

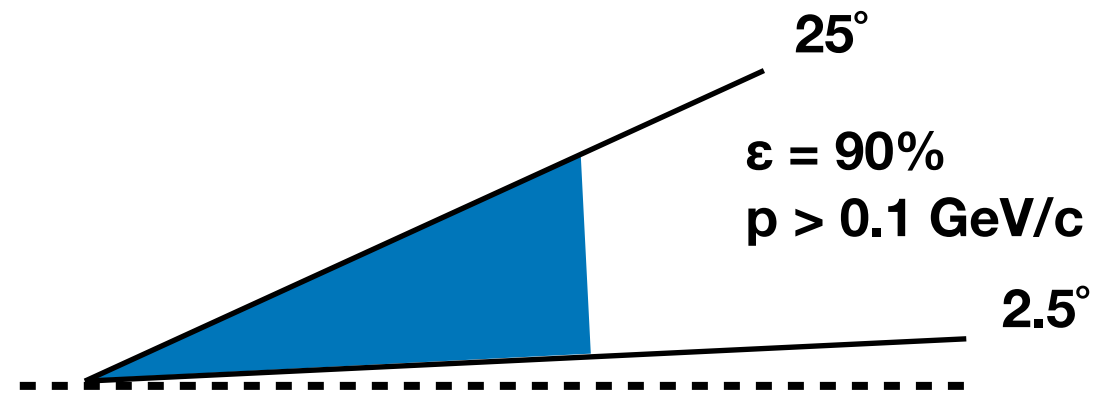
$p p J/\psi(ee)$

Simulating proton-proton reactions at CBM

R. Kliemt

$pp \rightarrow p p J/\psi \rightarrow p p e^+ e^-$

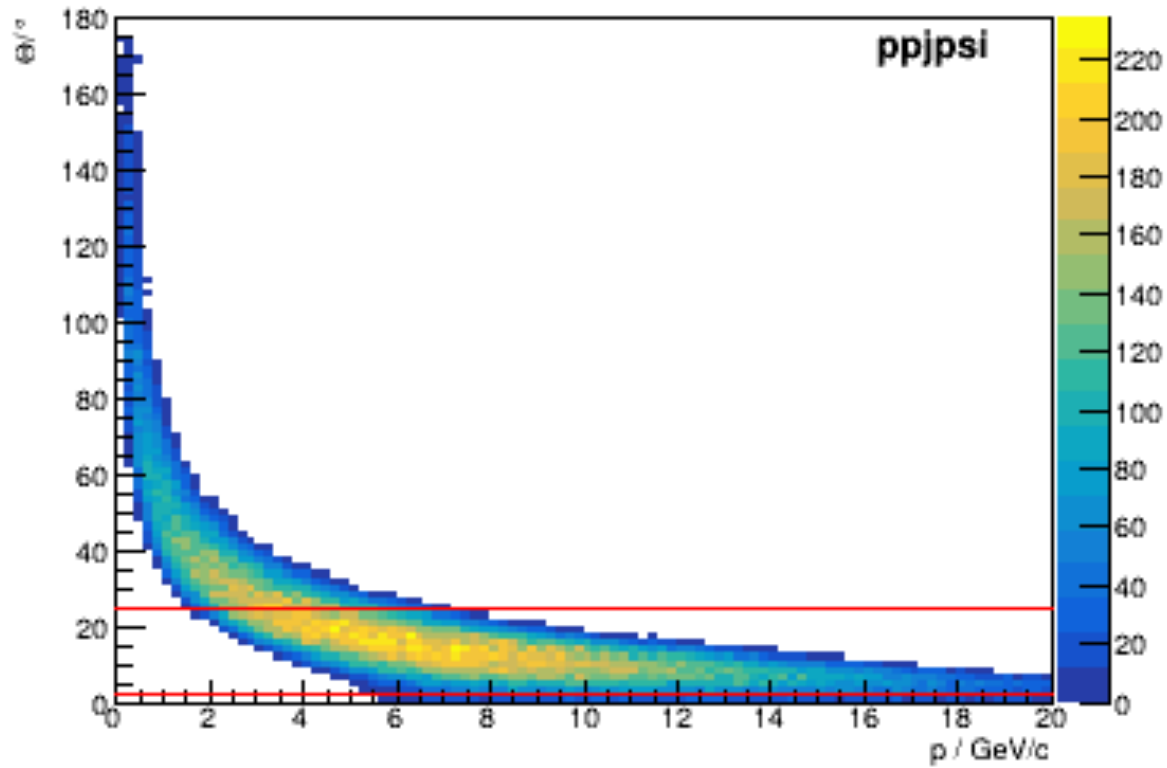
- threshold: $\sqrt{s} \geq 4.97346$ GeV
- Example beam is $T=25.0$ GeV
- 100k events



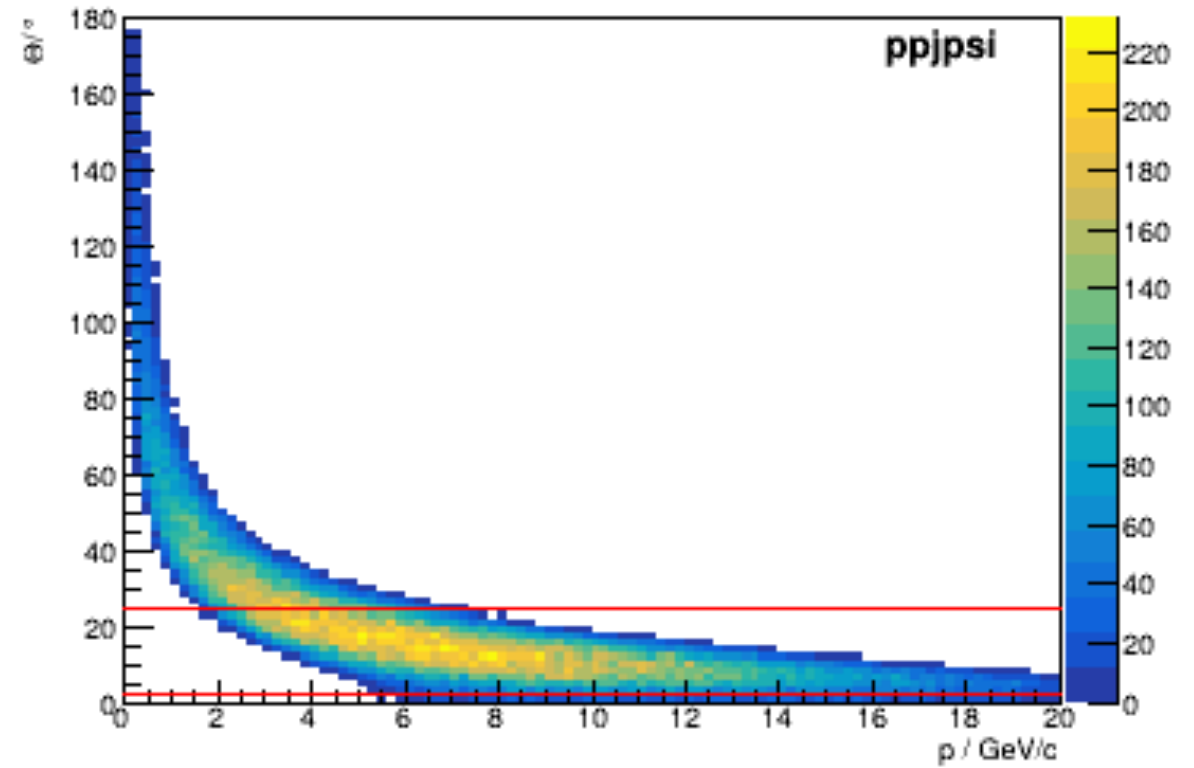
- Expected Acceptance (Pluto):
all 4 particles in $2.5^\circ < \theta < 25^\circ \rightarrow \underline{30.7\%}$
- Including tracking efficiency (Pluto):
90% random efficiency per particle and
 $p > 0.1$ GeV/c $\rightarrow \underline{18.0\%}$

electron & positron (Pluto)

