



SEARCH FOR

$K^+ \rightarrow \pi^- e^+ e^+$ DECAY: status

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$K^+ \rightarrow \pi^- e^+ e^+$ DECAY

- Violates lepton flavour
- Violates lepton number
- Forbidden in the SM
- Any positive signal is clear evidence of New Physics beyond SM
- Current best limit: $BR(K^+ \rightarrow \pi^- e^+ e^+) < 6.4 \times 10^{-10}$, BNL E865, [PRL85 \(2000\) 2877](#)

DATA SAMPLE 2016

- Use **Positron3TrackVtx** filter: at least one 3 track vertex and at least one positron identified in RICH or LKr
- Di-electron trigger: L0: RICH \times Qx \times (**ELKr>20**), L1: !LAV \times STRAWexotics, active from run 6477 (3 Oct 2016), always bit 4, typical DS=1 or 2
- ~58k bursts analyzed

SELECTION

SM AND NON-SM MODES

- Pre-selection, the same for both modes:
 - Exactly one 3 track vertex with at least one positron identified in RICH or LKr (like filter for Data), total vertex charge +1
 - Info from 4 STRAW chambers for each track
 - At least 5 CEDAR sectors
 - MUV3/IRC/SAC veto
- Use RICH or LKr or both of them for PID
- Zvertex, total energy in LKr (for MC), signal region cuts

