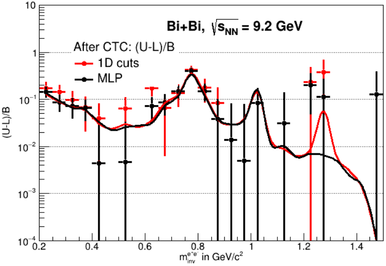
- Request 34, Number of Events: 13M ← 1D cuts and 12.1M ← MLP.
- Machine learning improves signal.
- After close TPC cut strategy, integrated S/B ratio is nearly 6%.
- Measured signal is close to true signal within uncertainties.
- ⇒ **Overall improvement of 2-3 factor in S/B ratio w.r.t. standard procedure w/ step 3 only.**

	Bef. NFP	Aft. NFP	Aft. CTC	
U	33848±184	26485±163	12340±111	
U	80823±284	53548±231	26978±164	
B	32972±182	25591±160	11559±108	← 1D cuts
B	79534±282	52225±229	25573±160	← MLP
U-B	876±258	893±228	781±155 (759)	
U-B	1289±400	1324±325	1405±229 (1649)	
(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)	
(U-B)/B (%)	1.62±0.01	2.53±0.02	5.49±0.05 (6.45)	
BFE	11	15	26 (24)	
BFE	10	17	38 (51)	

Request 34: ULS, LS and Signal

$0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV$/c^2$





	Bef. NFP	Aft. NFP	Aft. CTC
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U	80823±284	53548±231	26978±164
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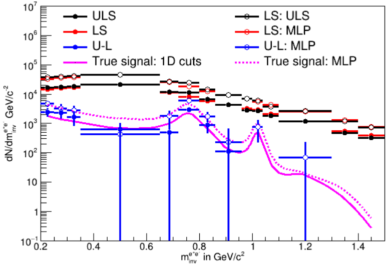
U-B	1289±400	1324±325	1405±229 (1649)
(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)
(U-B)/B (%)	1.62±0.01	2.53±0.02	5.49±0.05 (6.45)
BFE	11	15	26 (24)
BFE	10	17	38 (51)

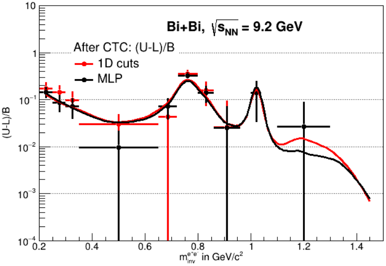
← 1D cuts

← MLP

Request 34: ULS, LS and Signal

$0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV$/c^2$





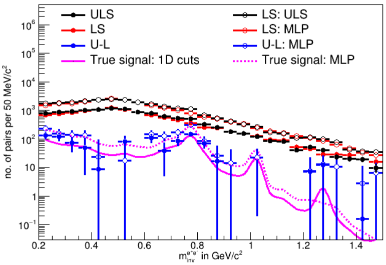
	Bef. NFP	Aft. NFP	Aft. CTC
U	33848±184	26485±163	12340±111
U	80823±284	53548±231	26978±164
B	32972±182	25591±160	11559±108
B	79534±282	52225±229	25573±160
U-B	876±258	893±228	781±155 (759)
U-B	1289±400	1324±325	1405±229 (1649)
(U-B)/B (%)	2.66±0.02	3.49±0.03	6.76±0.09 (6.57)
(U-B)/B (%)	1.62±0.01	2.53±0.02	5.49±0.05 (6.45)
BFE	11	15	26 (24)
BFE	10	17	38 (51)