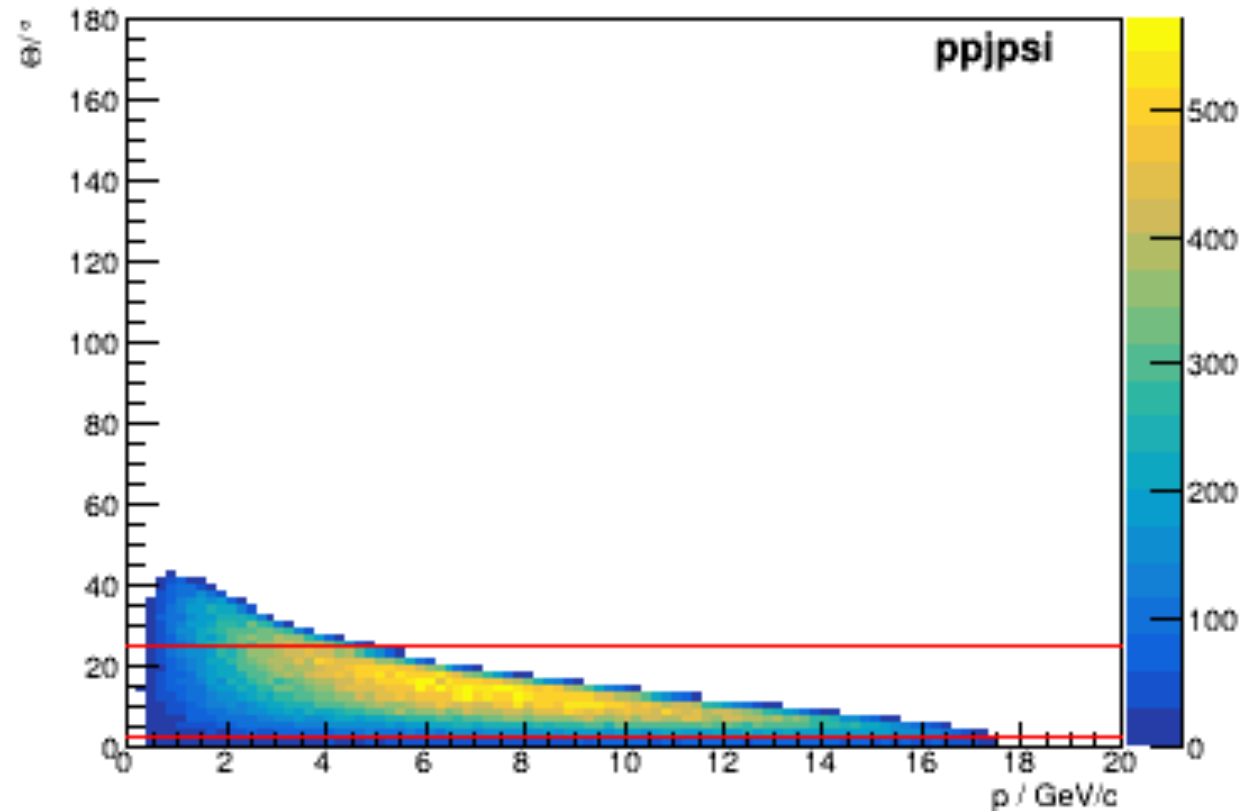
e^+ Theta-P distributions



e^- Theta-P distributions

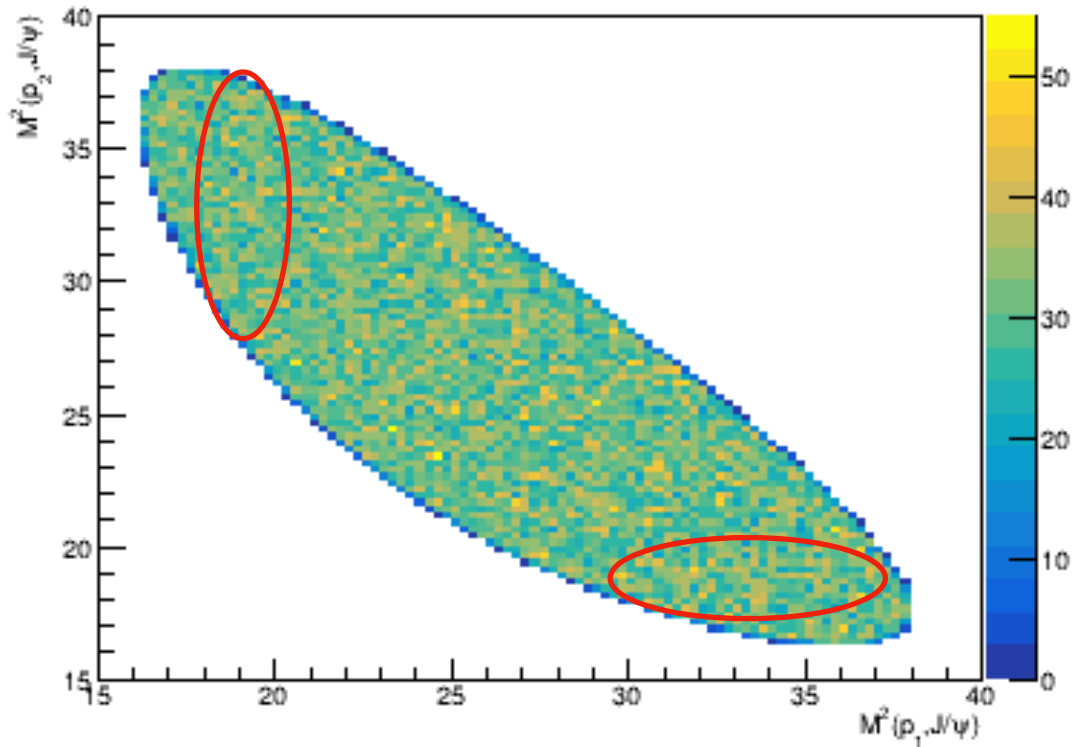


p Theta-P distributions

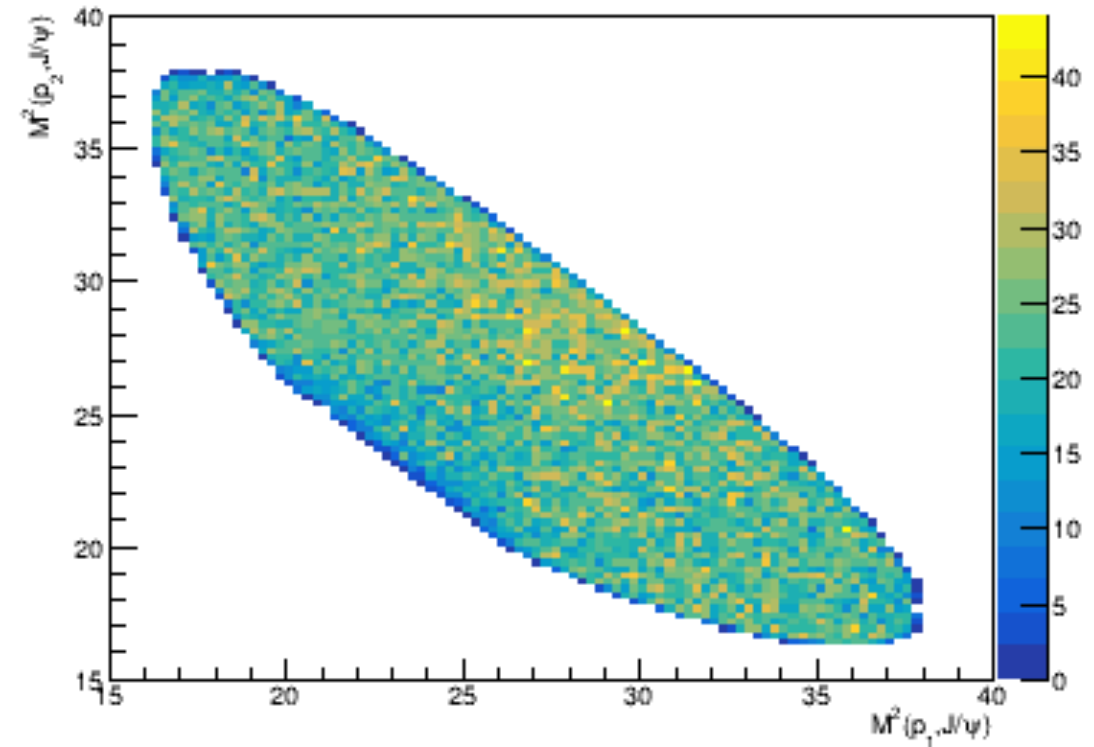


Dalitz Plot Acceptance

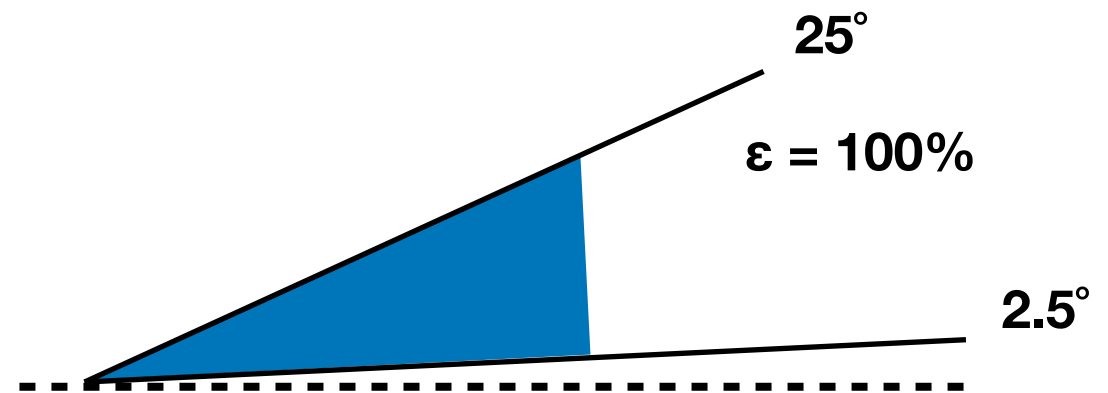
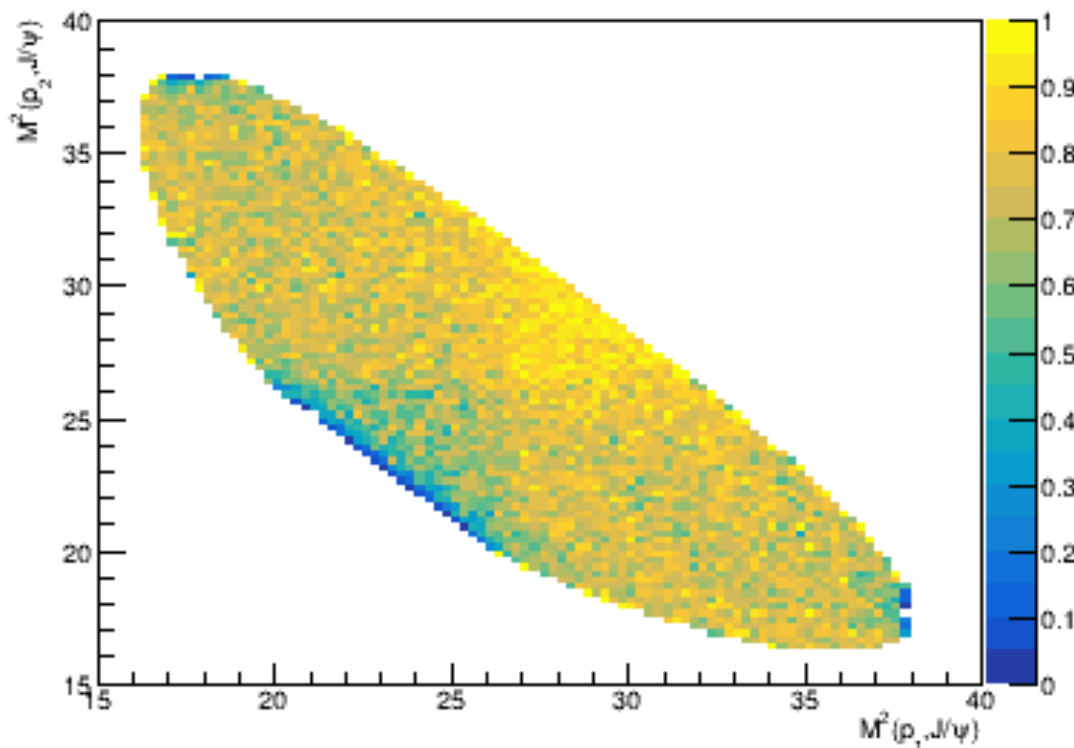
Dalitz Plot p p J/ψ (Pluto)



Dalitz Plot p p J/ψ (Pluto*Acceptance)

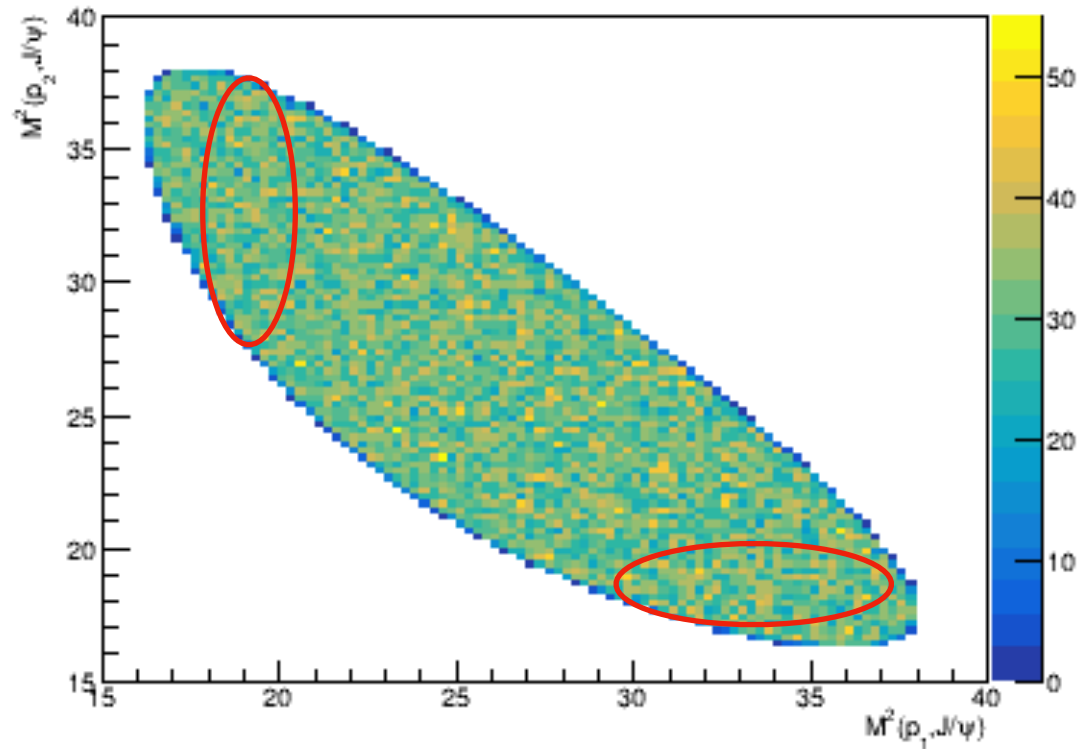


Dalitz Plot Acceptance p p J/ψ (Pluto)