SELECTION

SM AND NON-SM MODES

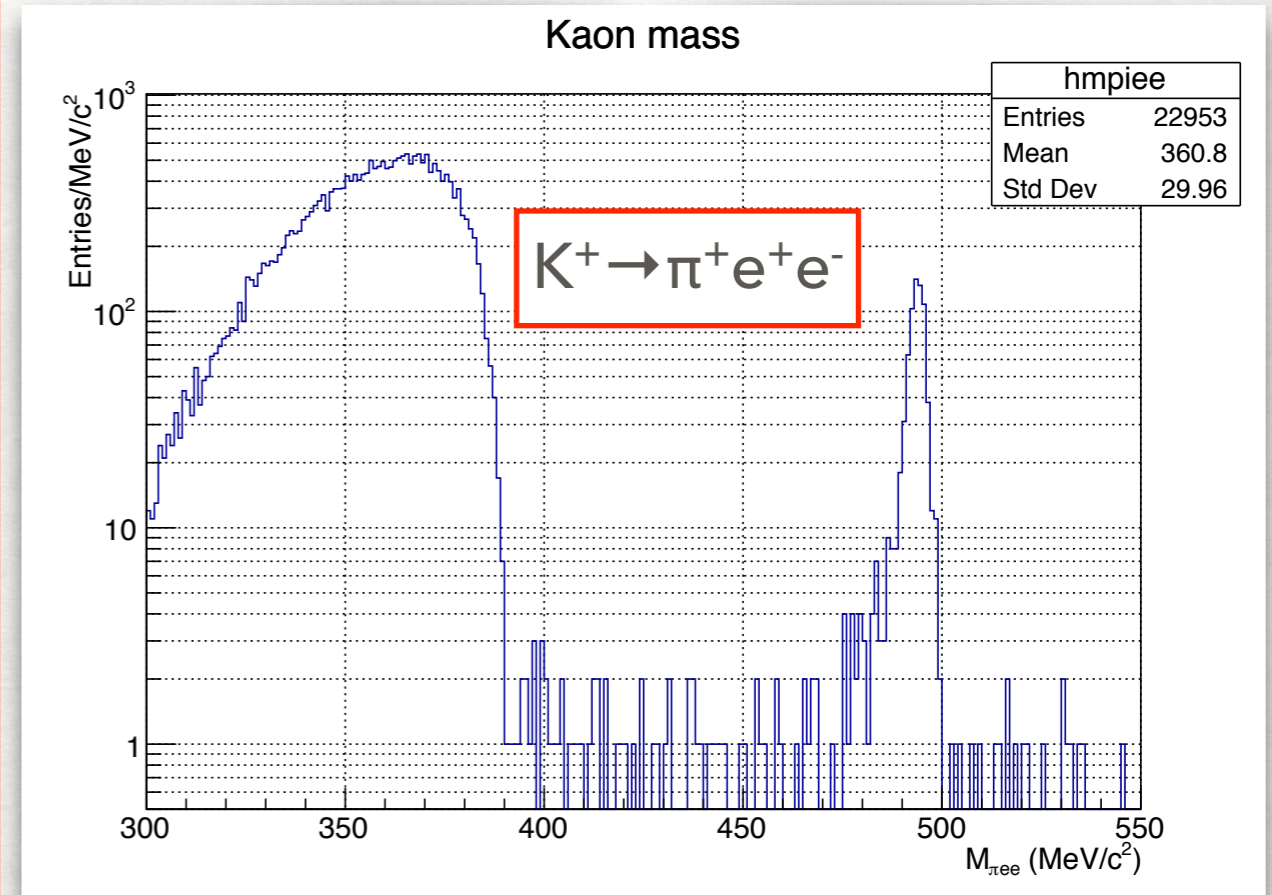
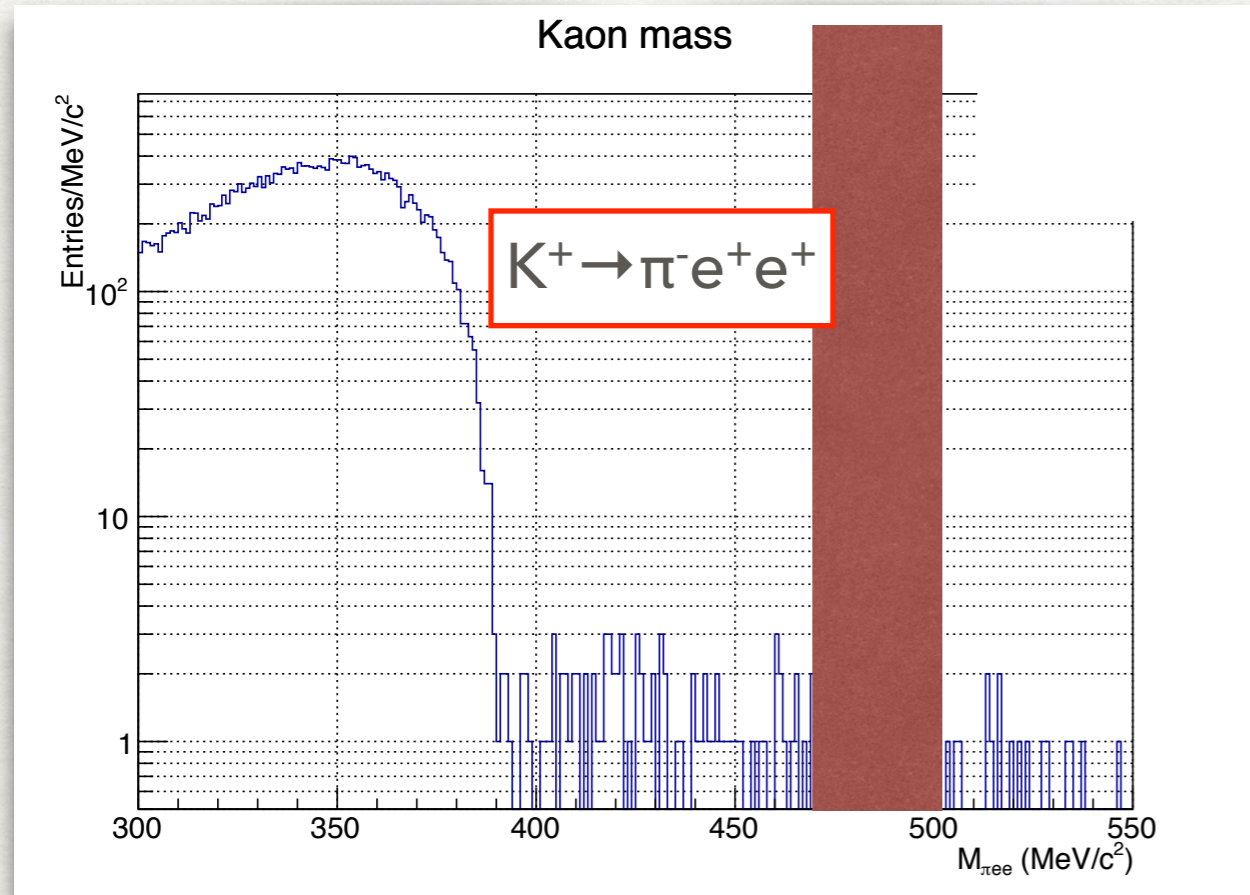
Particle identification. SELECTION 0: All particles are identified in LKr

