Update on dielectron studies and new production

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Outline

- Details on background rejection cuts
- New production

DCA selections

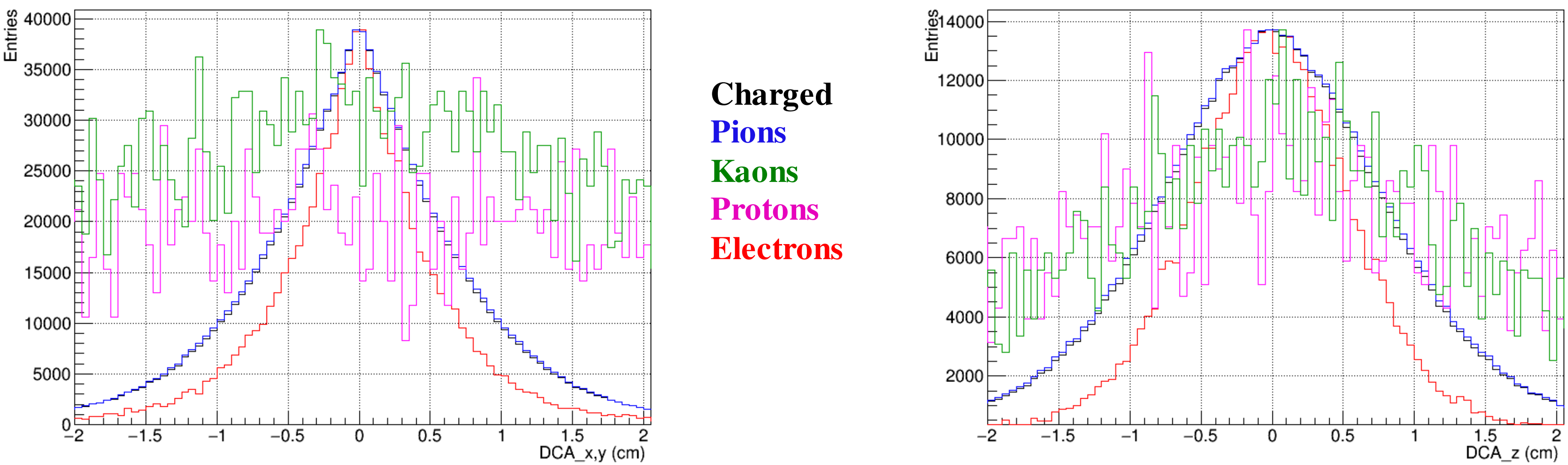
- DCA_x,y,z selections → reject tracks not from the primary vertex (conversion, weak decays, secondary interactions etc.)
- DCA selections are p_T, rapidity and centrality dependent → parameterization of the mean and width of DCA distributions vs. p_T, rapidity and centrality → normalization → apply n-σ cuts for selection of primary tracks
- Normalization of DCA is done using the inclusive sample of reconstructed charged particle tracks (mostly pions, composition changes with momentum and centrality)
  - ✓ Tracks should pass the basic analysis cuts for single tracks (except for DCA)
- Problems:
  - ✓ DCA parameterization approach (background and signal functions, how differential, etc.)
  - ✓ Mean and width of DCA distributions depend on the track selection cuts (n-hits, vertex, rapidity etc.)
- Questions:
  - ✓ How DCA for electrons is different from that for other hadrons or inclusive hadrons?
  - ✓ How much does the DCA cuts help to reject the photon conversion electrons?

DCA parameterization

- Followed the procedure described in the previous presentation
- DCA_x,y and DCA_z distributions are accumulated more differentially (7,500 bins):
  - ✓ 30 bins in η, $-1.5 < \eta < 1.5$
  - ✓ 10 centrality bins, 0 – 100%
  - ✓ 25 p_T bins, 0.05 – 2.55 GeV/c
- Number of bins and ranges are driven by available statistics
- DCA_xy and DCA_z distributions are fit to a sum of narrow Gaussian for signal + wide Gaussian for background), mean and width values are extracted for each η/centrality bin vs. p_T
- DCA_x,y,z values are normalized for n-sigma selections
- The DCA track selection cuts should depend on the analysis and optimized for better statistical significance and smaller systematic uncertainties

DCA vs. PID, primary particles

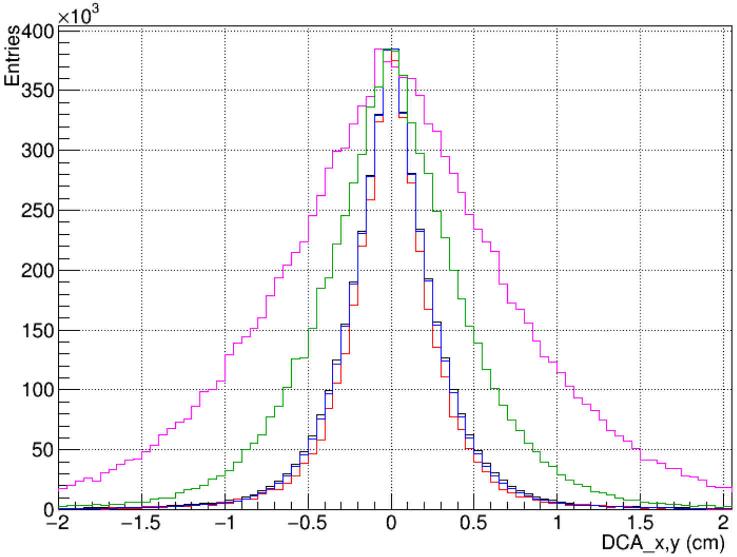
- DCA_x,y and DCA_z distributions (p_T integrated) for charged particles, pions, kaons, protons and electrons
- Distributions are normalized to have the same maximum
- p_T ~ 100 MeV/c

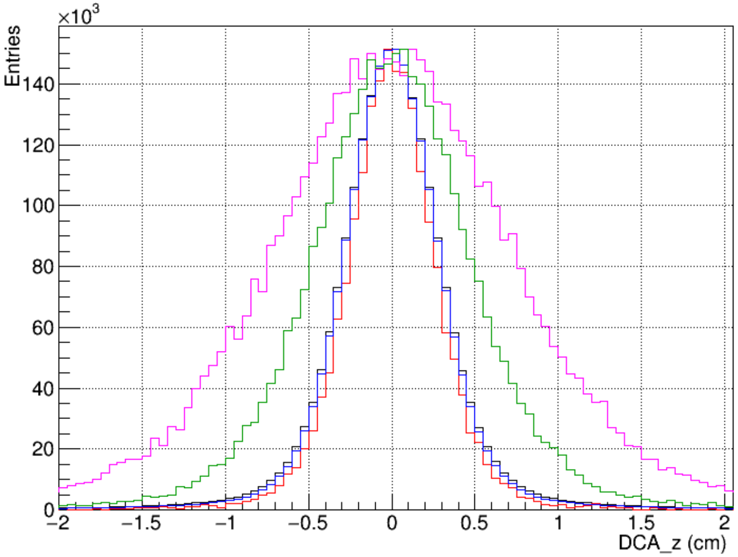


- Inclusive distributions are dominated by pions
- Width of DCA distributions shows strong PID dependence for all particles
- Significant difference between inclusive(pions) and electron distributions
- Kaons and protons are hardly matched to the primary vertex

DCA vs. PID, primary particles

- DCA_x,y and DCA_z distributions (p_T integrated) for charged particles, pions, kaons, protons and electrons
- Distributions are normalized to have the same maximum
- p_T ~ 200 MeV/c

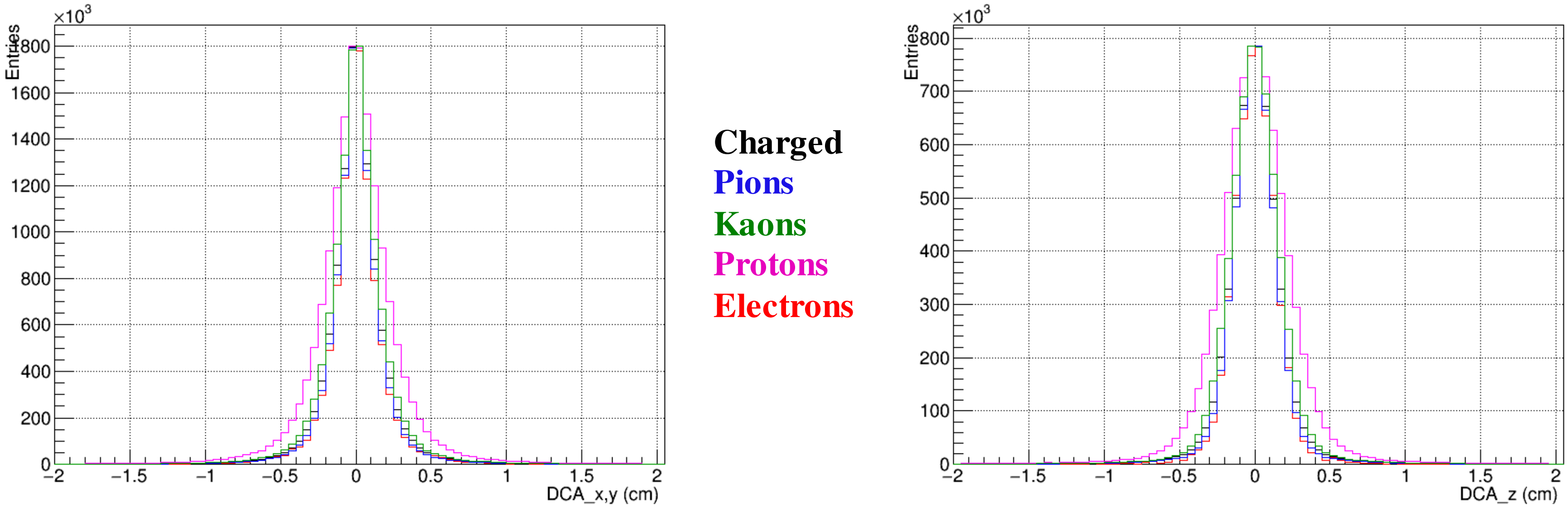




- Inclusive distributions are dominated by pions
- Width of DCA distributions shows strong PID dependence for kaons and protons
- Small difference between inclusive(pions) and electron distributions