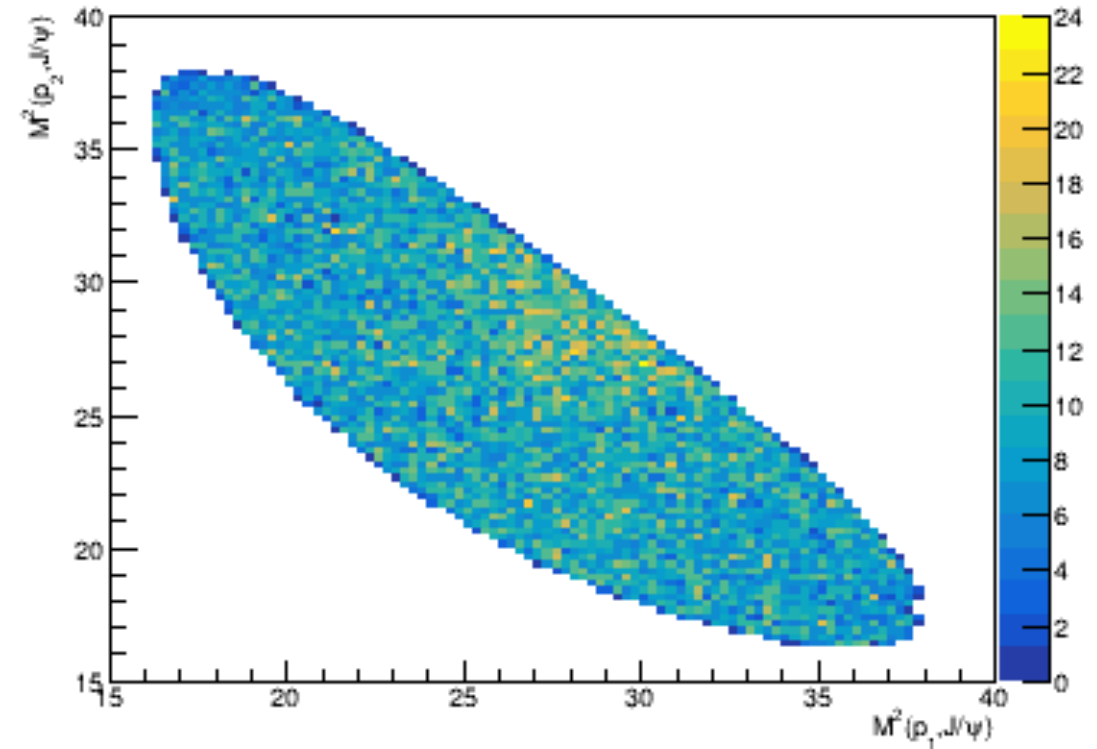


Dalitz Plot Acceptance

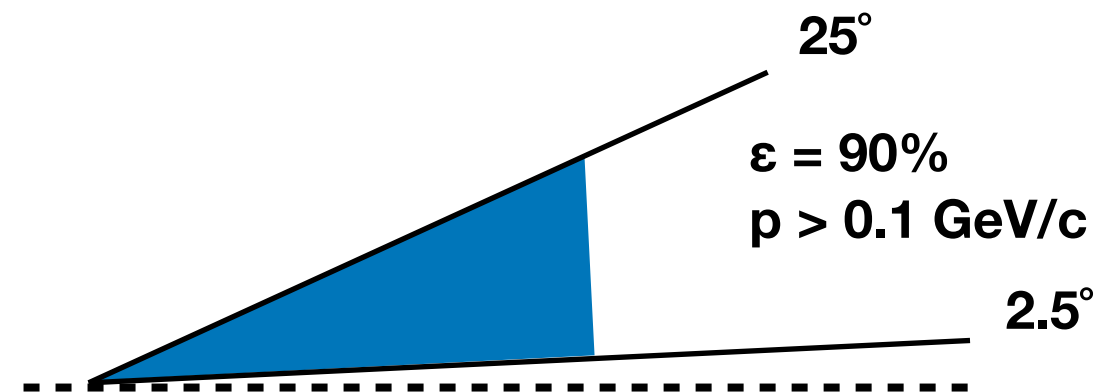
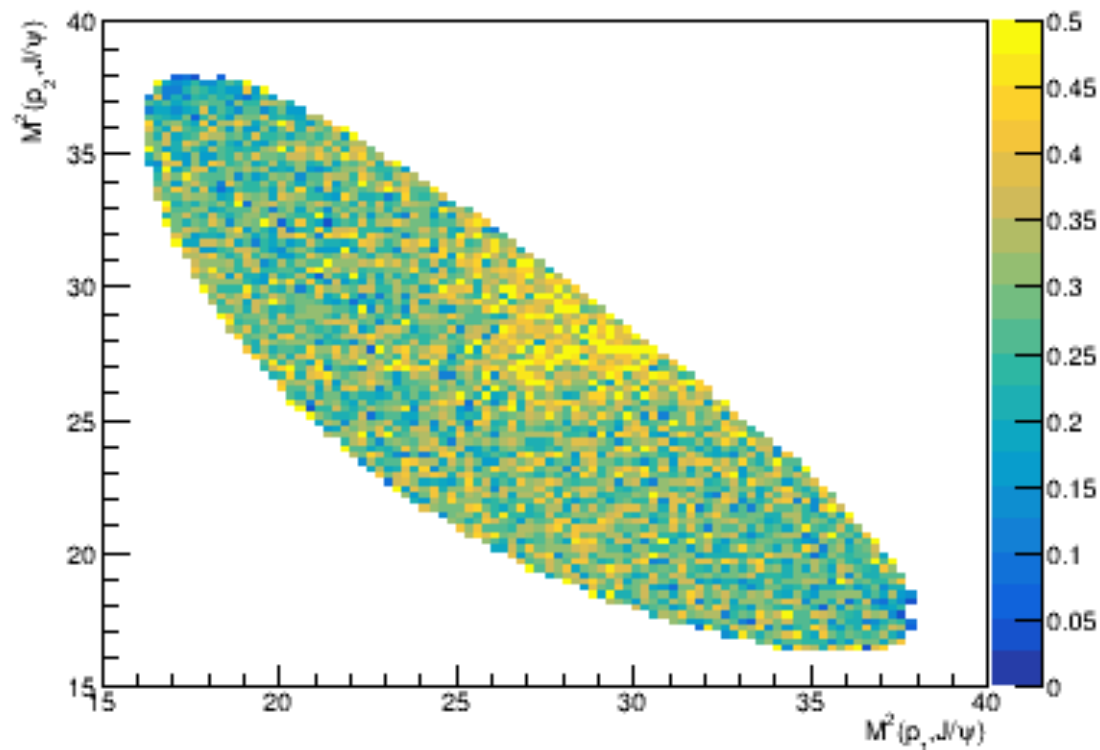
Dalitz Plot p p J/ψ (Pluto)



Dalitz Plot p p J/ψ (Pluto*Acceptance)



Dalitz Plot Acceptance p p J/ψ (Pluto)



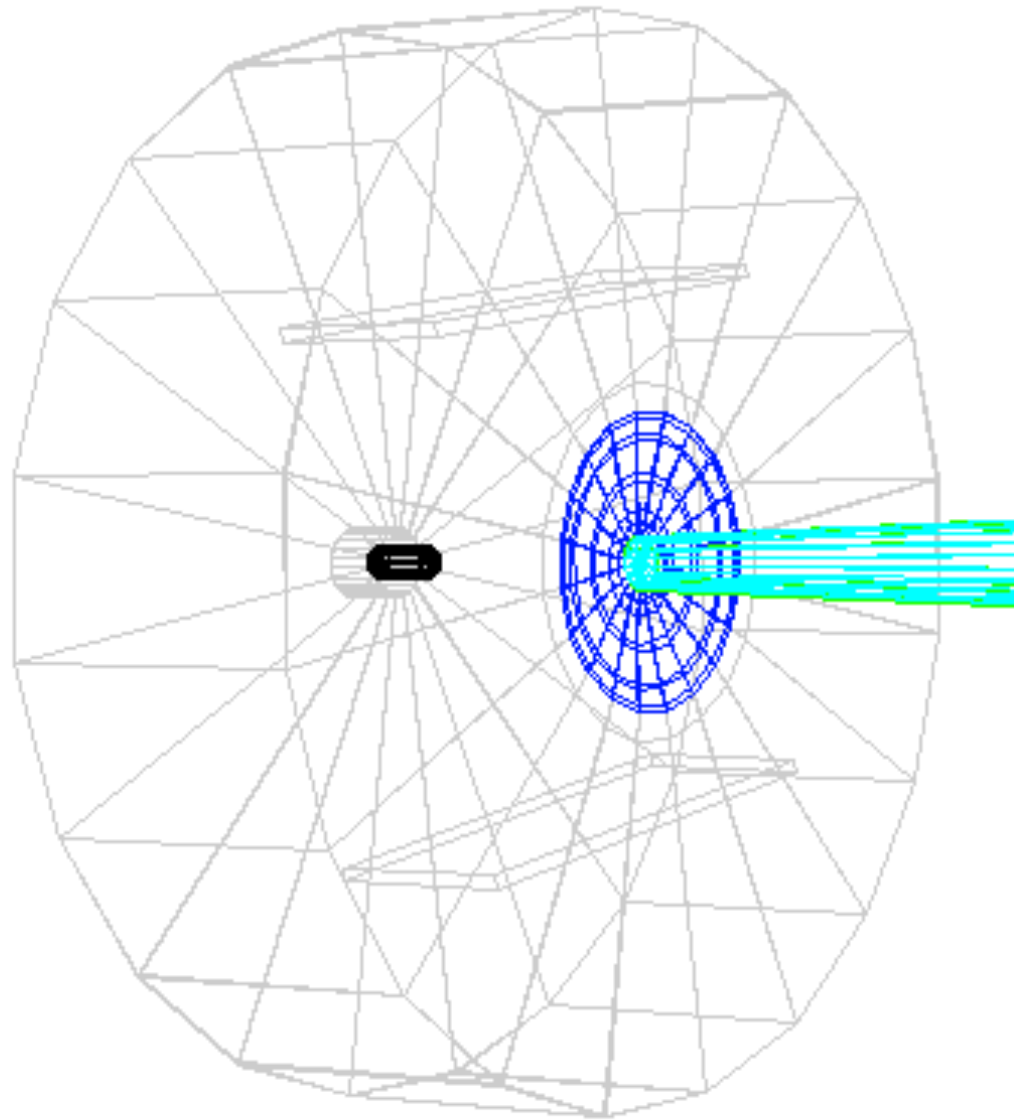
Liquid Hydrogen Target

- Master branch (Nov. 7 '24), (Merge Request [!1869](#))
- Adds default hydrogen target density (CbmTarget)
- Add support to pass custom densities (CbmTransport, CbmTransportConfig)
- Actual settings in the json config:

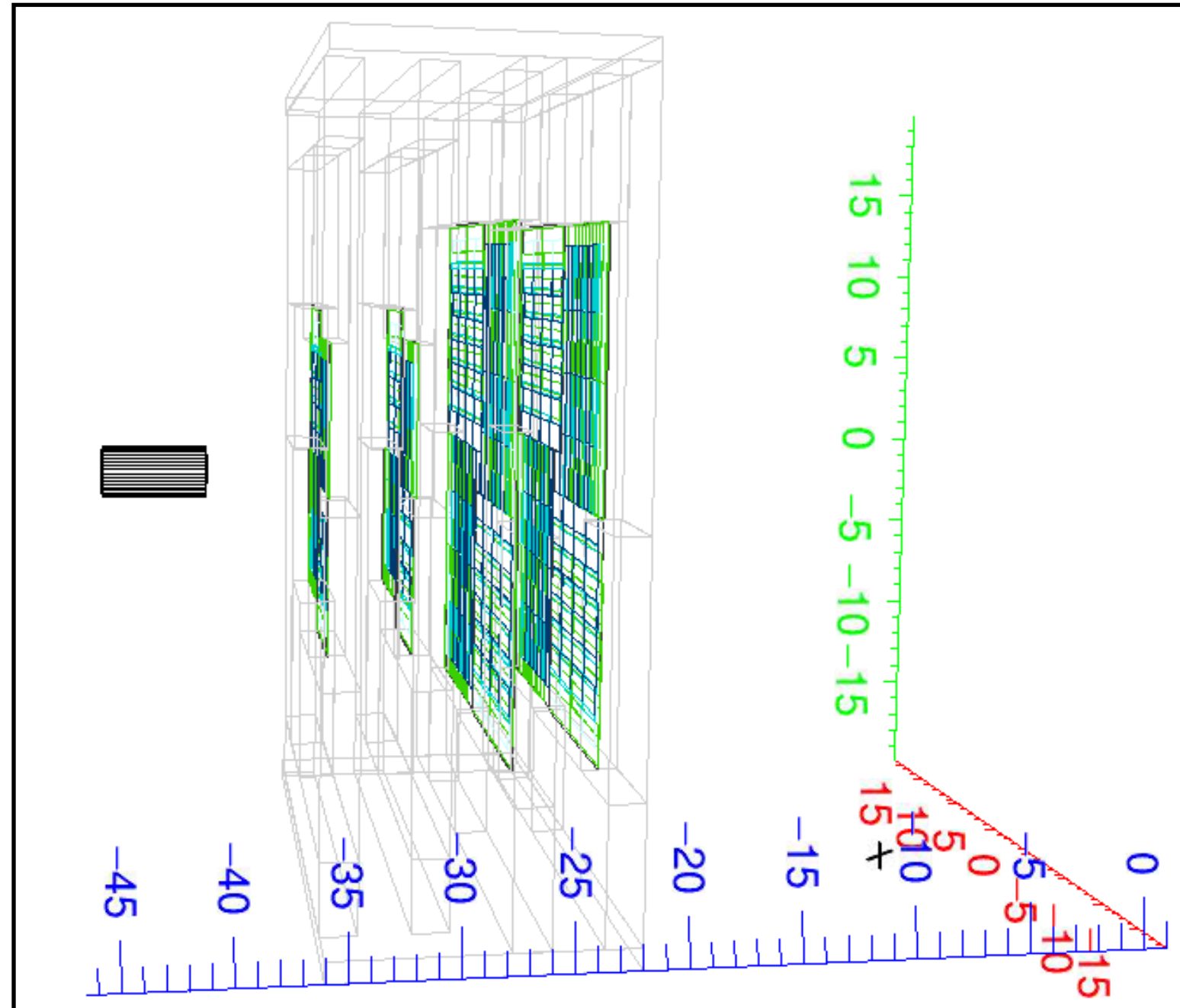
```
"target": {  
  "material": "H",  
  "thickness": 5.0,  
  "diameter": 2.5,  
  "position": {  
    "x": 0.0,  
    "y": 0.0,  
    "z": -44.0  
  },  
  "rotation.y": 0.0,  
  "density": 0.07085  
},
```

Geometry of the LH Target

(black)



Volume "pipe*/pipevac1_0/Target"



Simulation chain

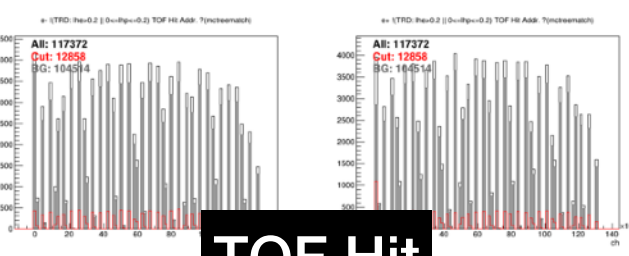
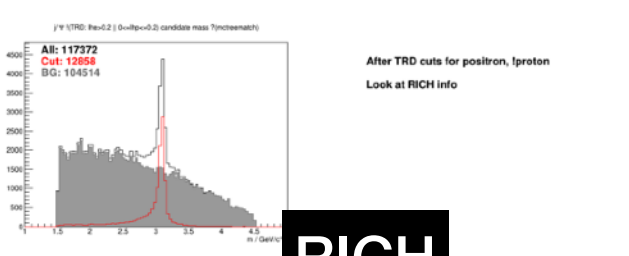
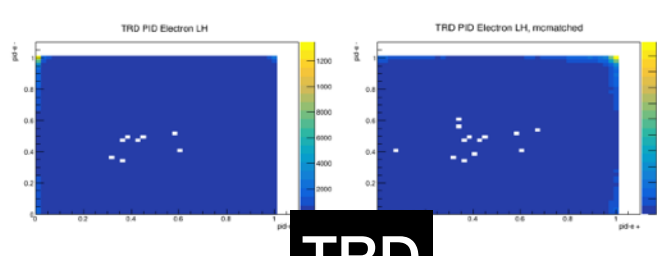
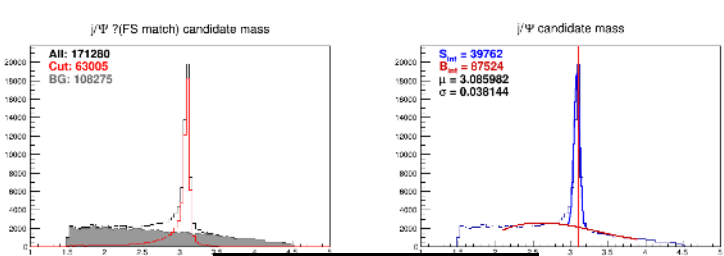
- CbmRoot master from Oct 14. 2024 (tag: dev_2024_42) plus liquid Hydrogen target (MR [!1869](#))
- Virgo cluster: vae23.hpc (Debian10)
- json configuration files & production macros
- Simulation, digitization & reconstruction

```
"geometry": {  
  "baseSetup": "sis100_electron",  
  "magneticField": {  
    "tag": "v22c",  
    "scale": 1.0,  
    "position": {  
      "x": 0.0,  
      "y": 0.0,  
      "z": 0.0  
    }  
  },  
  "magnet": "v22a",  
  "pipe": "v21d:v21h",  
  "mvd": "v20d_tr",  
  "sts": "v22d",  
  "rich": "v23a",  
  "trd": "v20b_1e",  
  "tof": "v21a_1e",  
  "psd": "v23a",  
  "fsd": "v23h",  
  "platform": "v22b"  
},  
"subsystems": {
```