	Non SM	SM
Generated decays	588000	292000
Good tracks	76312	40554
73 < Total Momentum < 77 GeV/c	73292	38955
piee Py < 30 MeV/c (to be tuned)	73224	38922
All tracks in LKr acceptance	42817	23555
All tracks not in LAV12	38973	21526
At least 3 clusters in LKr	34610	19168
All tracks associate with clusters	27164	15110
pi- found (eop<0.9) (pi+)	26466	14731
e1+ found (0.9<eop<1.15)	25204	14230
e2+ found (0.9<eop<1.15) (e-)	24354	13533
Mee > 140 MeV/c²	not applied	9910 $\approx 30\%$ loss
104 < Zvertex < 180 m (to be tuned)	23912	9712
Total cell energy > 20 GeV	23909	9711
Candidates(488<Mpiee<500=$\pm 3\sigma$)	23396	9490
Acceptance	0.0397891	0.0325

SELECTION

SM AND NON-SM MODES

Particle identification. SELECTION 0: All particles are identified in LKr



Candidates ($488 < M_{\pi ee} < 500 \text{ MeV/c}^2$)

667

$M_{\pi ee} < 488 \parallel M_{\pi ee} > 500 \text{ MeV/c}^2$

22286

SELECTION

SM AND NON-SM MODES

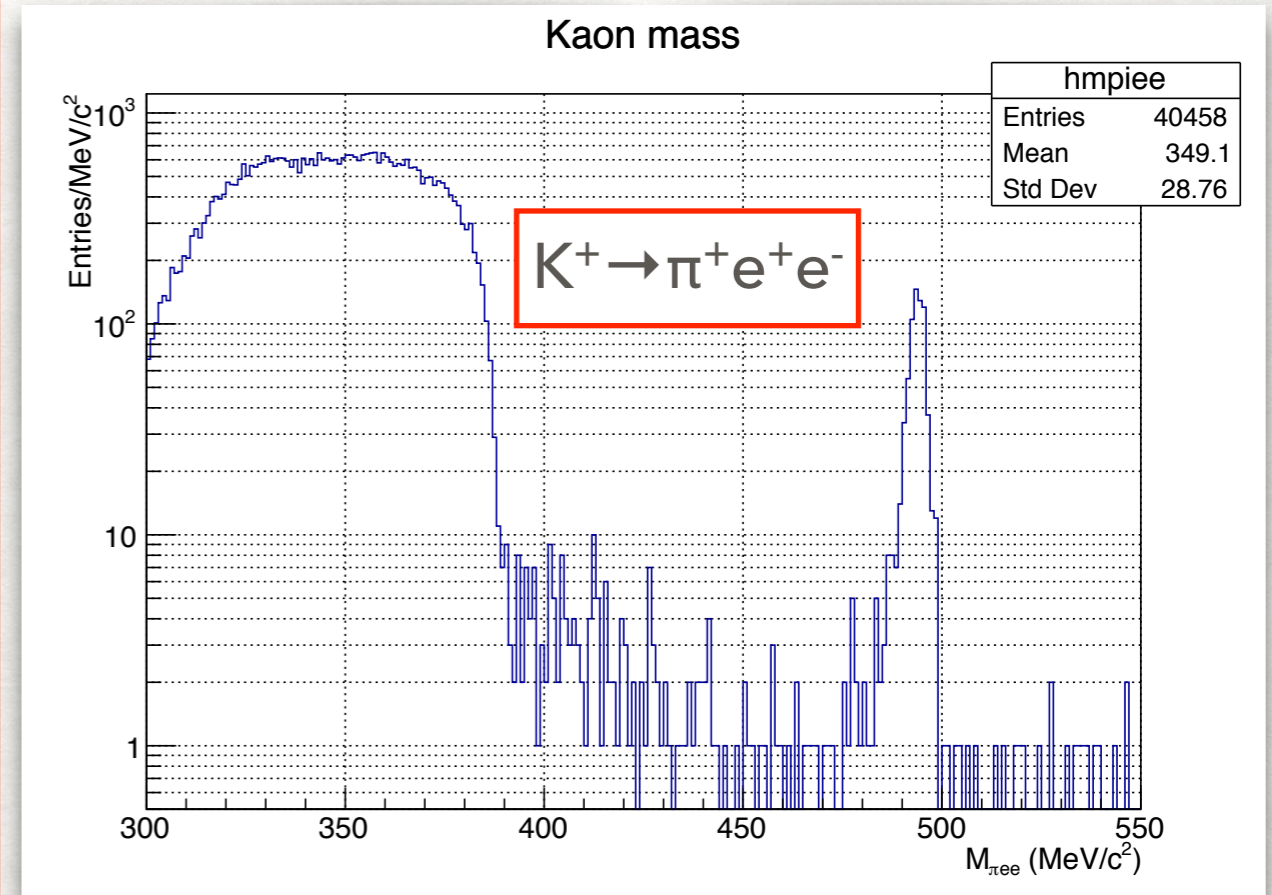
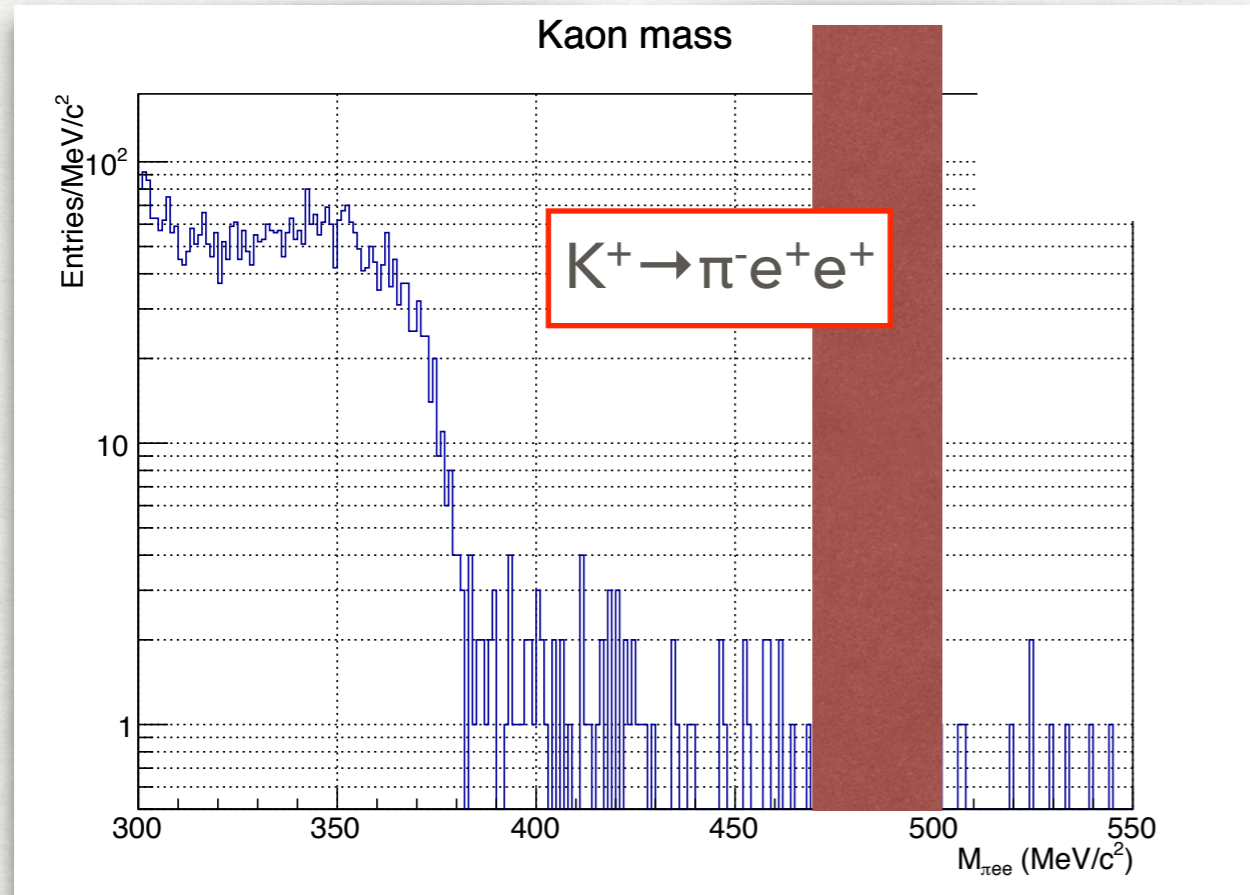
Particle identification. SELECTION 1: All particles are identified in RICH