DCA vs. PID, primary particles

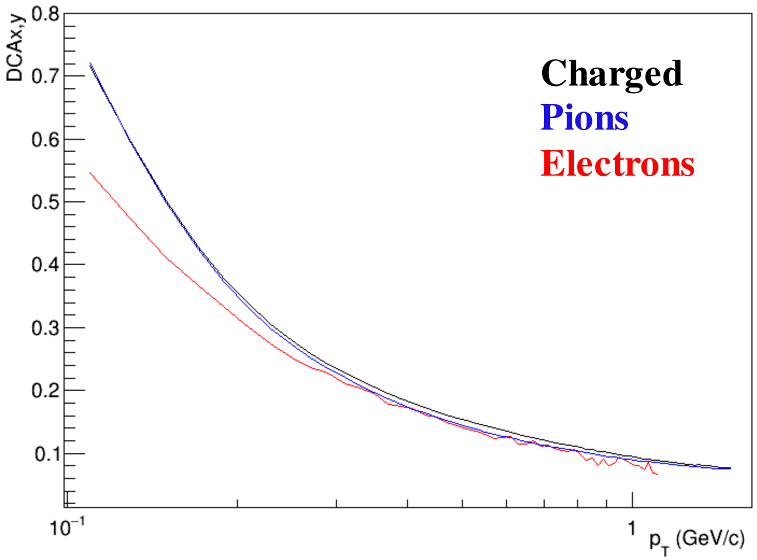
- DCA_x,y and DCA_z distributions (p_T integrated) for charged particles, pions, kaons, protons and electrons
- Distributions are normalized to have the same maximum
- p_T ~ 500 MeV/c

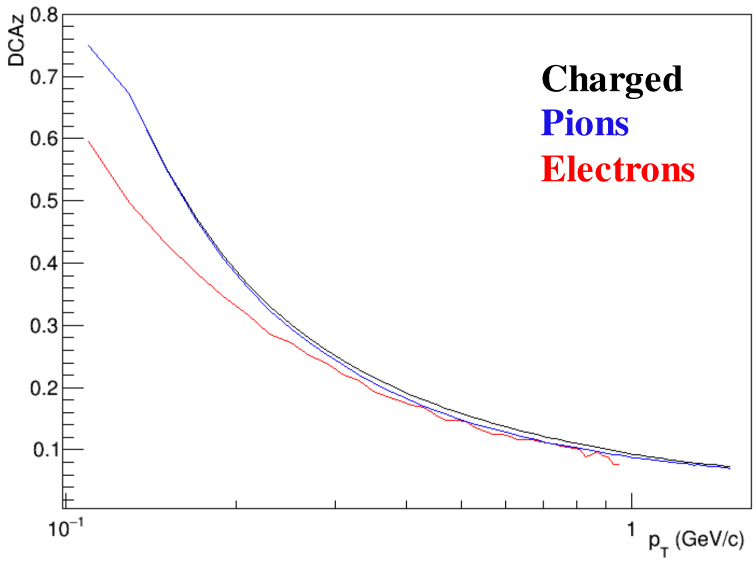


- Inclusive distributions are dominated by pions
- Width of DCA distributions shows modest PID dependence for protons
- No difference difference between inclusive(pions) and electron distributions

DCA vs. PID, primary particles

- Width of DCA_x,y and DCA_z distributions vs. p_T for charged particles, pions and electrons

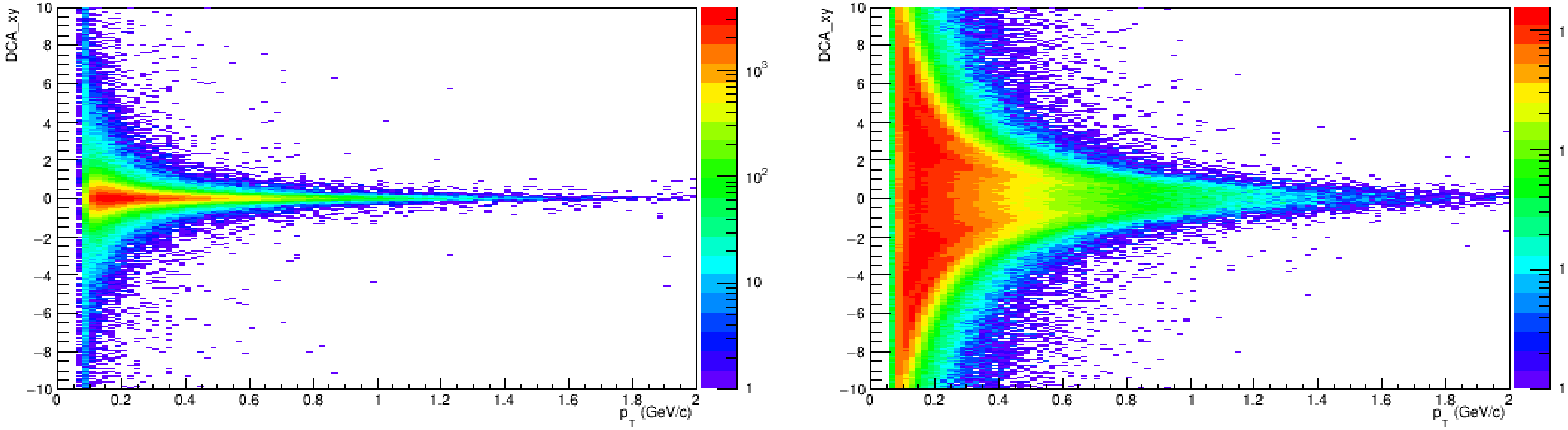




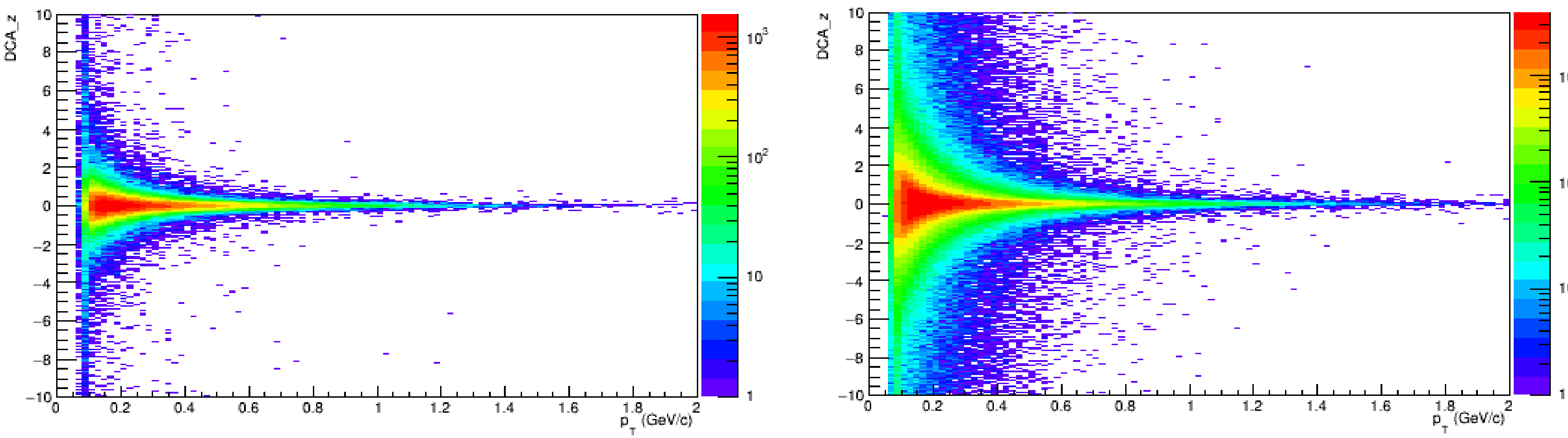
- All the differences between e/π/K/p are at very low momentum (~25%)
- At $p_T > 0.4$ GeV/c there is no difference between particles (except for protons)
- Tighter DCA cuts give some preference to electron selection at low p_T (for primary particles)

DCA for primary and secondary electrons

- DCA_x,y vs. p_T for primary (left) and secondary (right) electrons



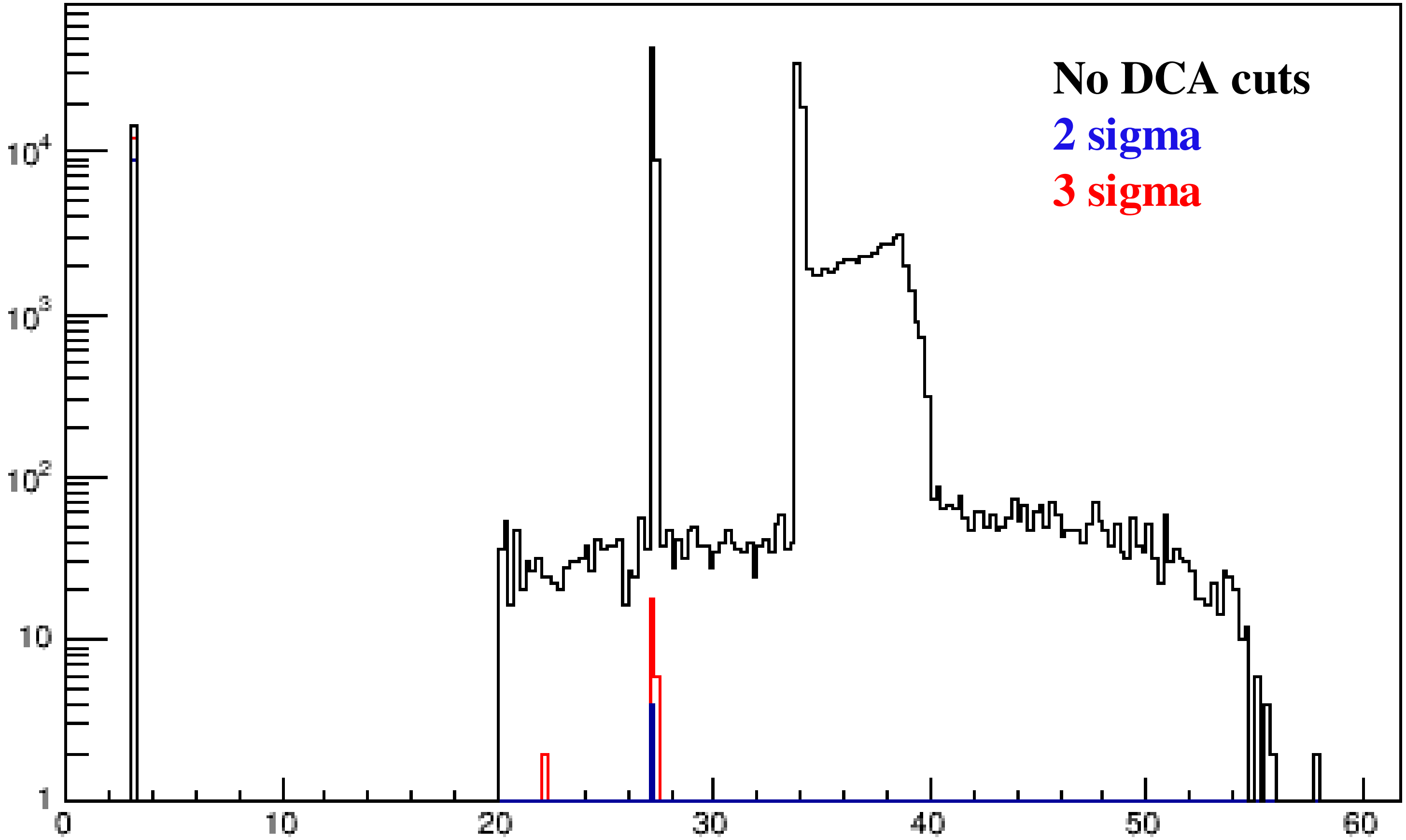
- DCA_z vs. p_T for primary (left) and secondary (right) electrons