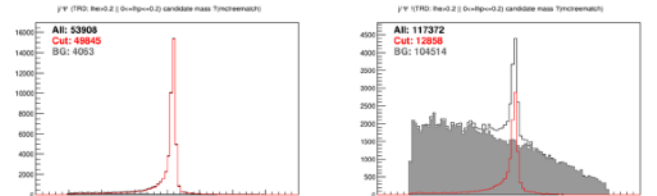
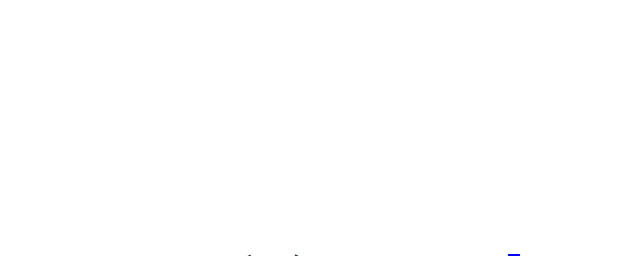
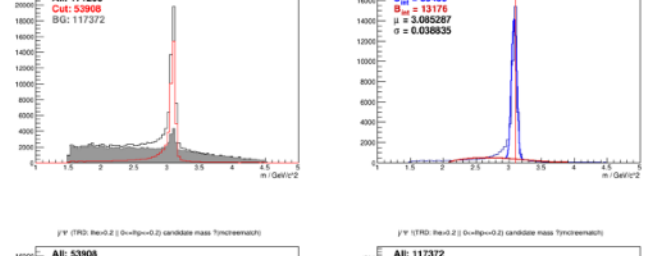
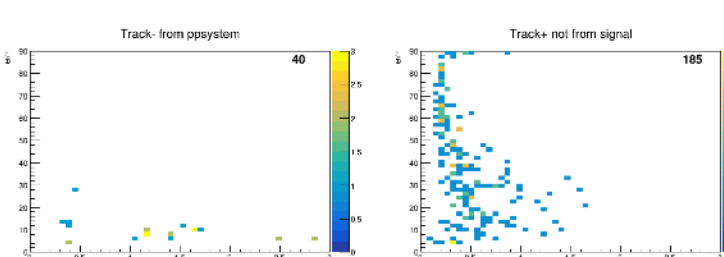
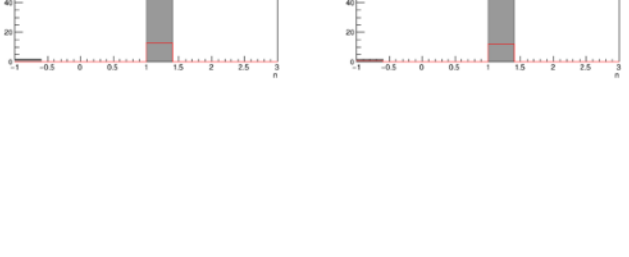
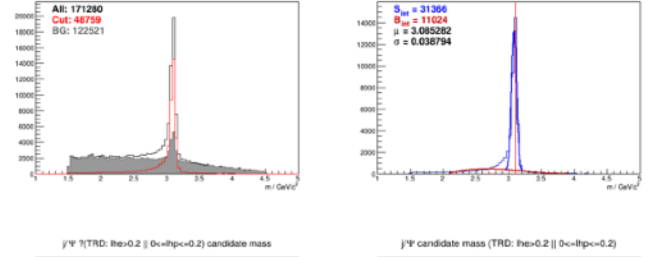
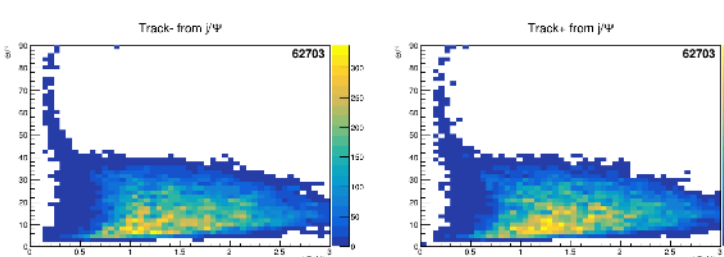
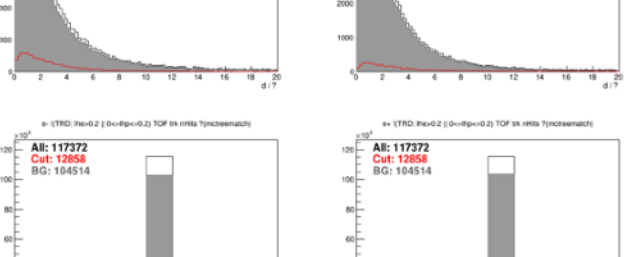
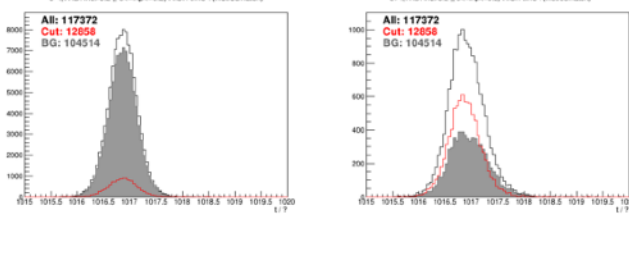
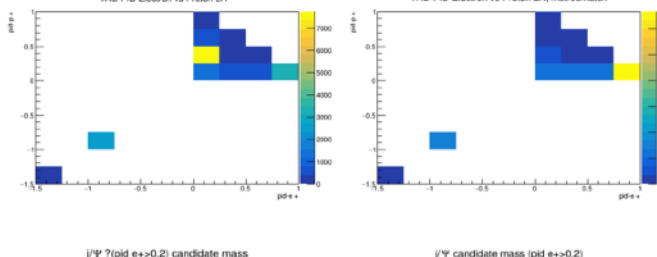
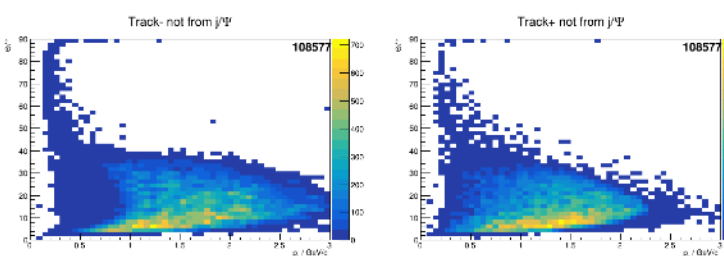
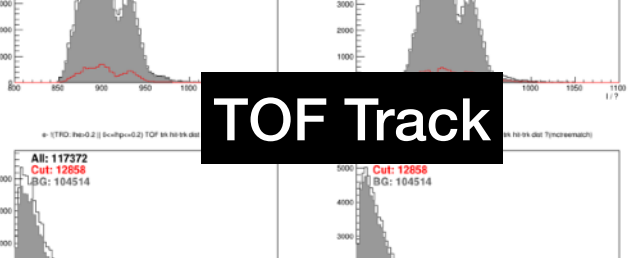
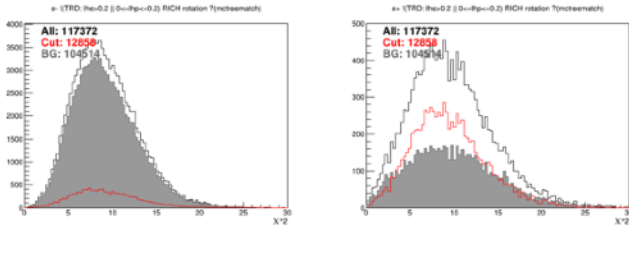
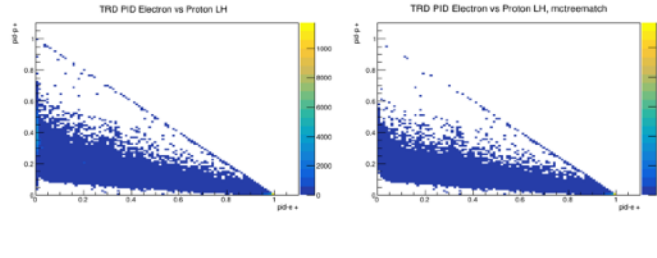
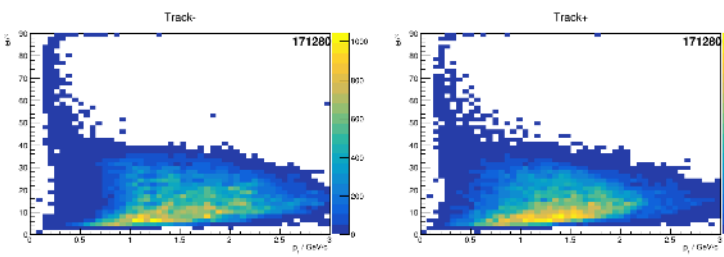
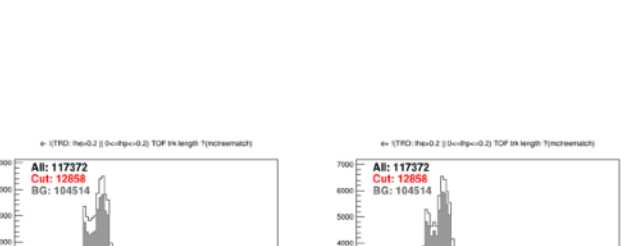
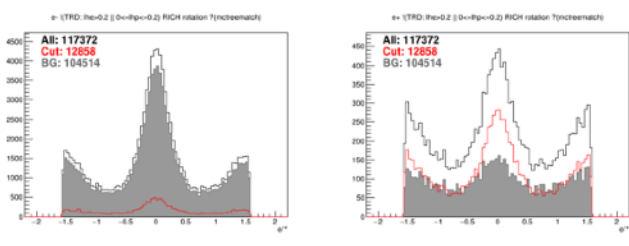
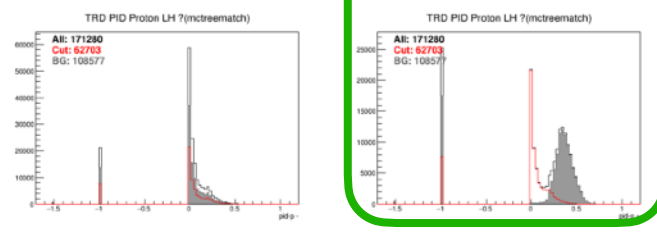
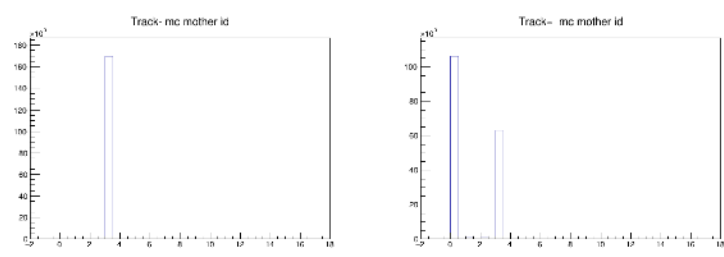
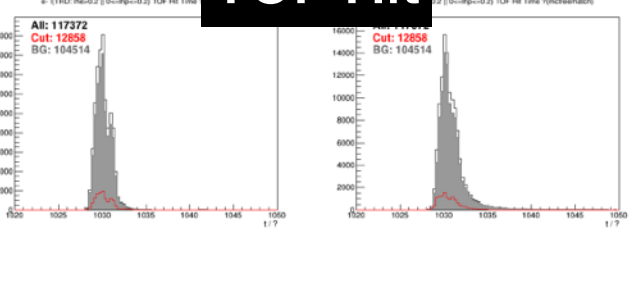
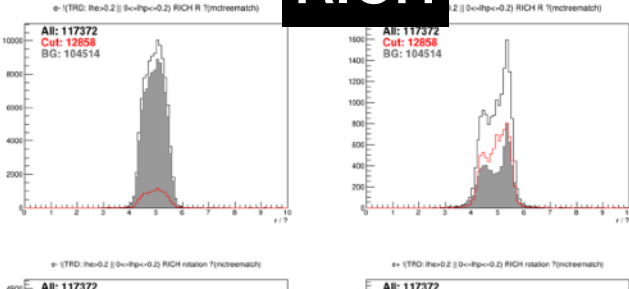
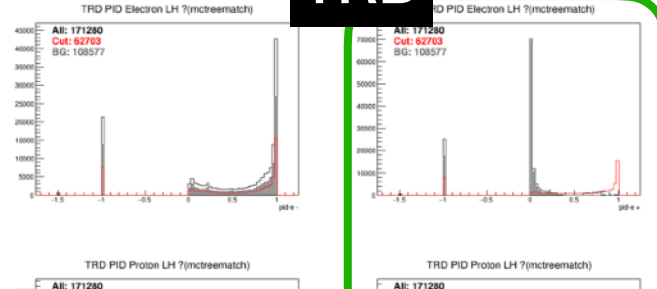
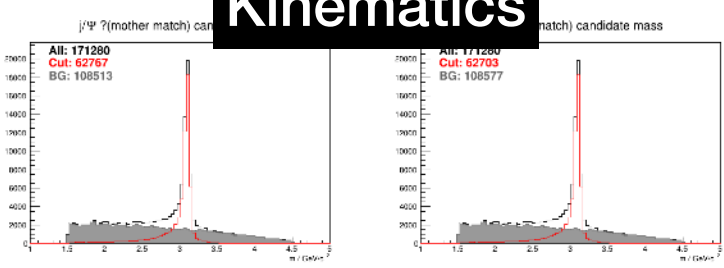

Analysis stage

- Custom simple candidate
- Simple tuple tool
- Tools to encapsulate tuple output
- 10k Events
- Combinatorics
- $e^+ e^-$ composite (J/ψ) candidate:
mass in $(1.5, 4.5) \text{ GeV}/c^2$
- store decay chain candidates
& Detector info