	Non SM	SM
Generated decays	588000	292000
Good tracks	76312	40554
$73 < \text{Total Momentum} < 77 \text{ GeV}/c$	73292	38955
$\text{piee } P_y < 30 \text{ MeV}/c$ (to be tuned)	73224	38922
All tracks have RICH association	73224	38922
π^- found (π^+)	41349	26698
e^+ found	34847	21837
e^- found (e^+)	27712	14434
$M_{ee} > 140 \text{ MeV}/c^2$	not applied	10154
$104 < Z_{\text{vertex}} < 180 \text{ m}$ (to be tuned)	27143	9894
Total cell energy $> 20 \text{ GeV}$	26152	9502
Candidates($488 < M_{\text{piee}} < 500 = \pm 3\sigma$)	25491	9275
Acceptance	0.043352	0.0317637

SELECTION

SM AND NON-SM MODES

Particle identification. SELECTION 1: All particles are identified in RICH



Candidates ($488 < M_{\pi ee} < 500 \text{ MeV}/c^2$)

672

$M_{\pi ee} < 488 \parallel M_{\pi ee} > 500 \text{ MeV}/c^2$

39786

SELECTION

SM AND NON-SM MODES

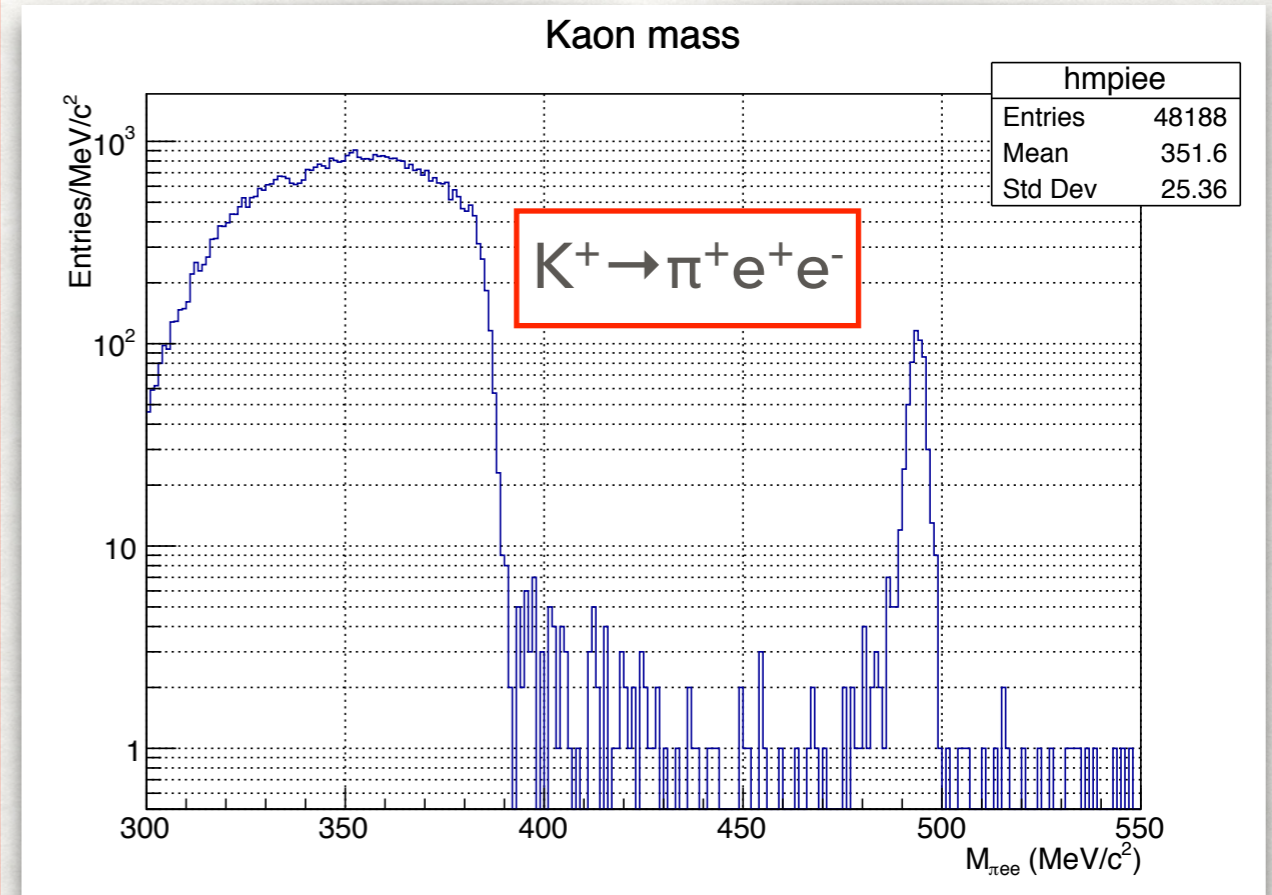
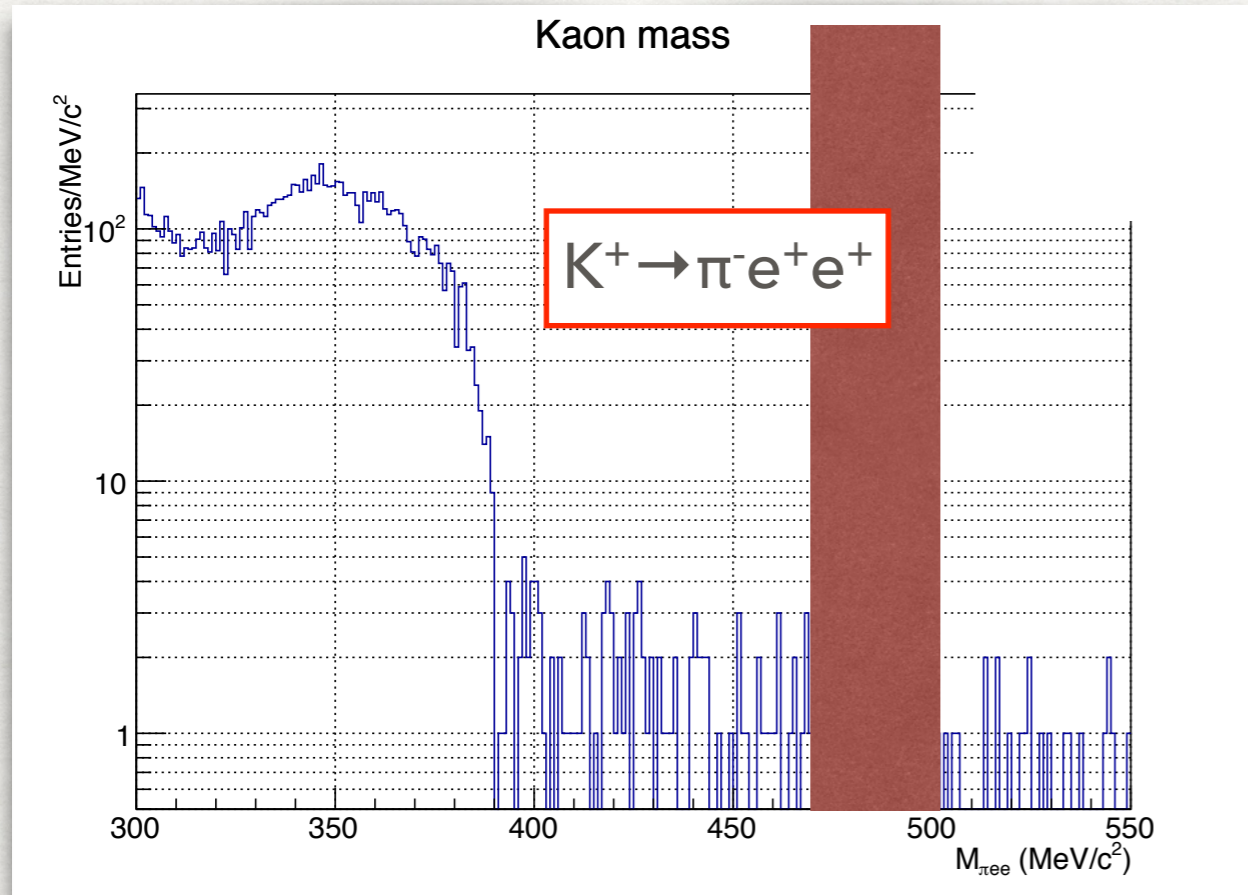
Particle identification. SELECTION 21: Lowest energy positrons in RICH (if $P < 30$ GeV, other in LKr, π^- in LKr for Non-SM decay. e^+/e^- with $P < 30$ GeV in RICH, other in LKr, π^+ in LKr for SM decay.