- Different widths of DCA distributions for primary and secondary electrons, especially in x,y projections
- Tight DCA cuts reject secondary electrons (mostly from conversion)

DCA vs. radius, electrons

- Production radius of e^+e^- pairs with different DCA_xyz cuts



- DCA cuts do not reject conversion at beam pipe
- DCA cuts reject most of conversion on the TPC vessels

Optimization of analysis cuts

- Criteria:
  - ✓ larger statistical significance of signals → smaller statistical uncertainties
  - ✓ higher S/B ratio → smaller systematic uncertainties from background normalization

- Signals:
  - ✓ LM region 0.2-0.6 GeV/c^2
  - ✓ LVM: Omega, Phi

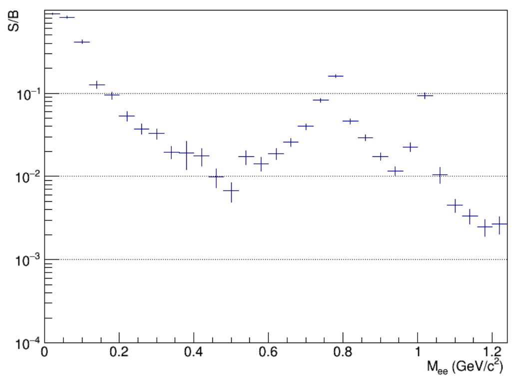
- Varied cuts:
  - ✓ electron DCA to PV within 1.5-3 σ
  - ✓ Dalitz cut within 0.1-0.2 GeV/c^2
  - ✓ $\sqrt{p_T^{e+} p_T^{e-}}$ cut within 0.25-0.4

- Questions: show differentially

DCA cut

- Criteria:
  - ✓ larger statistical significance of signals → smaller statistical uncertainties
  - ✓ higher S/B ratio → smaller systematic uncertainties from background normalization

DCA: 2 σ



S/B in 0.2-1.5: 0.028

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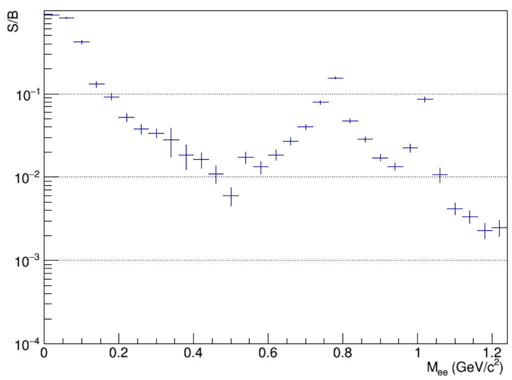
Omega (s/sqrt(b)): 2.93
Phi (s/sqrt(b)): 1.17
LMR (s/sqrt(b)): 0.56

======================

DCA: 2.5 σ



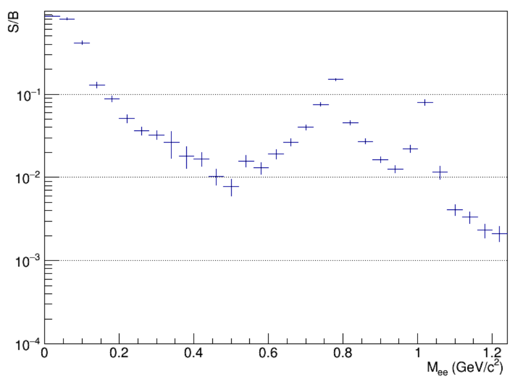
S/B in 0.2-1.5: 0.028

======================

Omega (s/sqrt(b)): 3.14
Phi (s/sqrt(b)): 1.2
LMR (s/sqrt(b)): 0.63

======================

DCA: 3 σ



S/B in 0.2-1.5: 0.027

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Omega (s/sqrt(b)): 3.18
Phi (s/sqrt(b)): 1.19
LMR (s/sqrt(b)): 0.64

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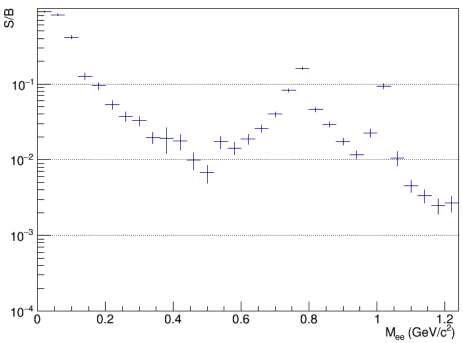
- Efficiency and purity are quite sensitive to DCA selections
- However dielectron signals show only very weak dependence on the DCA cuts

Dalitz cut

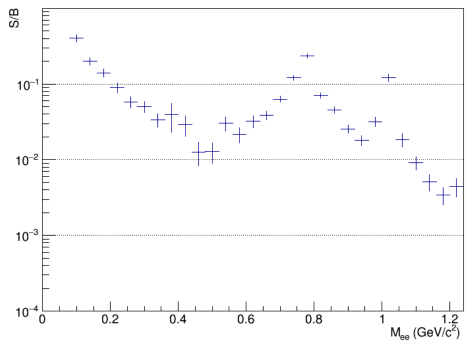
- Criteria:
  - ✓ larger statistical significance of signals → smaller statistical uncertainties
  - ✓ higher S/B ratio → smaller systematic uncertainties from background normalization

No cut



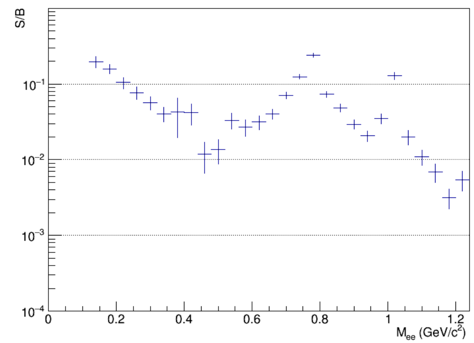
S/B in 0.2-1.5: 0.028
=====================
Omega (s/sqrt(b)): 2.93
Phi (s/sqrt(b)): 1.17
LMR (s/sqrt(b)): 0.56
=====================

$100\ MeV/c^2$



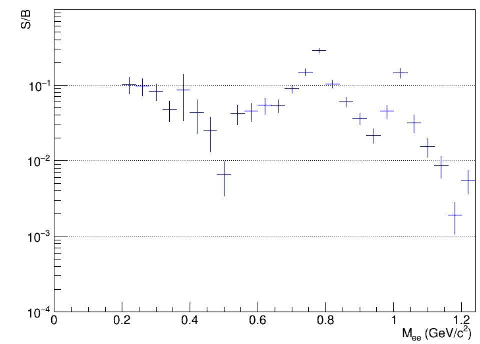
S/B in 0.2-1.5: 0.046
=====================
Omega (s/sqrt(b)): 3.13
Phi (s/sqrt(b)): 1.2
LMR (s/sqrt(b)): 0.6
=====================

$135\ MeV/c^2$



S/B in 0.2-1.5: 0.052
=====================
Omega (s/sqrt(b)): 2.89
Phi (s/sqrt(b)): 1.10
LMR (s/sqrt(b)): 0.56
=====================

$200\ MeV/c^2$



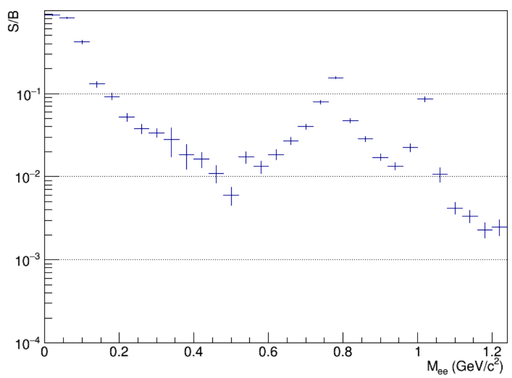
S/B in 0.2-1.5: 0.069
=====================
Omega (s/sqrt(b)): 2.62
Phi (s/sqrt(b)): 0.93
LMR (s/sqrt(b)): 0.49
=====================

- A cut of $M > 100\ MeV/c^2$ improves the S/B and signal significance
- Further improvements in S/B are at the expense of smaller statistical significance
- The cut is a source of systematic uncertainties, which are difficult to control and evaluate

$\sqrt{p_T^{e+} p_T^{e-}}$ cuts

- Criteria:
  - ✓ larger statistical significance of signals → smaller statistical uncertainties
  - ✓ higher S/B ratio → smaller systematic uncertainties from background normalization

No cut



S/B in 0.2-1.5: 0.028

======================

Omega (s/sqrt(b)): 3.14
Phi (s/sqrt(b)): 1.2
LMR (s/sqrt(b)): 0.63

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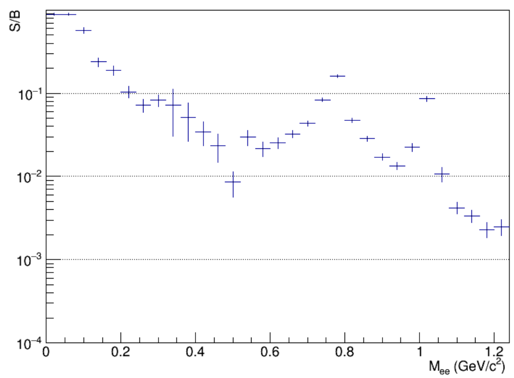
$\sqrt{p_T^{e+} p_T^{e-}} > 0.3$