X -empty-	mcidx	d0rchtime	d1mcidx	d1tofrkdist	d2mcvphi	d2d0rchaxa	d2d1pt	d2d1tohitadr
Y -empty-	d0px	d0tohitx	d1mcsmatch	d1tofrknhits	d2mcq	d2d0rchaxb	d2d1m	d2d1tohittime
Z -empty-	d0py	d0tohitzy	d1gbpx	d1mcpz	d2mcpid	d2d0rchaphi	d2d1q	d2d1tohitdtime
Scan box	d0pz	d0tohitz	d1gbpy	d1mcpy	d2mcmothid	d2d0rchchi2	d2d1pdg	d2d1tofrklen
E -empty-	d0e	d0tohitdx	d1gbpz	d1mcpz	d2mcidx	d2d0rchtime	d2d1mcidx	d2d1tofrkdist
E -empty-	d0p	d0tohitdy	d1gbpmag	d1mcpmag	d2d0px	d2d0tohitx	d2d1mcsmatch	d2d1tofrknhits
E -empty-	d0iht	d0tohitdz	d1gbpperp	d1mcppperp	d2d0py	d2d0tohitzy	d2d1gbpx	d2d1mcpz
E -empty-	d0phi	d0tohitdxy	d1gbpht	d1mcpht	d2d0pz	d2d0tohitz	d2d1gbpy	d2d1mcpy
E -empty-	d0pt	d0tohitadr	d1gbpphi	d1mcpphi	d2d0e	d2d0tohitdx	d2d1gbpz	d2d1mcpz
E -empty-	d0m	d0tohitdtime	d1gbvx	d1mcvx	d2d0p	d2d0tohitdy	d2d1gbpmag	d2d1mcpmag
E -empty-	d0q	d0tohitdtime	d1gbvy	d1mcvy	d2d0t	d2d0tohitdz	d2d1gbpperp	d2d1mcppperp
E -empty-	d0pdg	d0tofrklen	d1gbvz	d1mcvz	d2d0phi	d2d0tohitdxy	d2d1gbpht	d2d1mcpht
E -empty-	d0mcidx	d0tofrkdist	d1gbvmag	d1mcmvmag	d2d0pt	d2d0tohitadr	d2d1gbpphi	d2d1mcpphi
E -empty-	d0mcsmatch	d0tofrknhits	d1gbvpperp	d1mcpvpperp	d2d0m	d2d0tohitdtime	d2d1gbvx	d2d1mcvx
E -empty-	d0gbpx	d0mcpz	d1gbvht	d1mcpvht	d2d0q	d2d0tohitdtime	d2d1gbvy	d2d1mcvy
px	d0gbpy	d0mcpy	d1gbvphi	d1mcpvphi	d2d0pdg	d2d0tofrklen	d2d1gbvz	d2d1mcvz
py	d0gbpz	d0mcpz	d1SisTrack	d1mq	d2d0mcidx	d2d0tofrkdist	d2d1gbvmag	d2d1mcmvmag
pz	d0gbpmag	d0mcpmag	d1trdeloss	d1mcpid	d2d0mcsmatch	d2d0tofrknhits	d2d1gbvpperp	d2d1mcpvpperp
e	d0gbpperp	d0mcppperp	d1trdpidhe	d1mcmothid	d2d0gbpx	d2d0mcpz	d2d1gbvht	d2d1mcpvht
p	d0gbpht	d0mcpht	d1trdpidhmu	d2px	d2d0gbpy	d2d0mcpy	d2d1gbvphi	d2d1mcpvphi
ht	d0gbpphi	d0mcpphi	d1trdpidphi	d2py	d2d0gbpz	d2d0mcpz	d2d1SisTrack	d2d1mcq
phi	d0gbvx	d0mcpvx	d1trdpidhk	d2pz	d2d0gbpmag	d2d0mcpmag	d2d1trdeloss	d2d1mcpid
pt	d0gbvy	d0mcpvy	d1trdpidhp	d2e	d2d0gbpperp	d2d0mcppperp	d2d1trdpidhe	d2d1mcmothid
m	d0gbvz	d0mcpvz	d1rchcx	d2p	d2d0gbpht	d2d0mcpht	d2d1trdpidhmu	MMpx
q	d0gbvmag	d0mcmvmag	d1rchcy	d2t	d2d0gbpphi	d2d0mcpphi	d2d1trdpidphi	MMpy
mcpz	d0gbvpperp	d0mcpvpperp	d1rchrad	d2phi	d2d0gbvx	d2d0mcpvx	d2d1trdpidhk	MMpz
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mcpz	d0gbvphi	d0mcpvphi	d1rchaxb	d2m	d2d0gbvz	d2d0mcpvz	d2d1rchcx	MMp
mcpmag	d0iSisTrack	d0mcq	d1rchaphi	d2q	d2d0gbvmag	d2d0mcmvmag	d2d1rchcy	MMht
mcppperp	d0trdeloss	d0mcpid	d1rchchi2	d2mcpz	d2d0gbvpperp	d2d0mcpvpperp	d2d1rchrad	MMphi
mcpht	d0trdpidhe	d0mcmothid	d1rchtime	d2mcpy	d2d0gbvht	d2d0mcpvht	d2d1rchaxa	MMpt
mcpphi	d0trdpidhmu	d1px	d1tohitx	d2mcpz	d2d0gbvphi	d2d0mcpvphi	d2d1rchaxb	MMm
mcpvx	d0trdpidphi	d1py	d1tohitzy	d2mcpmag	d2d0gbvx	d2d0mcpvx	d2d1rchaphi	mclsmatch
mcvy	d0trdpidhk	d1pz	d1tohitz	d2mcppperp	d2d0gbvy	d2d0mcpvy	d2d1rchchi2	mcmothermatch
mcvz	d0trdpidhp	d1e	d1tohitdx	d2mcpht	d2d0gbvz	d2d0mcpvz	d2d1rchtime	mcreematch
mcmvmag	d0rchcx	d1p	d1tohitdxy	d2mcpphi	d2d0trdpidhmu	d2d0trdeloss	d2d1tohitx	d2mclsmatch
mcpvpperp	d0rchcy	d1t	d1tohitdz	d2mcpvx	d2d0trdpidphi	d2d0trdpidhe	d2d1tohitzy	d2mcmothermatch
mcpvht	d0rchrad	d1phi	d1tohitdxy	d2mcpvy	d2d0trdpidhk	d2d0trdpidhp	d2d1tohitx	d2mcmothermatch
mcpvphi	d0rchaxa	d1pt	d1tohitadr	d2mcpvz	d2d0trdpidhp	d2d0trdpidhp	d2d1tohitdx	d2mcmothermatch
mcq	d0rchaxb	d1m	d1tohitdtime	d2mcmvmag	d2d0trdeloss	d2d0trdeloss	d2d1tohitdy	d2mcmothermatch
mcpid	d0rchaphi	d1q	d1tohitdtime	d2mcpvpperp	d2d0rchcy	d2d0rchcy	d2d1tohitdz	d2mcmothermatch
mcmothid	d0rchchi2	d1pdg	d1tofrklen	d2mcpvht	d2d0rchrad	d2d0rchrad	d2d1tohitdxy	d2mcmothermatch



Kinematics



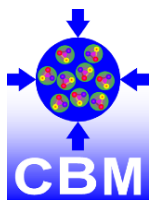
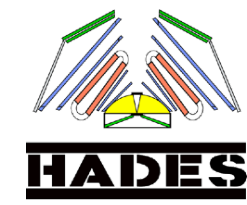
TRD

RICH

TOF Hit

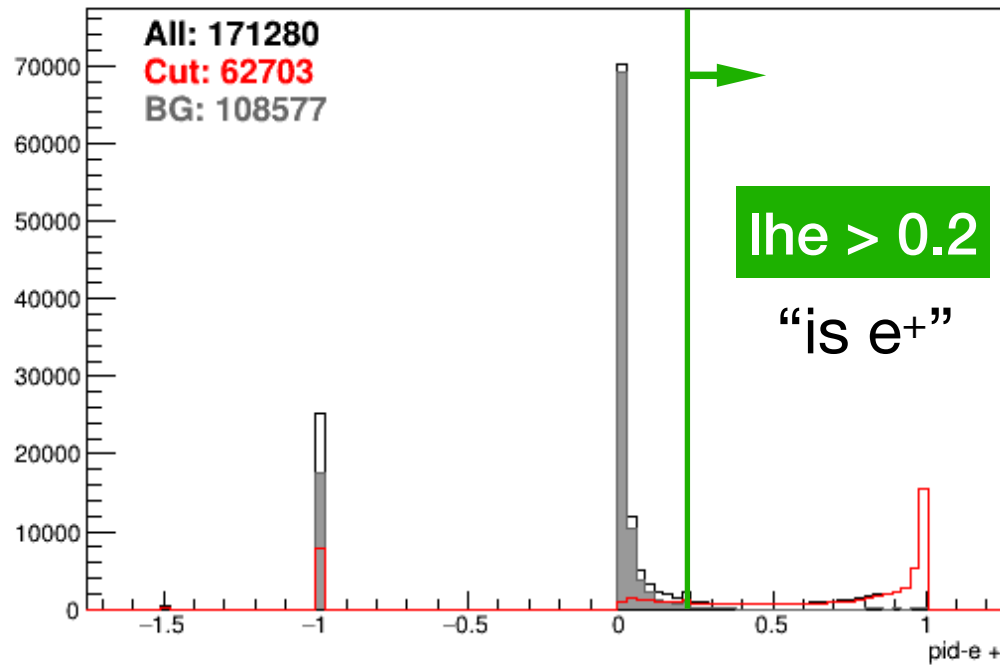
TOF Track

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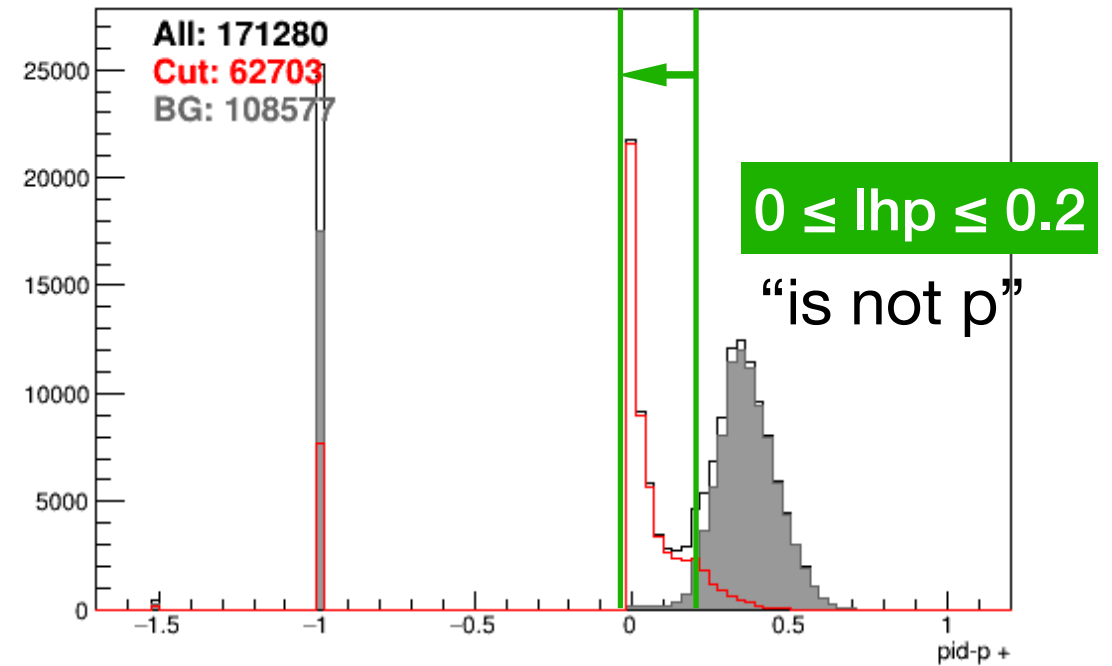
TRD PID for e/p separation

TRD PID Electron LH ?(mctreematch)