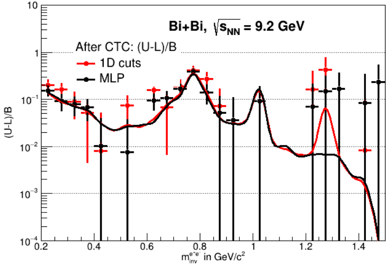
← 1D cuts

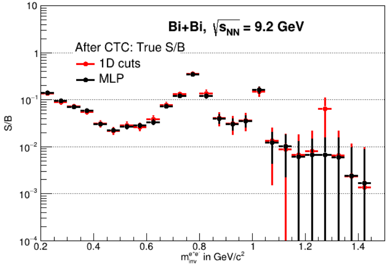
← MLP

Request 34: ULS, LS and Signal

Mass range: $0.2 < m_{inv}^{e^+e^-} < 1.5$ GeV/c^2

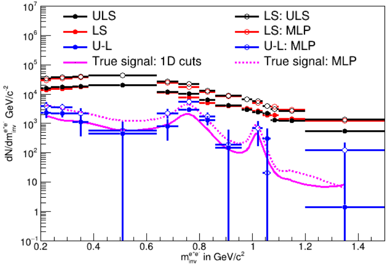


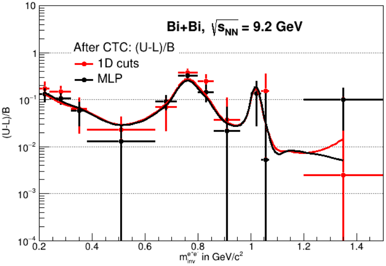


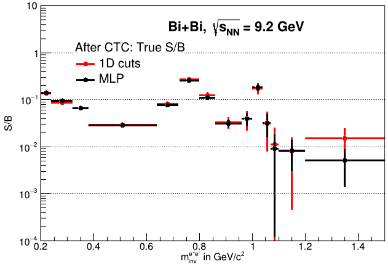


Request 34: ULS, LS and Signal

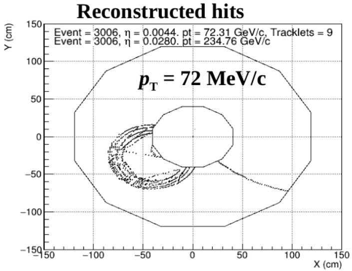
Mass range: $0.2 < m_{inv}^{e^+e^-} < 1.5\ \mathrm{GeV}/c^2$