S/B in 0.2-1.5: 0.047

======================

Omega (s/sqrt(b)): 3.18
Phi (s/sqrt(b)): 1.2
LMR (s/sqrt(b)): 0.63

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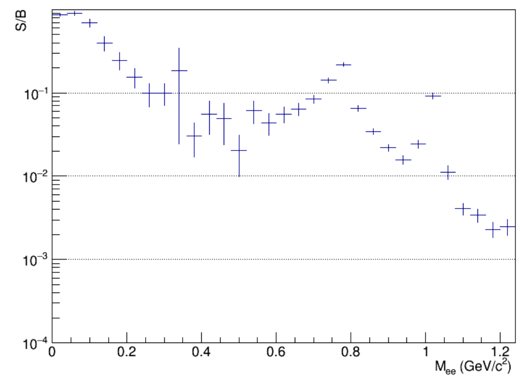
$\sqrt{p_T^{e+} p_T^{e-}} > 0.4$



S/B in 0.2-1.5: 0.065

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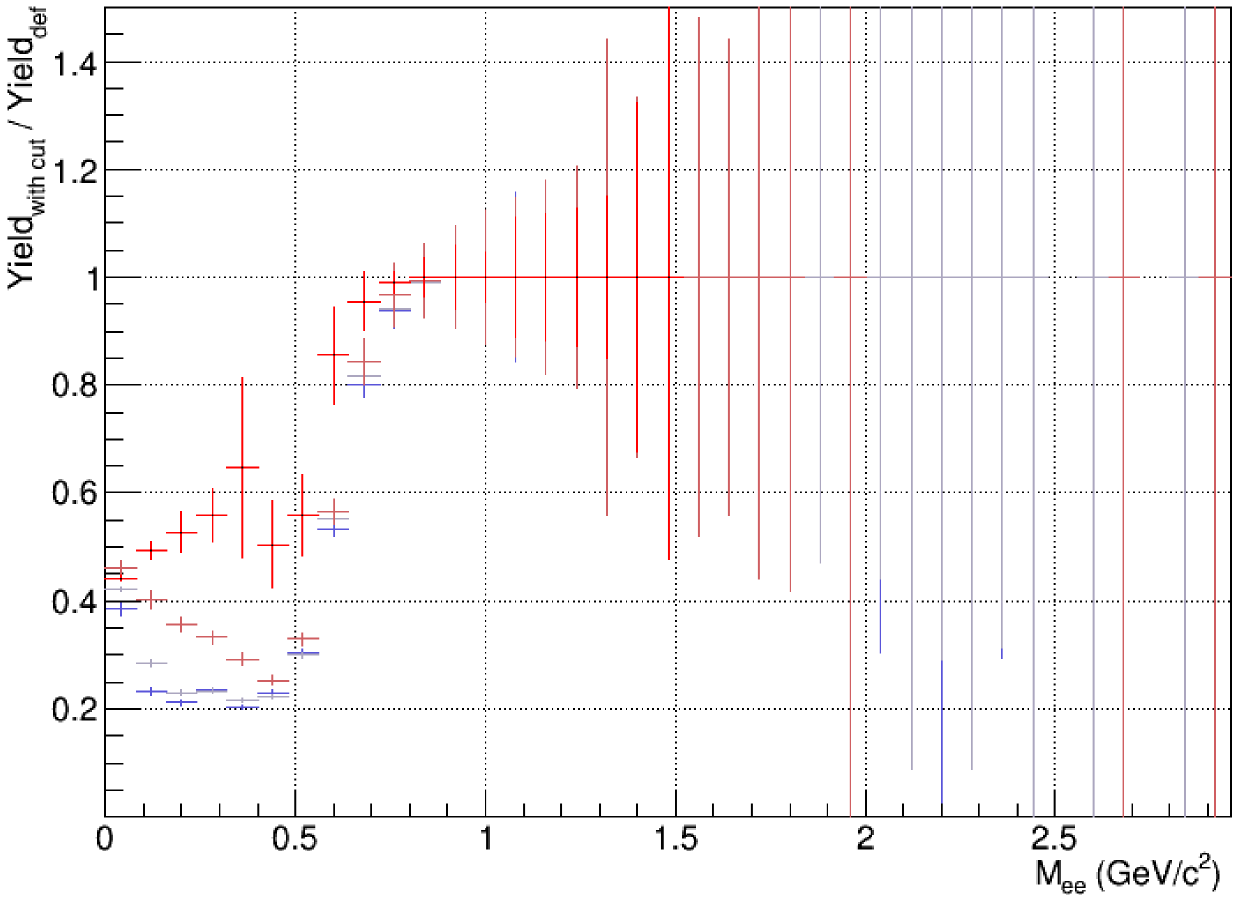
Omega (s/sqrt(b)): 2.83
Phi (s/sqrt(b)): 1.24
LMR (s/sqrt(b)): 0.48

=========================

- $\sqrt{p_T^{e+} p_T^{e-}}$ cut improves S/B
- Up to $\sqrt{p_T^{e+} p_T^{e-}} > 0.3$, signal significance is not affected
- Tighter cuts reduce statistical significance

$\sqrt{p_T^{e+} p_T^{e-}} > 0.3$ cut, more details

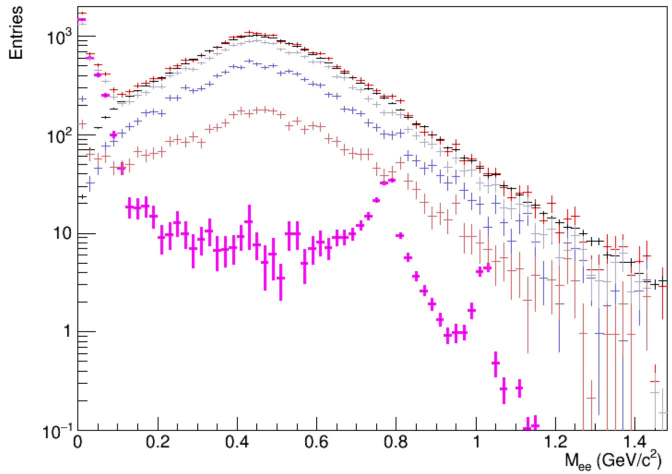
- Ratio of **e^+e^- continuum**, **e^+e^- from η**, **e^+e^- from π^0** and **e^+e^- from conversion**

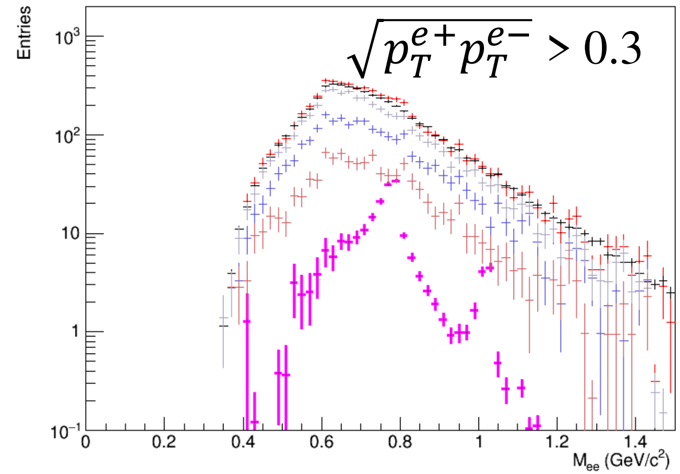


- $\sqrt{p_T^{e+} p_T^{e-}} > 0.3$ cut rejects signal at low mass
- However, pairs with Dalitz and conversion electrons are rejected more effectively

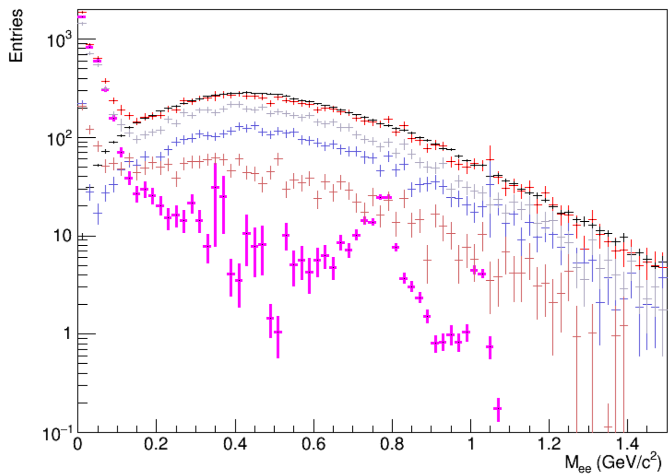
$\sqrt{p_T^{e+} p_T^{e-}} > 0.3$ cut, more differentially

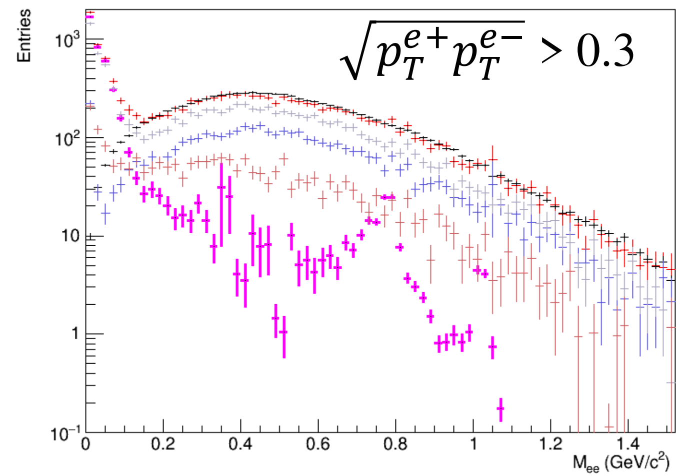
- $0 < p_T < 0.5$ GeV/c





- $0.5 < p_T < 1.0$ GeV/c



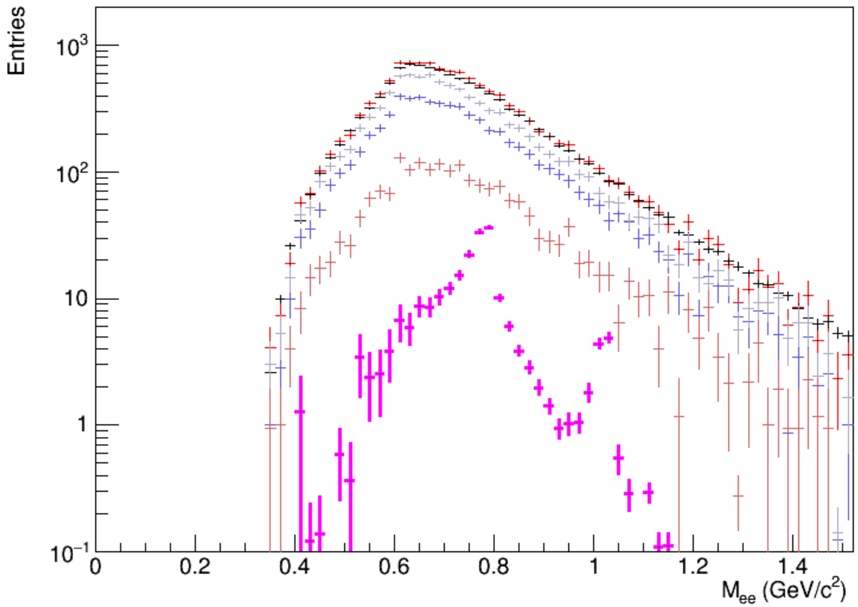


- $\sqrt{p_T^{e+} p_T^{e-}} > 0.3$ cut is very similar to $p_T^{e+} > 0.3$ and $p_T^{e-} > 0.3$ cuts