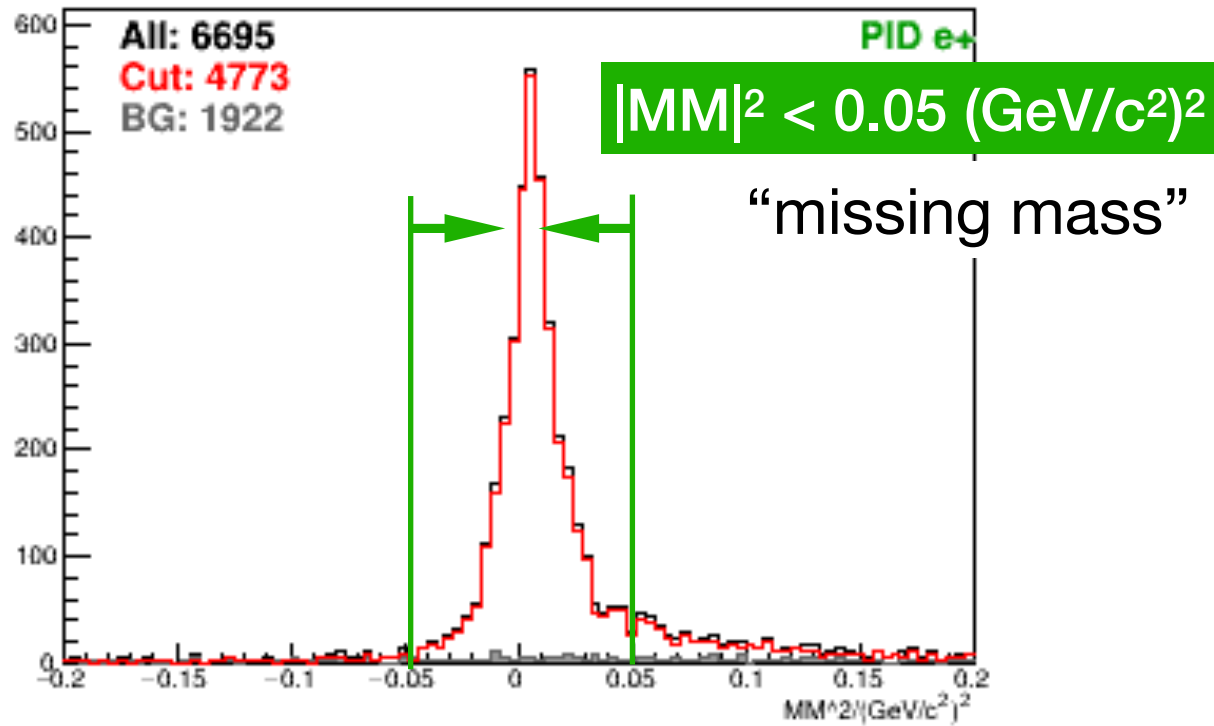


OR

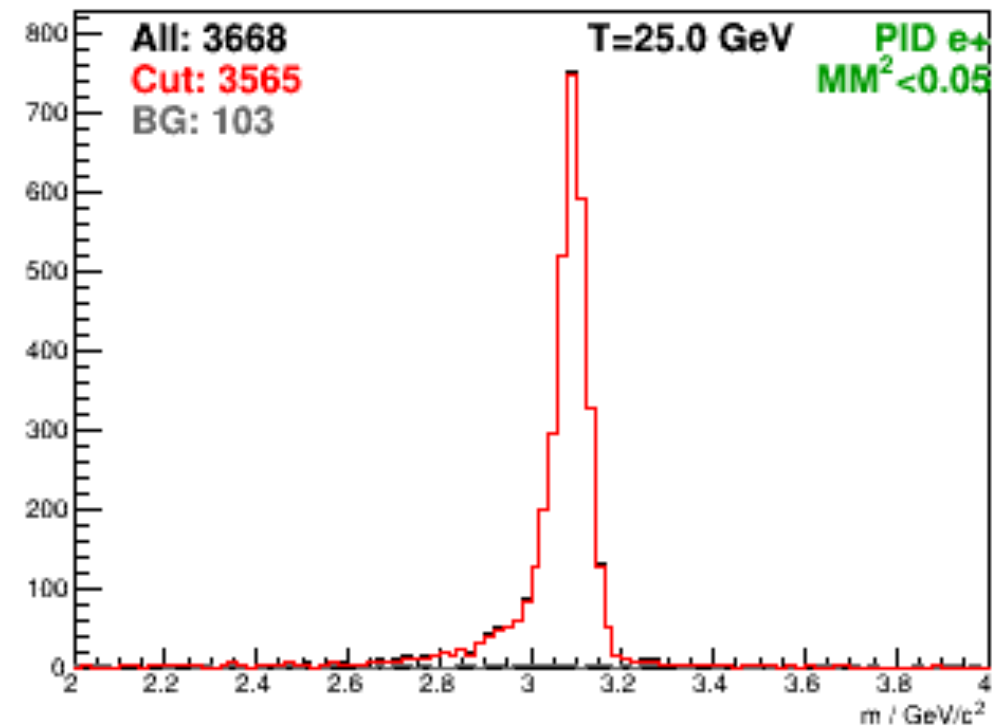
TRD PID Proton LH ?(mctreematch)



MM² ?(mctreematch)



J/ψ ?(MC tree match) candidate mass

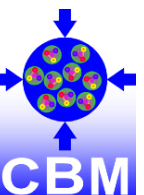
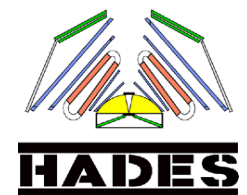


"PID e⁺": $l_{he} > 0.2$ OR $0 \leq l_{hp} \leq 0.2$

10k Events

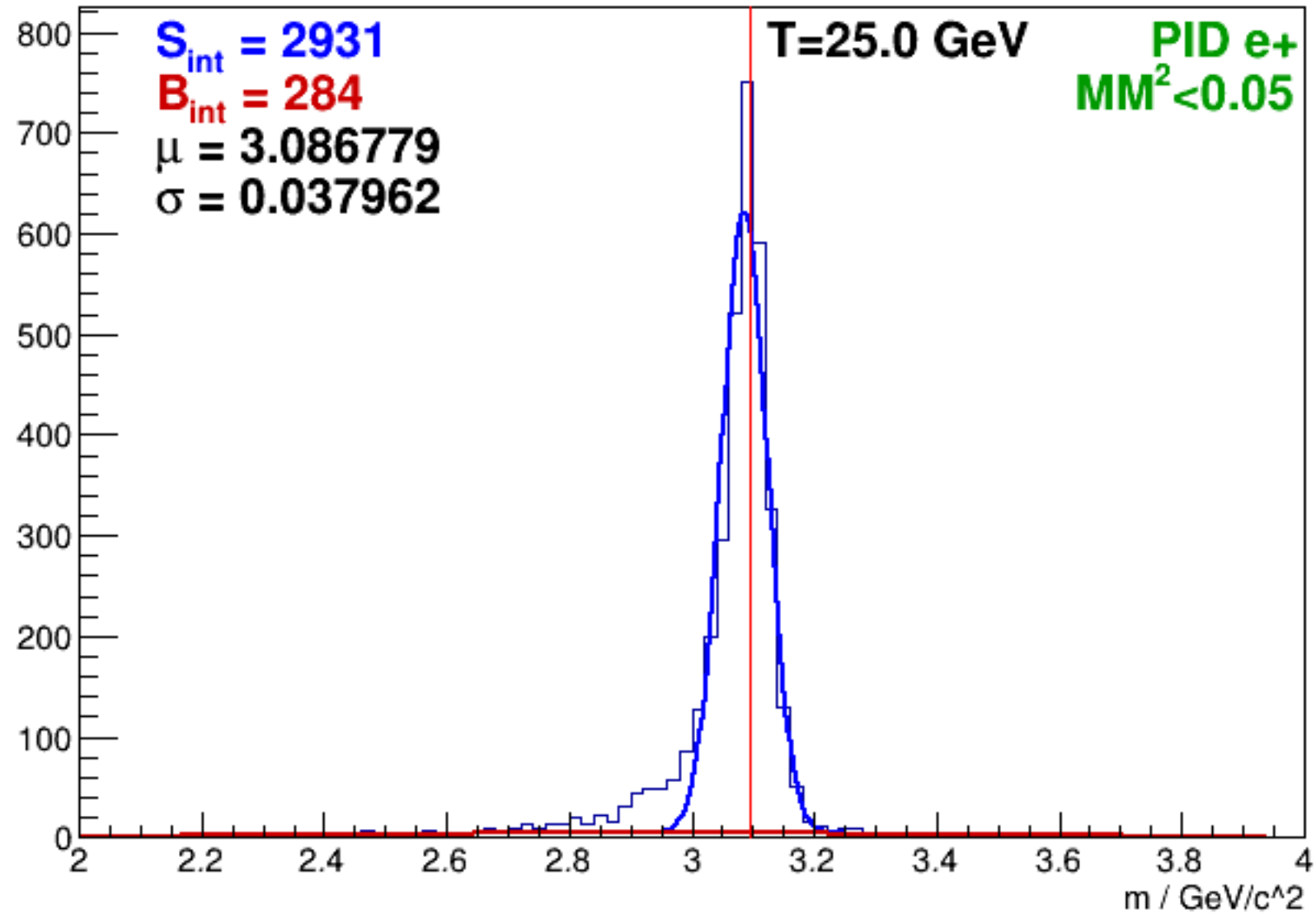


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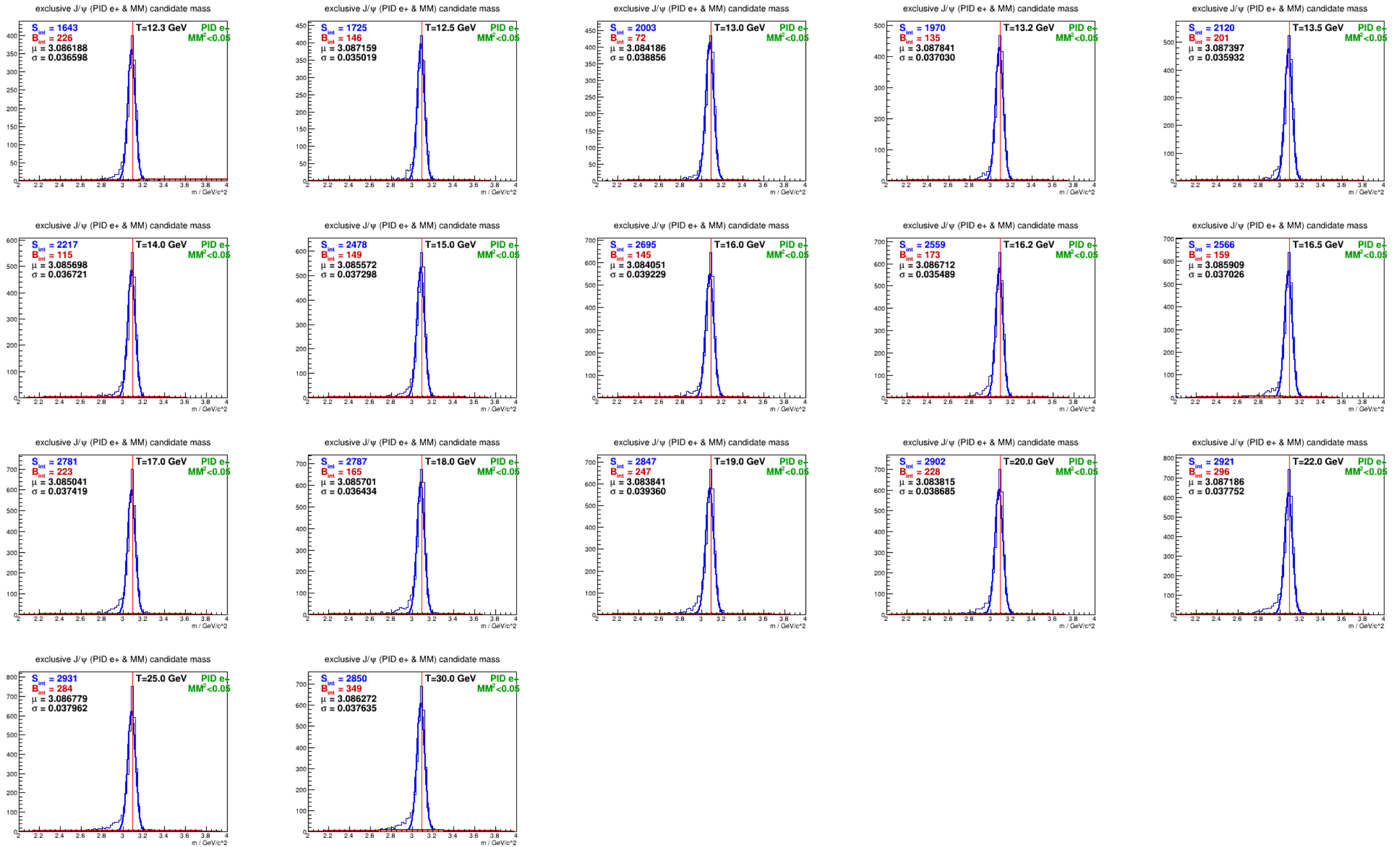


Simple Gauss + Pol2 Fit

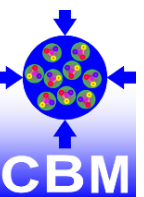
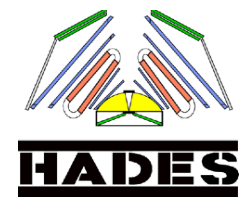
exclusive J/ ψ (PID e+ & MM) candidate mass