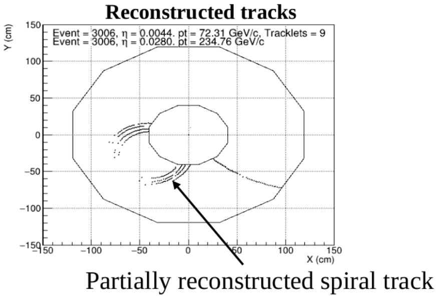






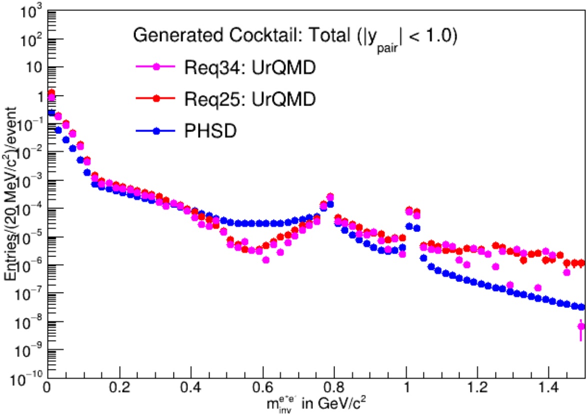
Quick recap





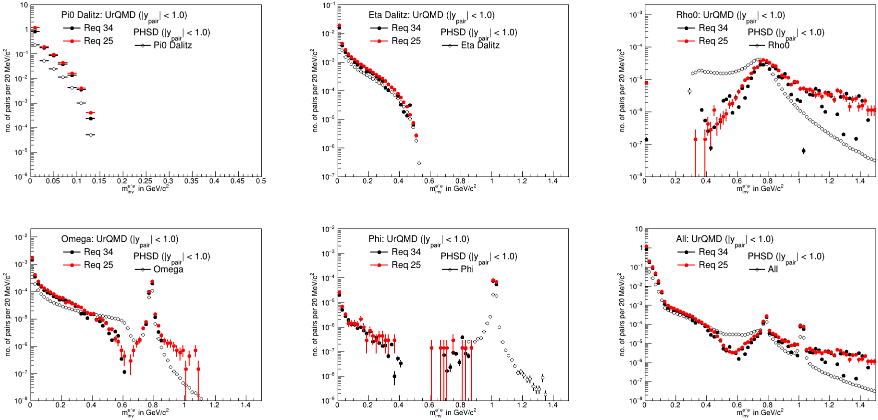
- With current track reconstruction algorithm, low p_T tracks are not reconstructed properly even though full hit information is available in the detector for tracks that enter the TPC ($p_T >\approx 30$ MeV/c).
- Question is, in an ideal detector, what would be the maximum possible benefit in the combinatorial background (CB) reduction, if we were to detect these tracks.
- As per our principle study, potentially, there is about 5-8 factor improvement possible in CB rejection.

Cocktail shape UrQMD and PHSD: Request 34 and 25

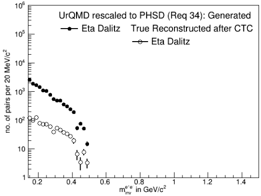


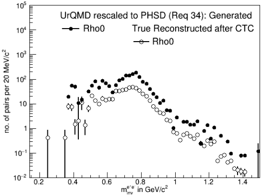
- Ratio of PHSD to UrQMD is used as weights to get PHSD shape.
- Apart from this, there were few bugs in my task, so, could not use train output.
- Ran my task privately and results are shown from next slides.

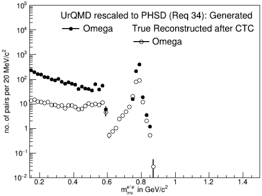
Cocktail shape UrQMD and PHSD: Request 34 and 25

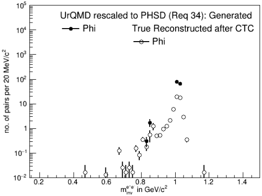


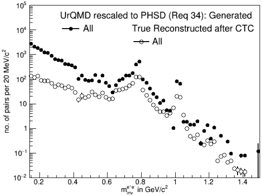
Cocktail shape Reconstructed: Request 34



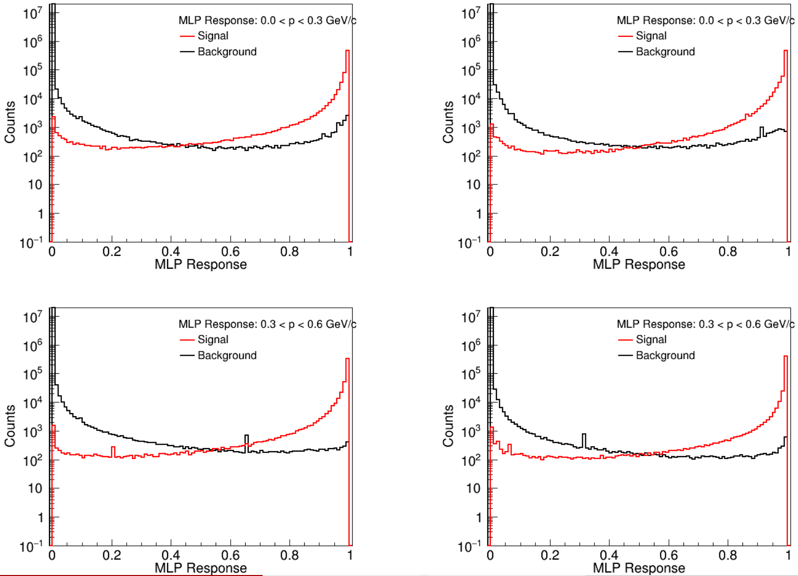








MLP response: pT Integrated vs Differential training



MLP response: pT Integrated vs Differential training