$\sqrt{p_T^{e+} p_T^{e-}} > 0.3$ cut, more differentially

- $0 < p_T < 0.5$ GeV/c

$\sqrt{p_T^{e+} p_T^{e-}} > 0.3$



S/B in 0.2-1.5: 0.019

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Omega (s/sqrt(b)): 1.6
Phi (s/sqrt(b)): 0.60
LMR (s/sqrt(b)): 0.16

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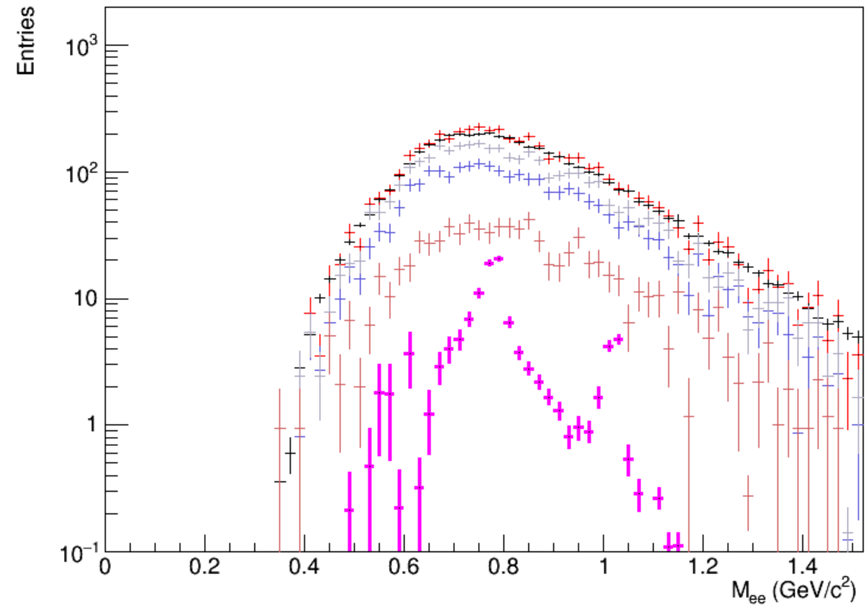
$p_T^{e+} > 0.3$ and $p_T^{e-} > 0.3$



S/B in 0.2-1.5: 0.025

======================

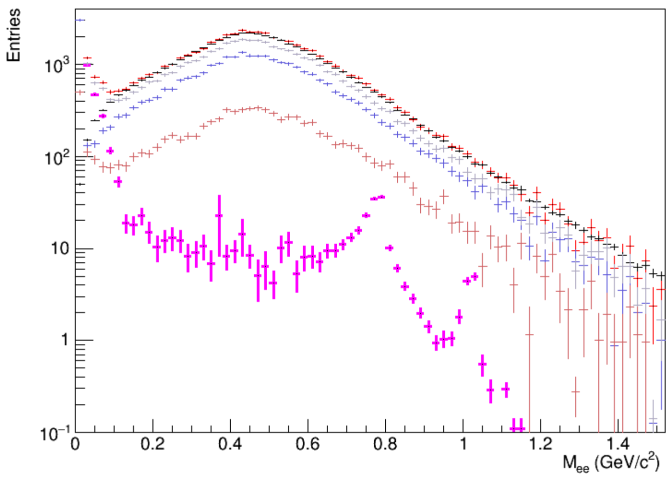
Omega (s/sqrt(b)): 1.33
Phi (s/sqrt(b)): 0.64
LMR (s/sqrt(b)): 0.11

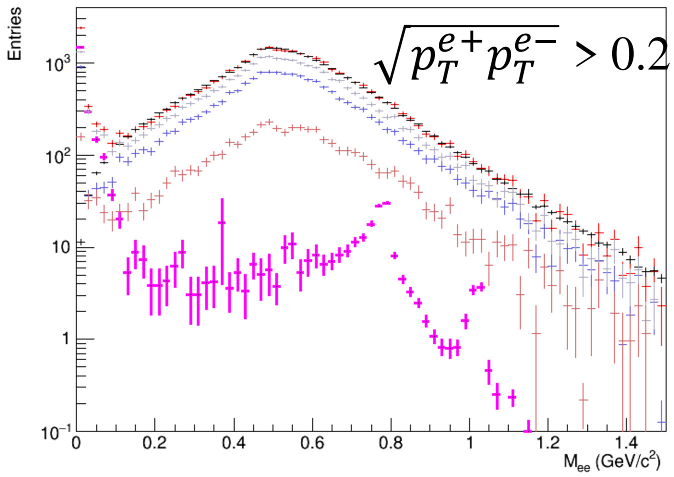
======================

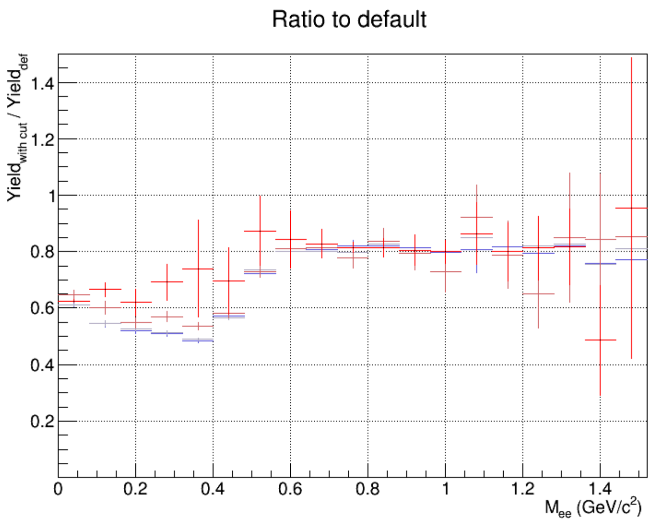
- Two cuts only look similar but have very different efficiency
- However both cuts reject low-mass pairs at low p_T

$\sqrt{p_T^{e+} p_T^{e-}} > 0.2$ cut

- $0 < p_T < 0.5$ GeV/c







- Looser cuts could be used depending on the background situation

New Monte Carlo production

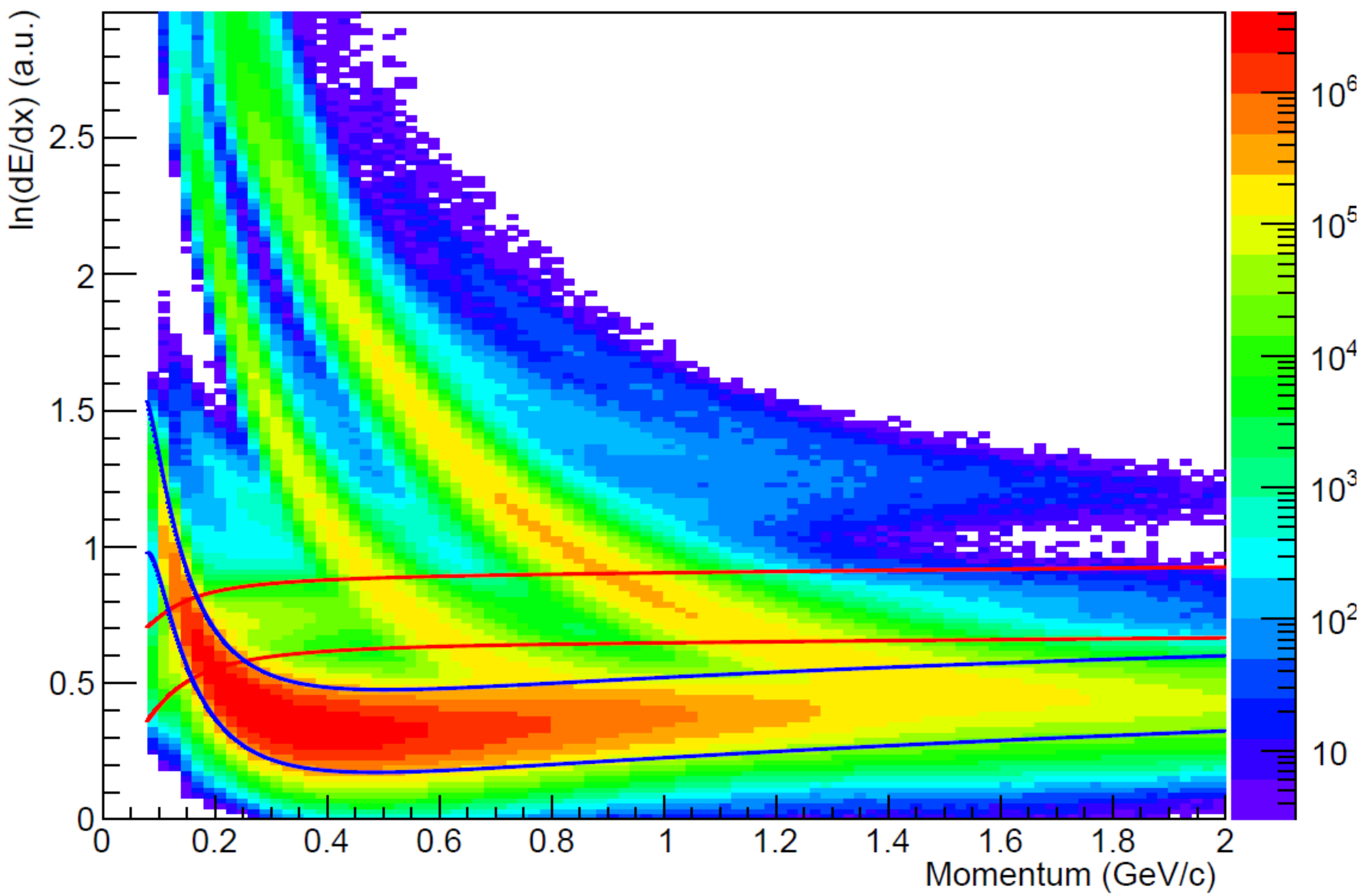
- Request11: *PWG4 - dielectrons, 15M minbias BiBi@9.2*
- The production has been finished a few days ago
- Aims at dielectron studies but good for most of other analyses
- Features (what's different compared to previous dielectron productions):
  - ✓ latest MpdRoot version with the updated materials, detector response and reconstruction algorithms
  - ✓ realistic dE/dx calculations with Geant-4
  - ✓ dphi, dzed variables for better track-to-TOF matching
  - ✓ most probable first collision system, BiBi@9.2
  - ✓ high statistics, 15 M events