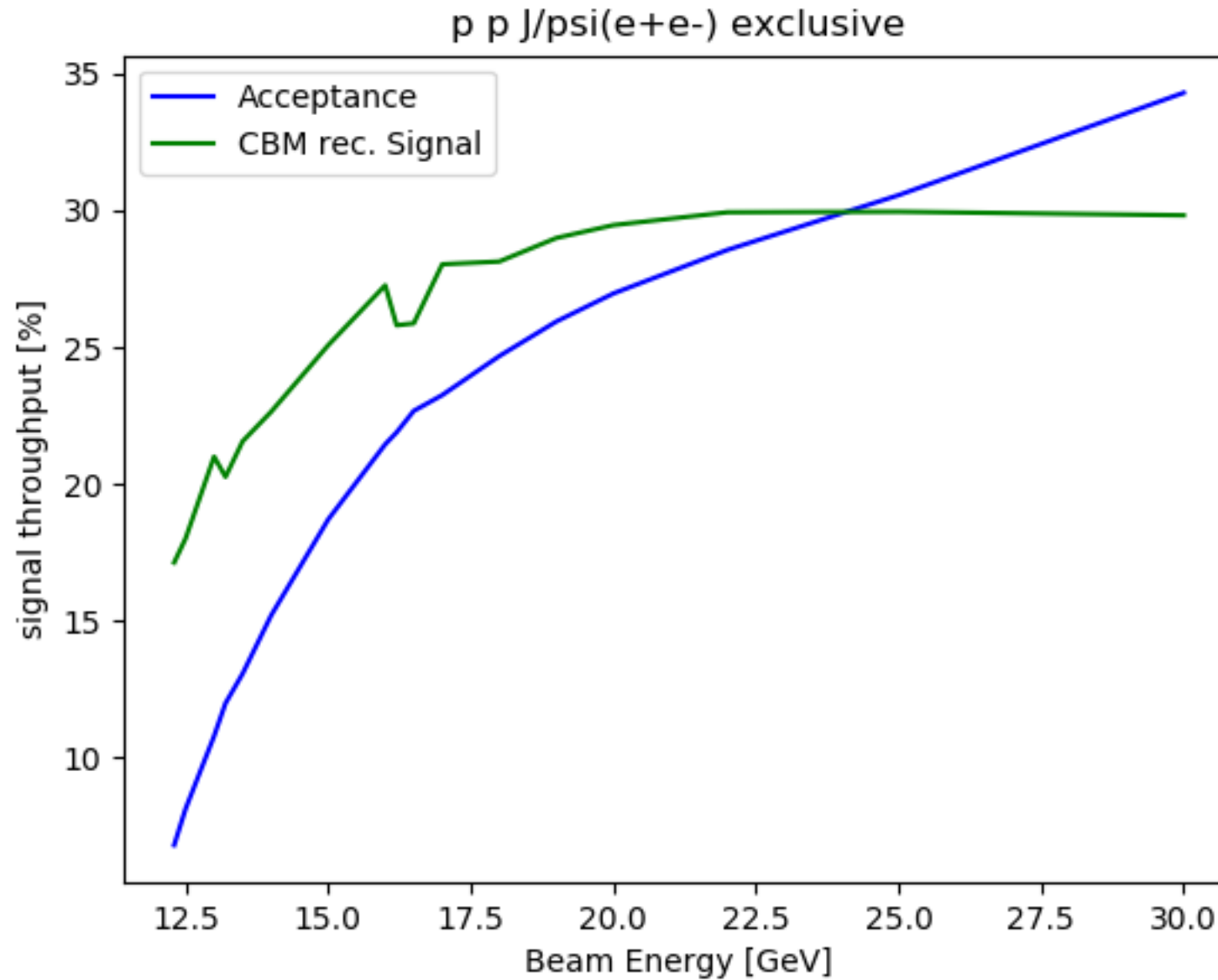
Various beam energy points



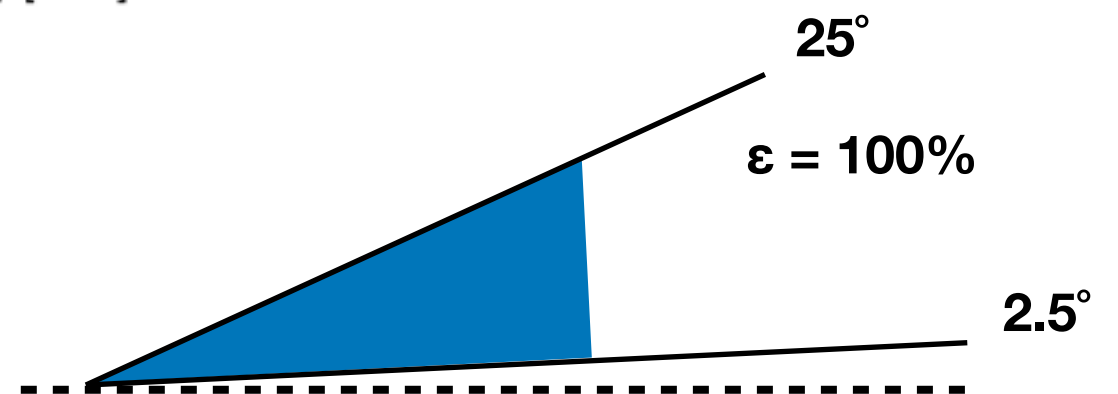
R. Kliemt



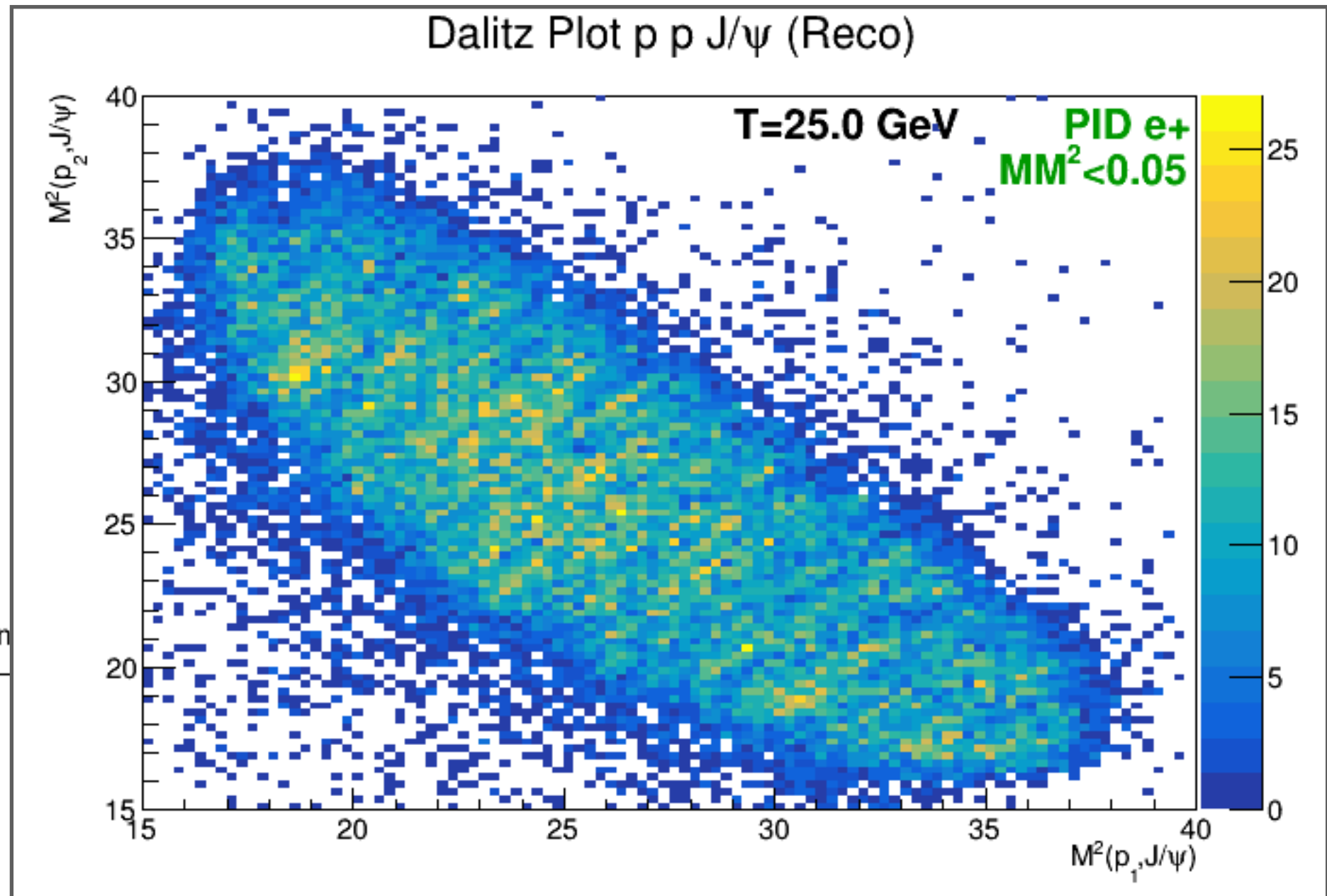
First Result



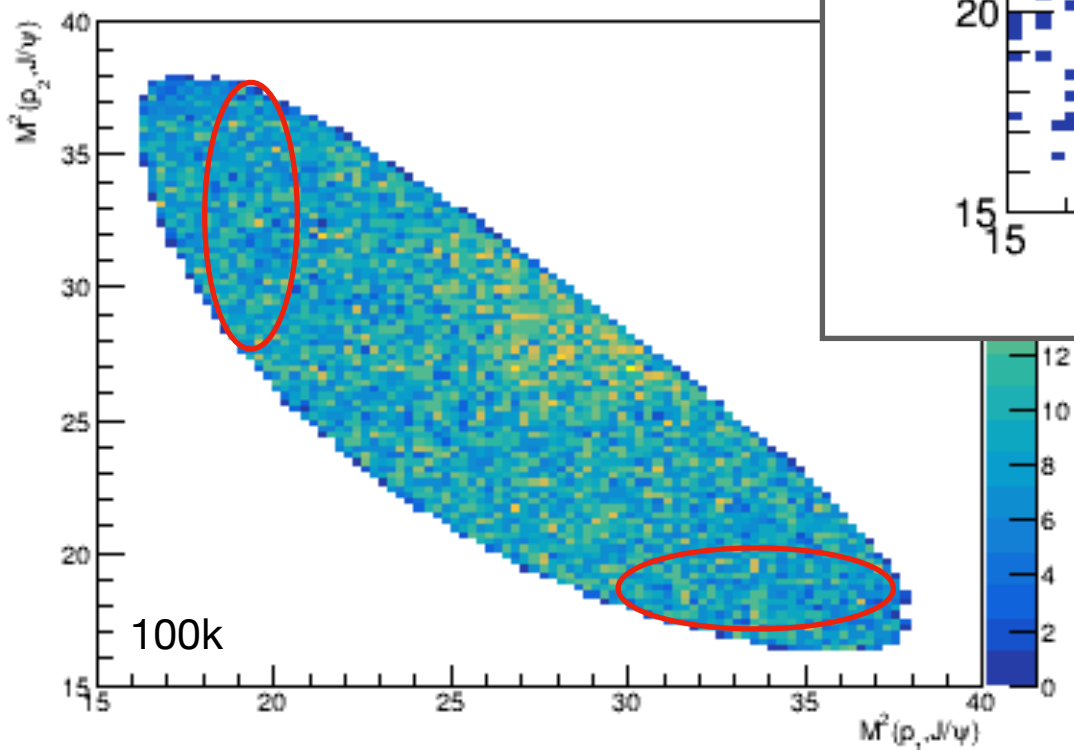
Simple acceptance matches
“signal only” reconstruction



Dalitz Plot Acceptance

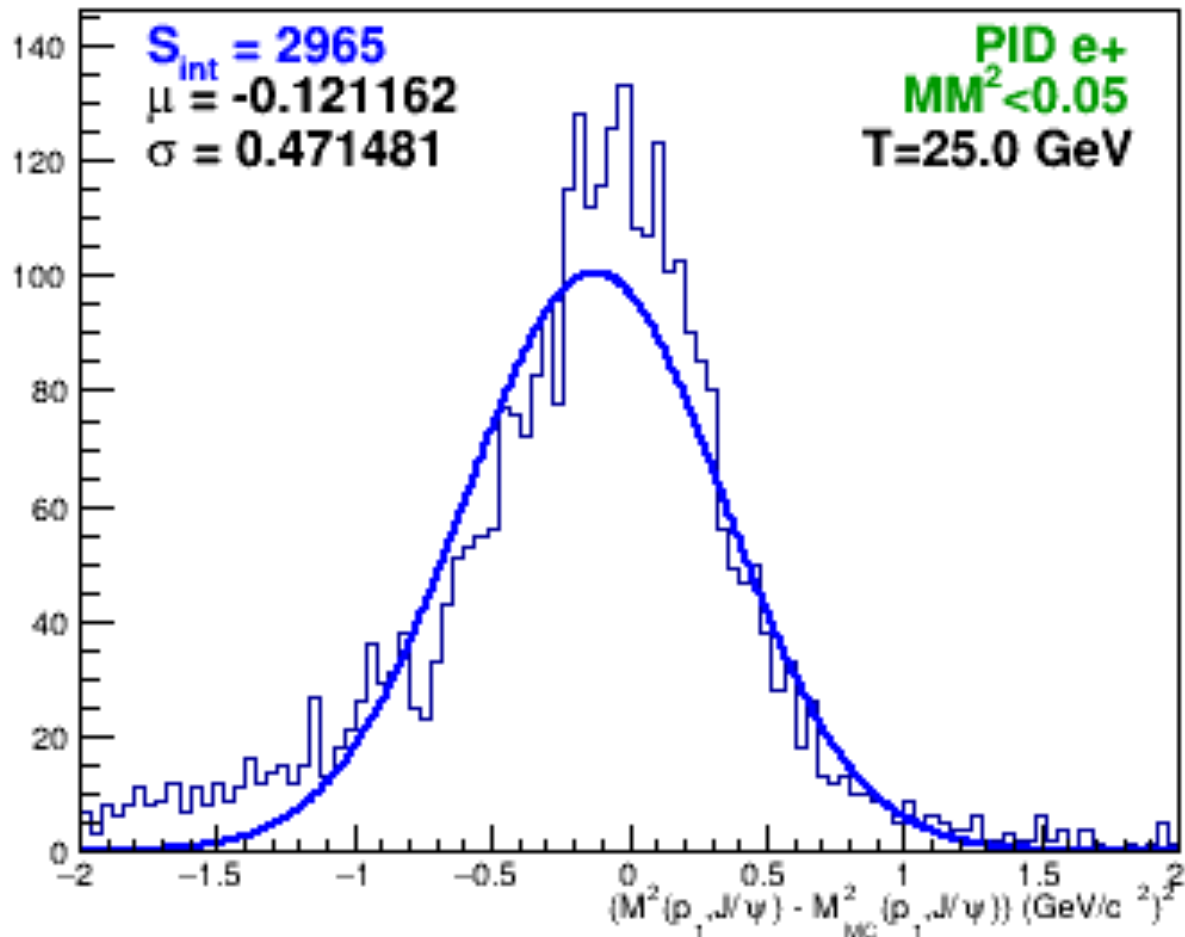


Dalitz Plot $p p J/\psi$ (Pluto*Acceptance)