- Output data:
  - ✓ /eos/nica/mpd/sim/data/exp/dst-BiBi-09.2GeV-mp02-21-500ev/BiBi/09.2GeV-mb/UrQMD/BiBi-09.2GeV-mp02-21-500ev/
  - ✓ 30,000 DST files

dE/dx parameterization

- Selected tracks:
  - ✓ hits > 39
  - ✓ $|\eta| < 1$
  - ✓ |DCA_x,y,z| < 3 σ

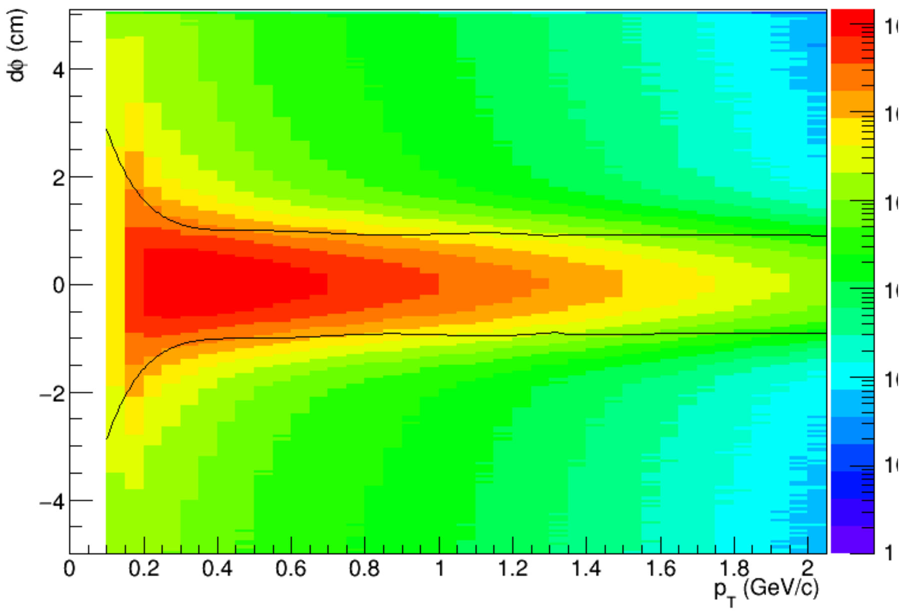
- Parameterized log(dE/dx) vs. momentum for electrons and pions
- Red and blue bands show 2σ selections for $e^{\pm}$ and $\pi^{\pm}$

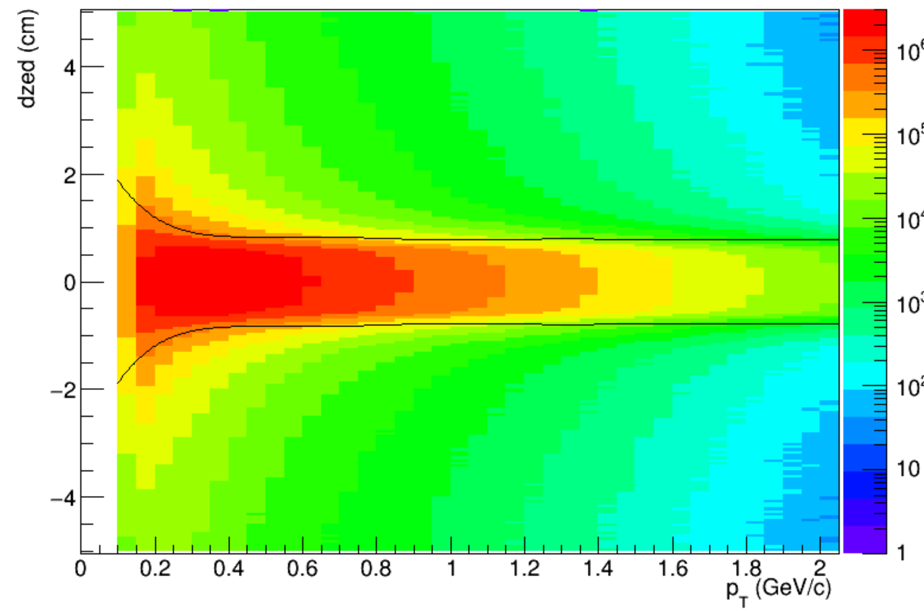


Track-to-TOF matching distributions vs. p_T

- Selected tracks:
  - ✓ hits > 39
  - ✓ $|\eta| < 1$
  - ✓ |DCA_x,y,z| < 3 σ

- Default track-to-TOF matching cut is |*distance*| < 7 cm
- Split *distance* to dphi and dzed and then parameterized matching distributions for all charged tracks vs. p_T

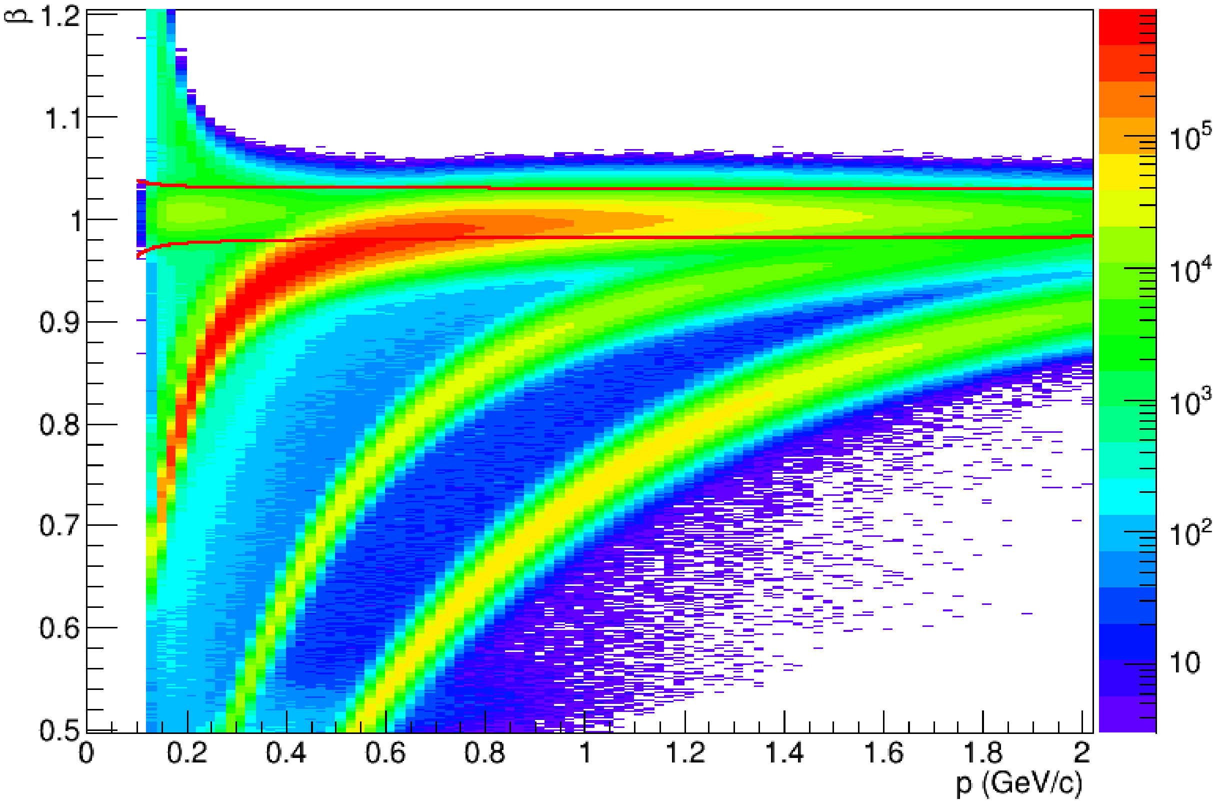




- 2σ bands are shown with black lines
- Do not observed a significant charge dependence of dφ
- Selection of matching cuts is analysis dependent

Beta parameterization

- Selected tracks:
  - ✓ hits > 39
  - ✓ |η| < 1
  - ✓ |DCA_x,y,z| < 3 σ
  - ✓ 2σ matching to TOF

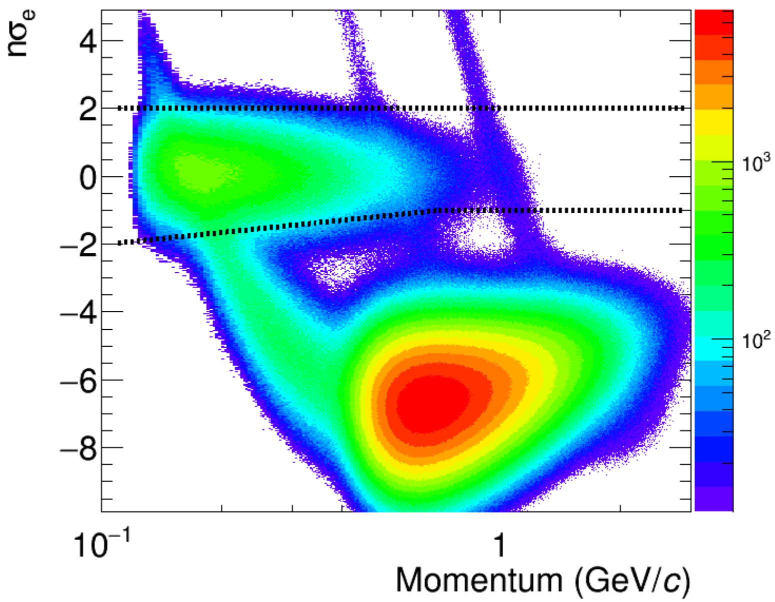


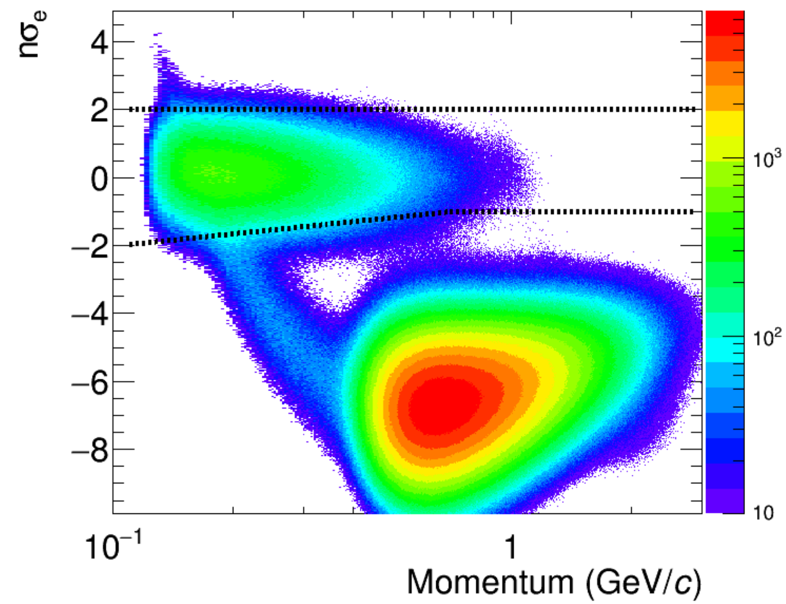
- 2σ bands are shown with red lines
- Very weak dependence of width on p_T
- Tail at β > 1 remains and is clearly seen

dE/dx with TOF selections

- Selected tracks:
  - ✓ hits > 39
  - ✓ |η| < 1
  - ✓ |DCA_x,y,z| < 3 σ
  - ✓ Default matching

- Selected tracks:
  - ✓ hits > 39
  - ✓ |η| < 1
  - ✓ |DCA_x,y,z| < 3 σ
  - ✓ 2σ matching to TOF

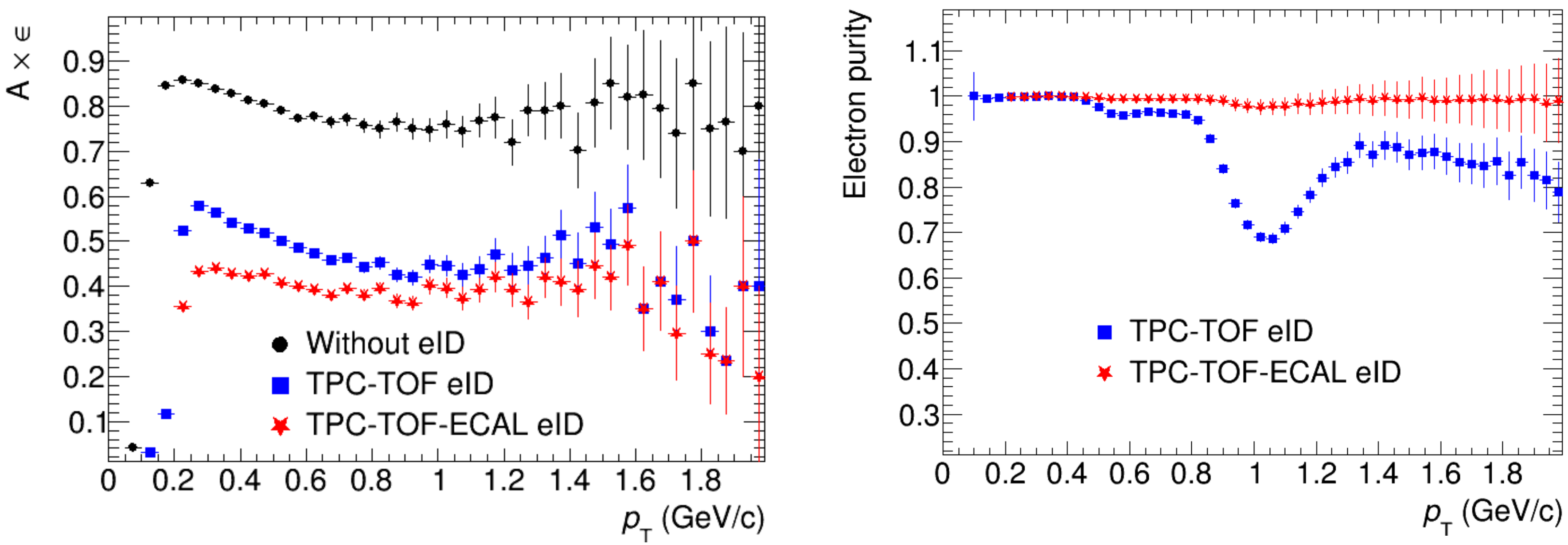




- 2σ matching reduces background from wrong association of tracks and TOF hits
- Background remains anyway, including β > 1 tail
- Dashed lines show the cuts which improve separation of pions and electrons at the expense of lower efficiency

Efficiency and purity

- Selected tracks:
  - ✓ hits > 39
  - ✓ |η| < 1
  - ✓ |DCA_x,y,z| < 3 σ
  - ✓ 2σ matching to TOF
  - ✓ 1-2σ TPC-eID
  - ✓ 2σ TOF-eID



- Performance is comparable to that in previous studies
- Next step is to look at dielectrons …

BACKUP

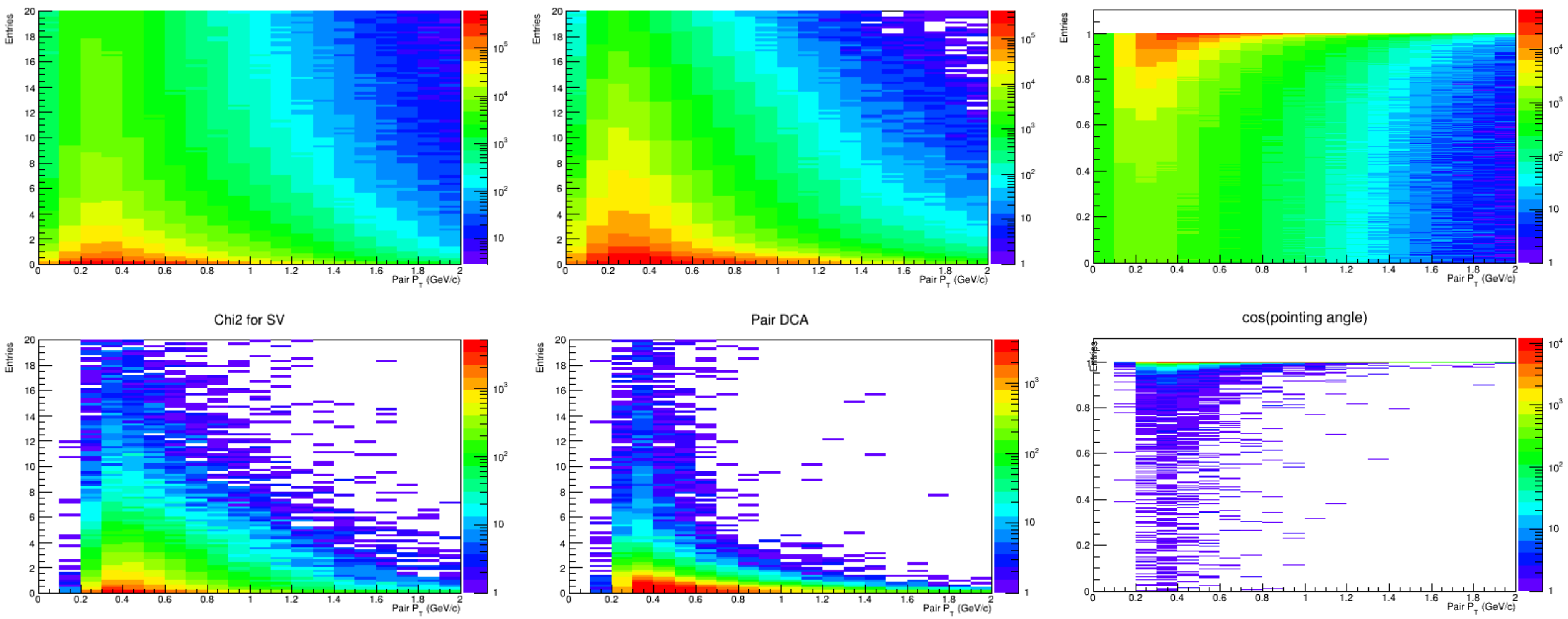
Conversions

- 10 M minbias BiBi@9.45 (UrMQD v.3.4) events
- Idea is to pair electron candidate tracks and then reject tracks that are consistent with $\gamma \to ee$
- Form pairs:
  - ✓ track #1 – passes tight dielectron analysis selection cuts (n-hits > 39, DCA < 2σ; |eta| < 1.0; p_T > 50 MeV/c; TPC-TOF 2σ eID + TPC π-ID 2σ veto)
  - ✓ track #2 – passes loose e-ID cuts (n-hits > 20; |eta| < 2.5; p_T > 50 MeV/c; TPC 2σ e-ID (no TOF) ‖ TPC-TPF 2σ e-ID
- Compare distributions for all pairs and for those from conversion:
  - ✓ Chi2 for secondary vertex, distance between the tracks
  - ✓ pointing angle
  - ✓ Mass_ee
  - ✓ distance to primary vertex
  - ✓ …. many more, but all variables are correlated