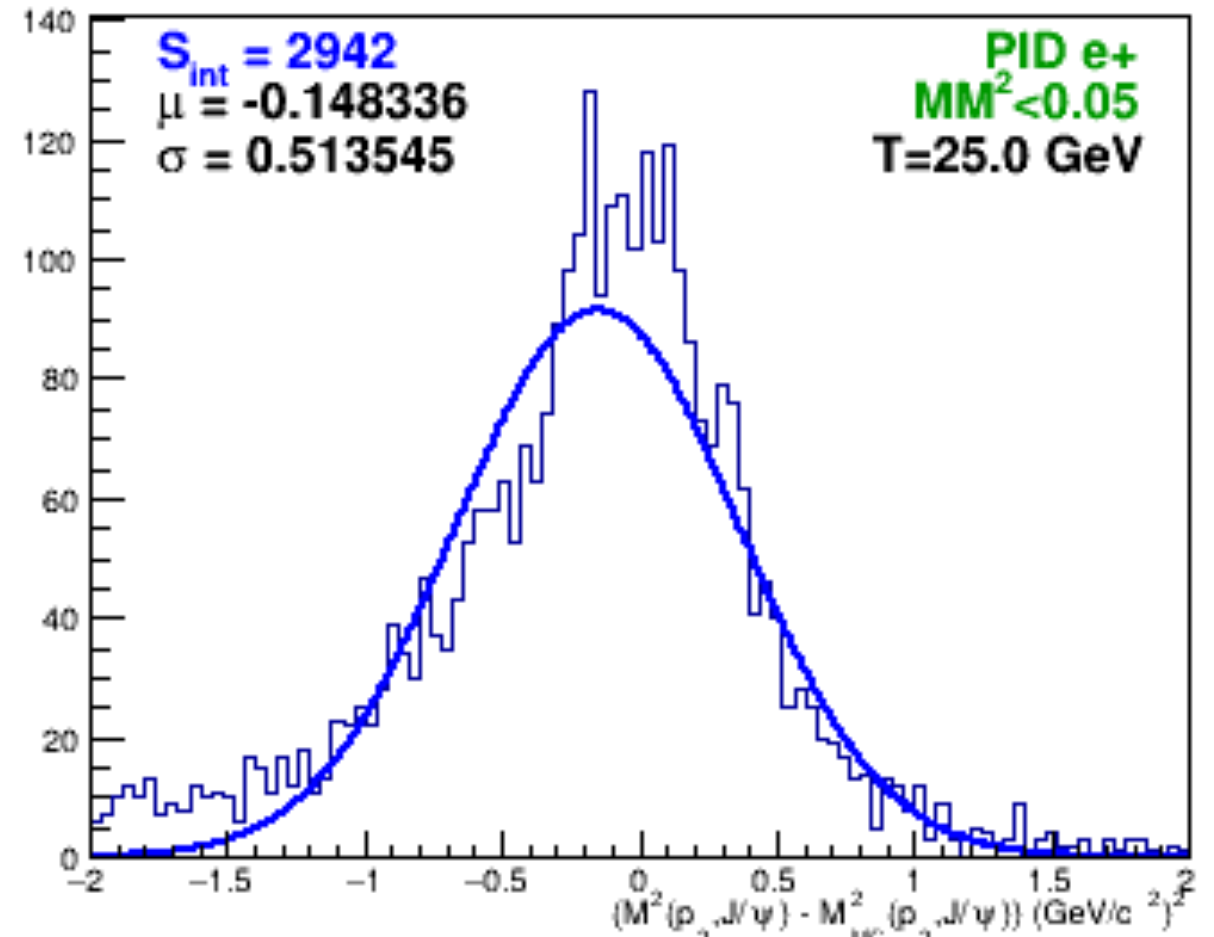


Dalitz plot resolutions

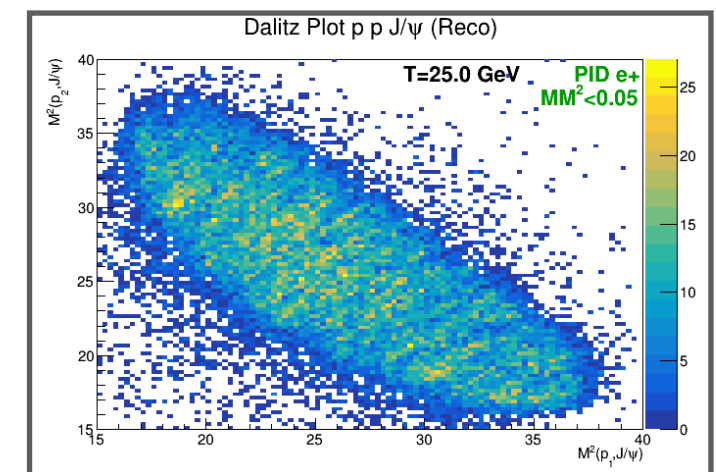
Dalitz Coordinate Resolution (p1 J/ψ)



Dalitz Coordinate Resolution (p2 J/ψ)

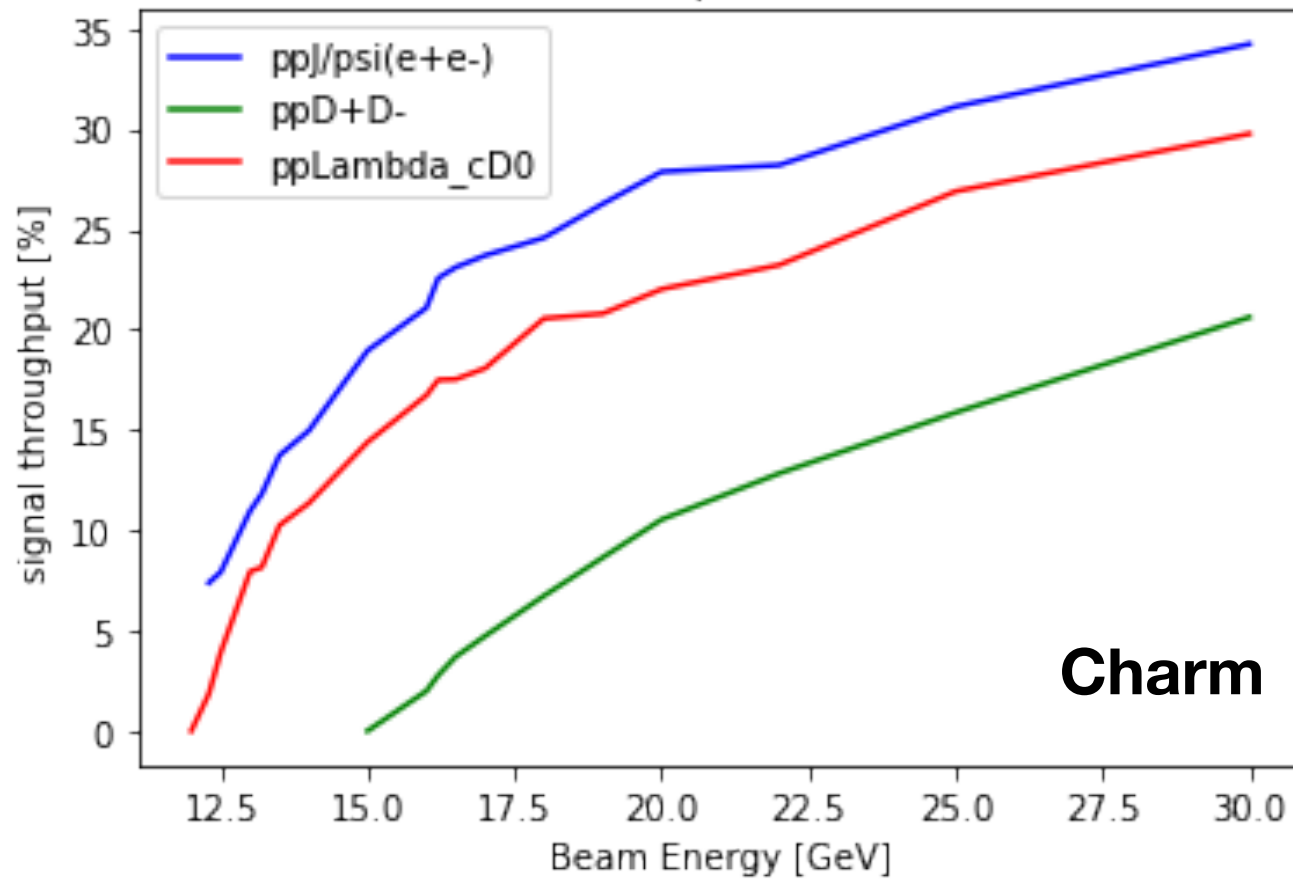


Kinematic fit needed to improve resolution



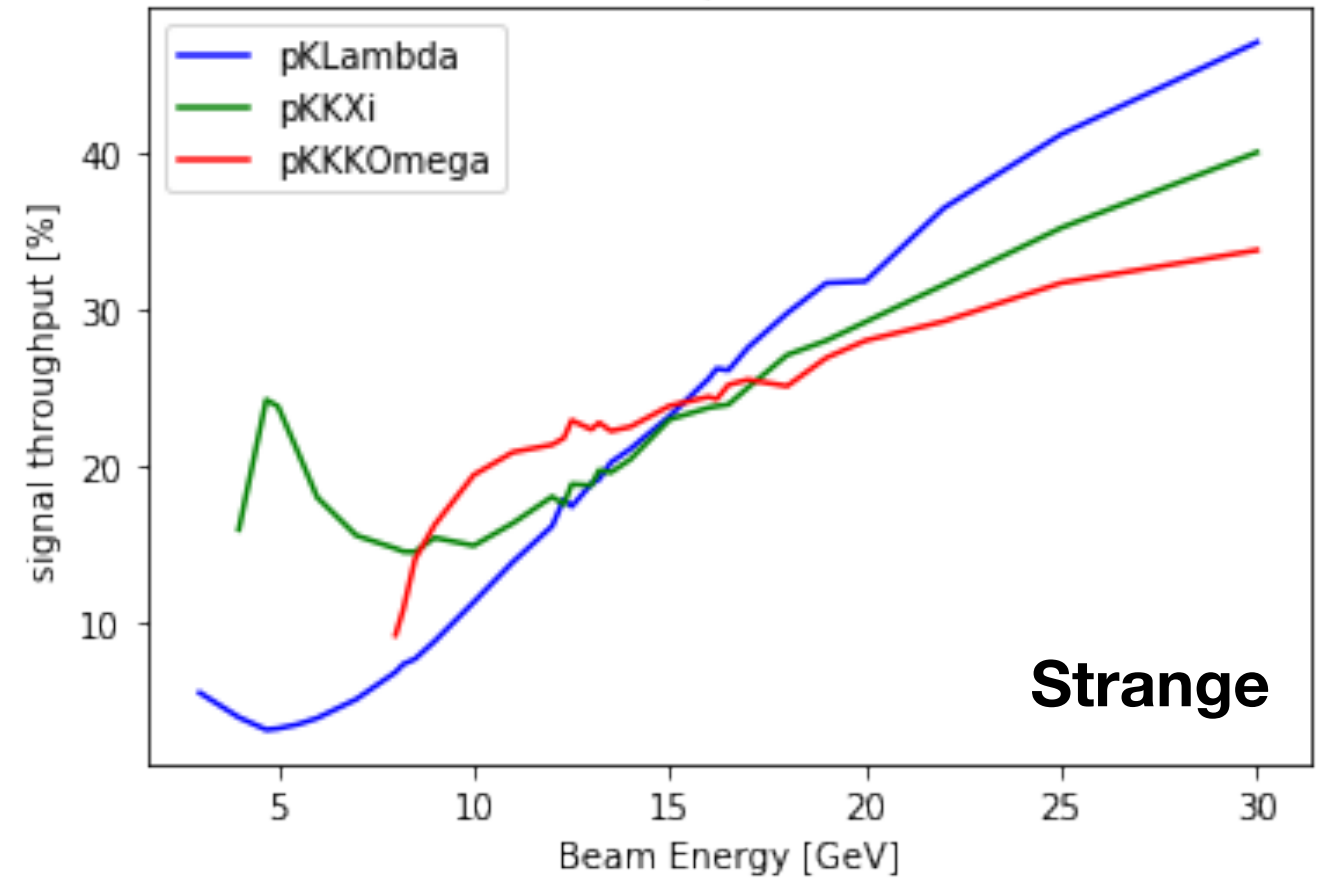
Acceptance for other channels

Acceptance



Charm

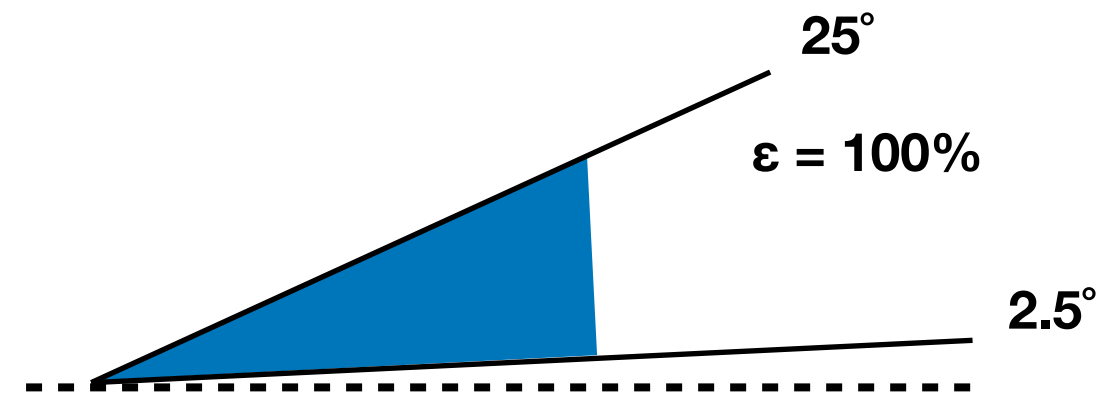
Acceptance



Strange

$pp \rightarrow p p J/\psi \rightarrow p p e^+ e^-$
 $pp \rightarrow p p D^- D^+ \rightarrow K^+ \pi^- \pi^- K^- \pi^+ \pi^+$
 $pp \rightarrow p \Lambda_c^+ D^0 \rightarrow p K^- \pi^+ K^+ \pi^-$

$pp \rightarrow p K^+ \Lambda^0 \rightarrow p K^+ p \pi^-$
 $pp \rightarrow p K^+ K^+ \Xi^- \rightarrow p K^+ K^+ \Lambda^0 (p \pi^-) \pi^-$
 $pp \rightarrow p K^+ K^+ K^0 \Omega^- \rightarrow p K^+ K^+ K^0 (\pi^+ \pi^-) \Lambda^0 (p \pi^-) K^-$



Things open

- Background
 - Dedicated channels
 - FTF Generator
 - **Filtering** before Simulation needed!
- Signals: Add e.g. a (p J/ ψ) resonance
- Energy loss correction for electrons
- **4C fit** \rightarrow Resolution
- Vertexing for strangeness channels



R. Kliemt