Chi2, DCA and PA distributions

- 10 M minbias BiBi@9.45 (UrMQD v.3.4) events

Chi2 for secondary vertex **DCA between the tracks** **Pointing angle**

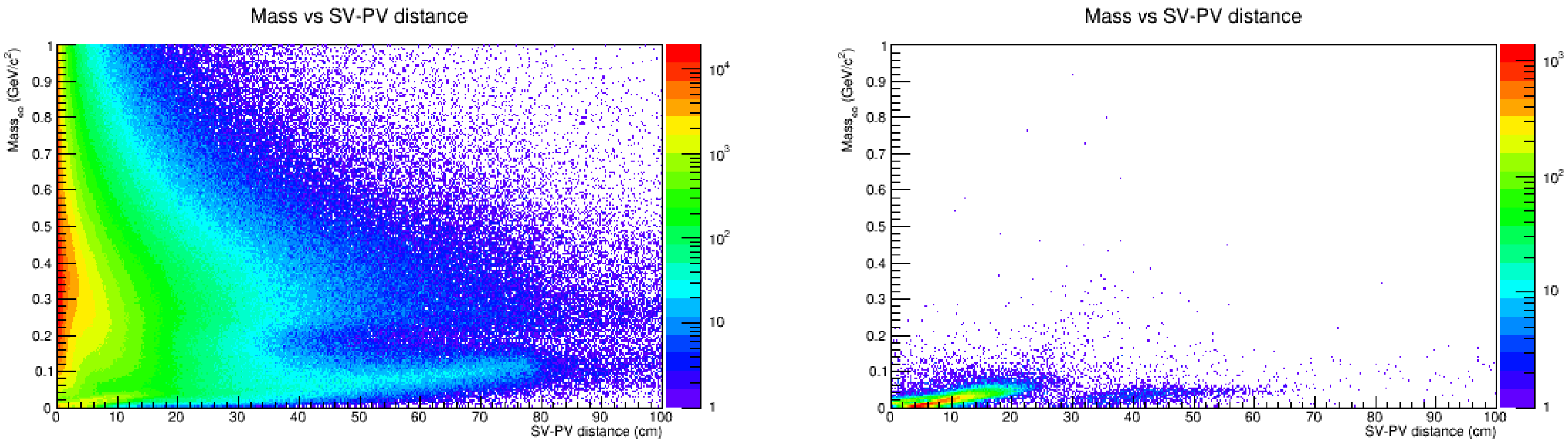


- p_T-dependent selections for Chi2, DCA and pointing angle are set to accept 95% of conversion pairs

Mass vs. distance distributions

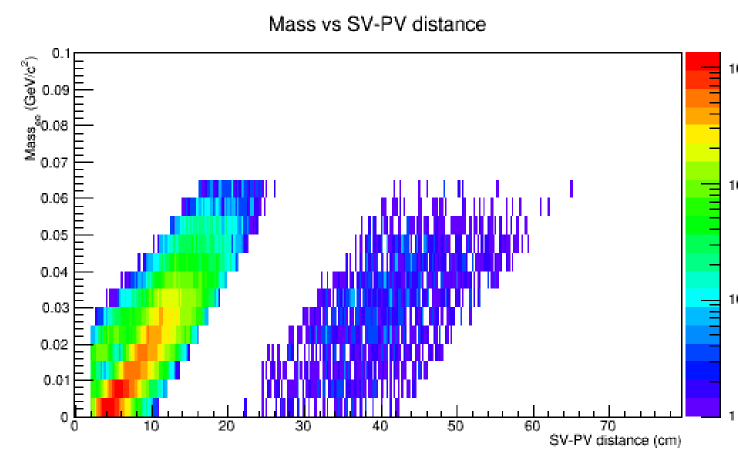
- 10 M minbias BiBi@9.45 (UrMQD v.3.4) events

Mass vs. SV-PV distance



- Tight DCA cut for track#1 rejects conversions at large angles

- Selections for conversion pairs:
  - ✓ SV-PV distance > 2 cm
  - ✓ Mass_ee < 65 MeV/c^2
  - ✓ select two bands for the beam pipe and TPC vessels

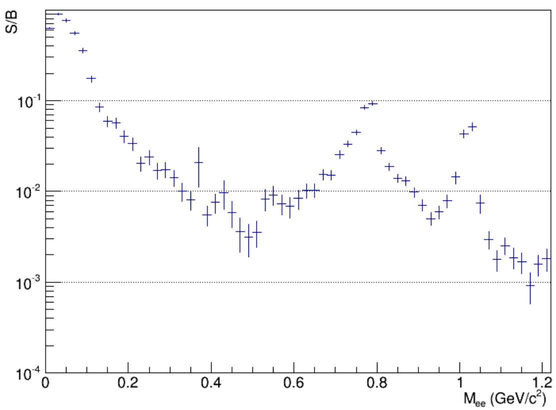


- Once find a loosely e-IDed track which is consistent with a conversion partner for the tightly e-IDed track → both tracks are tagged as a conversion pair candidates and then rejected from the analysis

Conversion rejection, results

- 10 M minbias BiBi@9.45 (UrMQD v.3.4) events

No conversion rejection



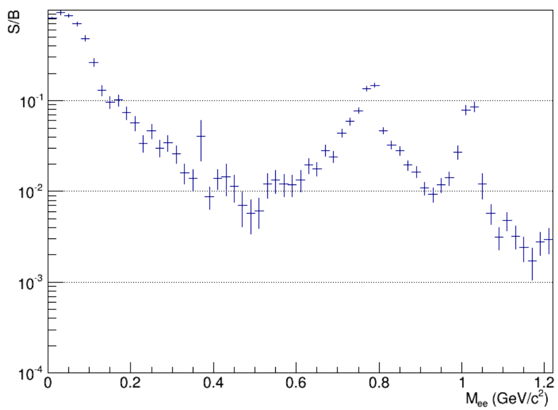
S/B in 0.2-1.5: 0.014

============================

Omega (s/sqrt(b)): 2.23
Phi (s/sqrt(b)): 0.86
LMR (s/sqrt(b)): 0.42

============================

Previous variant of conversion rejection



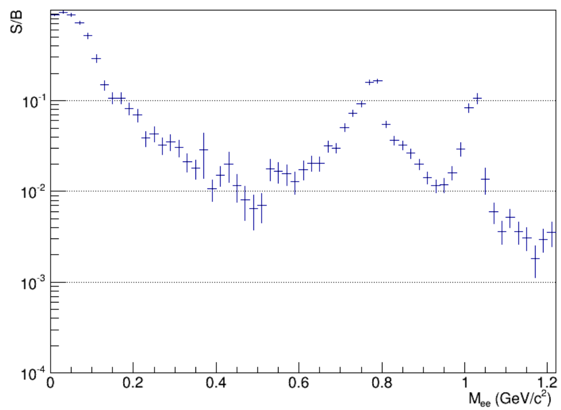
S/B in 0.2-1.5: 0.025

============================

Omega (s/sqrt(b)): 2.65
Phi (s/sqrt(b)): 1.07
LMR (s/sqrt(b)): 0.52

============================

New variant of conversion rejection



S/B in 0.2-1.5: 0.028

============================

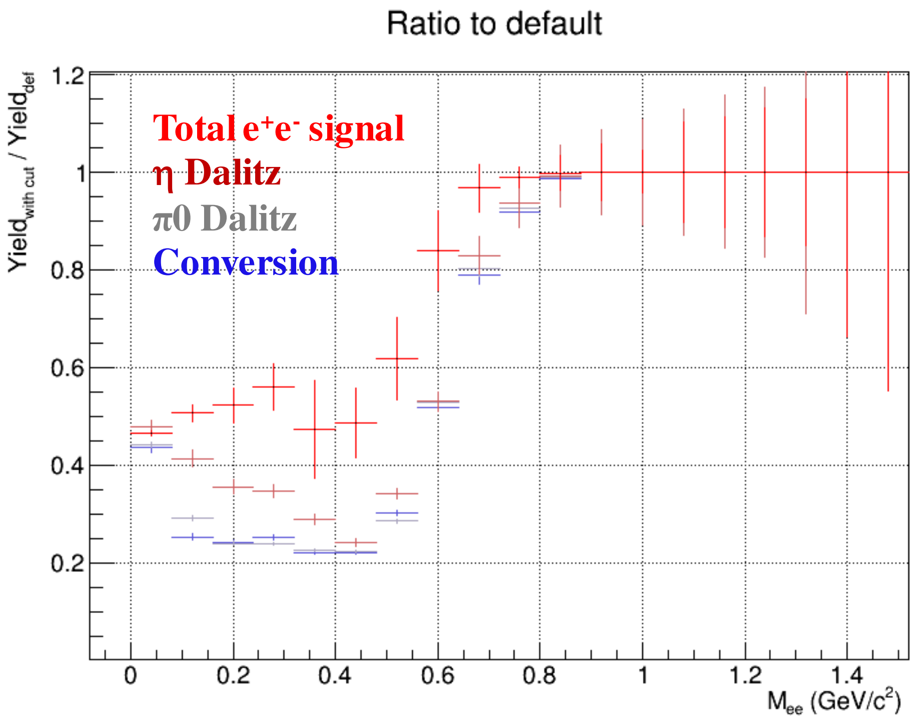
Omega (s/sqrt(b)): 2.93
Phi (s/sqrt(b)): 1.17
LMR (s/sqrt(b)): 0.56

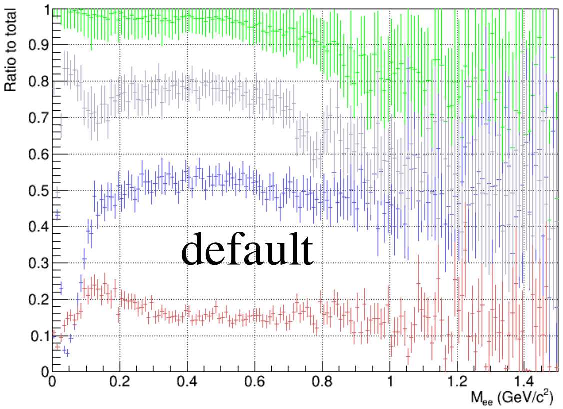
============================

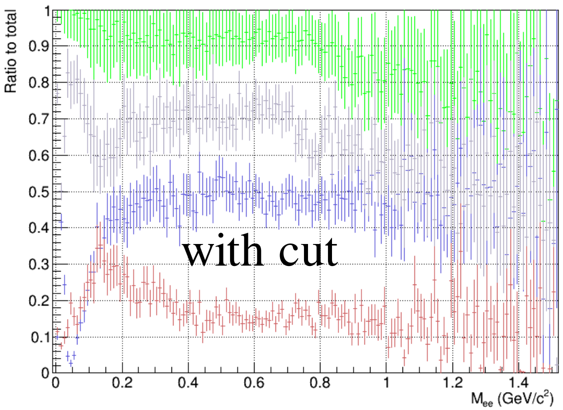
- Rejection of conversion candidates improves S/B by a factor of 2
- Signal significance also improves
- Mild improvements with respect to previous variant of conversion rejection for S/B
- New variant of conversion rejection is a new default variant

S/B, different cuts: asymmetry

- $\sqrt{p_T^{e-} p_T^{e+}} > 0.3$: a low-$p_T$ electron must pair only with a high-p_T electron







- The cut rejects ~ 50% of the total signal, 60% of e-η, 75% of e-π^0 and e-conversion pairs
- Redistribution of pairs for from different sources at low masses