	Non SM	SM
Generated decays	588000	292000
Good tracks	76312	40554
$73 < \text{Total Momentum} < 77$ GeV/c	73292	38955
$\text{piee } P_y < 30$ MeV/c (to be tuned)	73224	38922
e1+ found	61797	34243
e2+ found (e-)	56169	24702
π^- found (π^+)	28097	13434
$M_{ee} > 140$ MeV/c ²	not applied	9620
$104 < Z_{\text{vertex}} < 180$ m (to be tuned)	27561	9436
Total cell energy > 20 GeV	27040	9174
Candidates($488 < M_{\text{piee}} < 500 = \pm 3\sigma$)	26395	8947
Acceptance	0.0448895	0.0306404

SELECTION

SM AND NON-SM MODES

Particle identification. SELECTION 21: Lowest energy positrons in RICH (if $P < 30$ GeV, other in LKr, pi- in LKr for Non-SM decay. e+/e- with $P < 30$ GeV in RICH, other in LKr, pi+ in LKr for SM decay.



Candidates ($488 < M_{\text{piee}} < 500 \text{ MeV}/c^2$)

531

$M_{\text{piee}} < 488 \parallel M_{\text{piee}} > 500 \text{ MeV}/c^2$

47657

SELECTION

SM AND NON-SM MODES

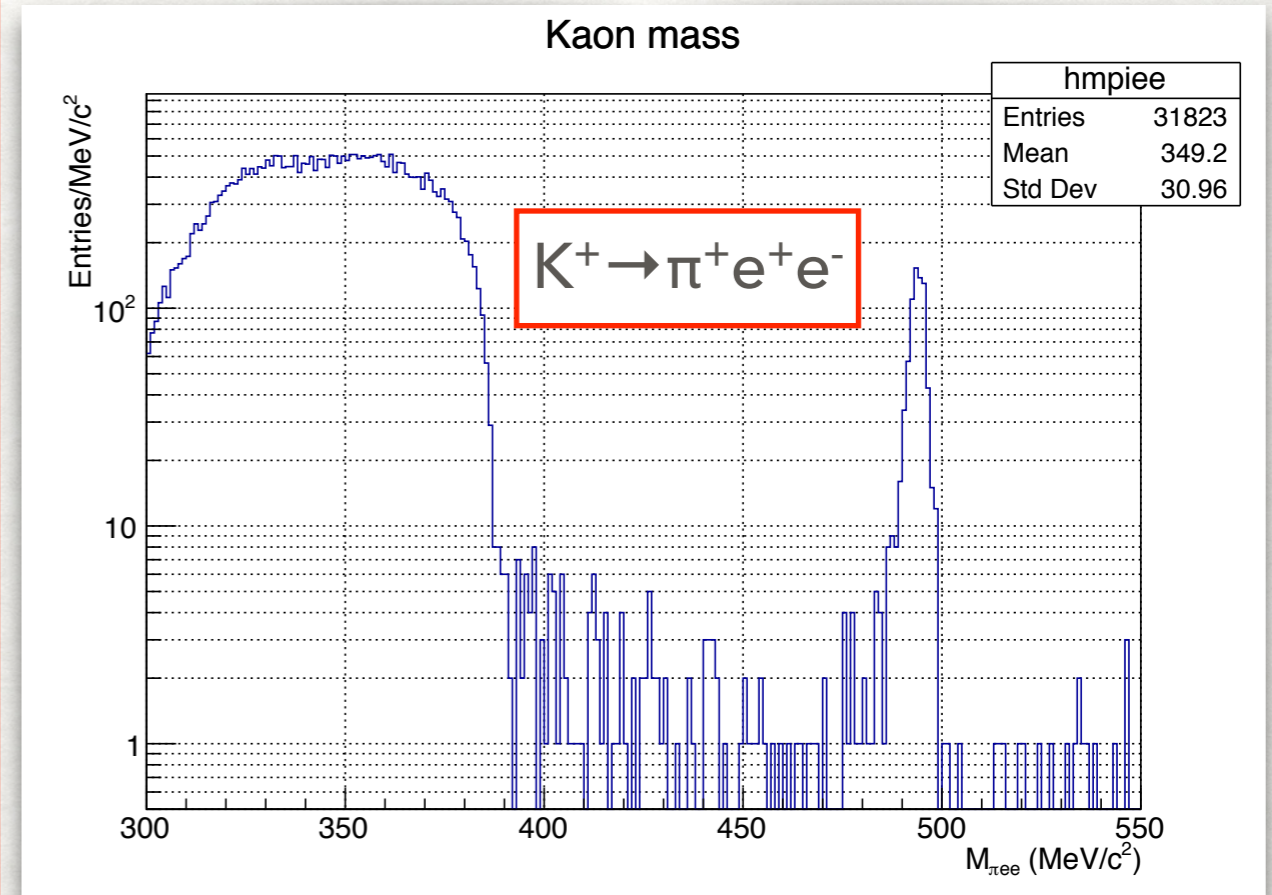
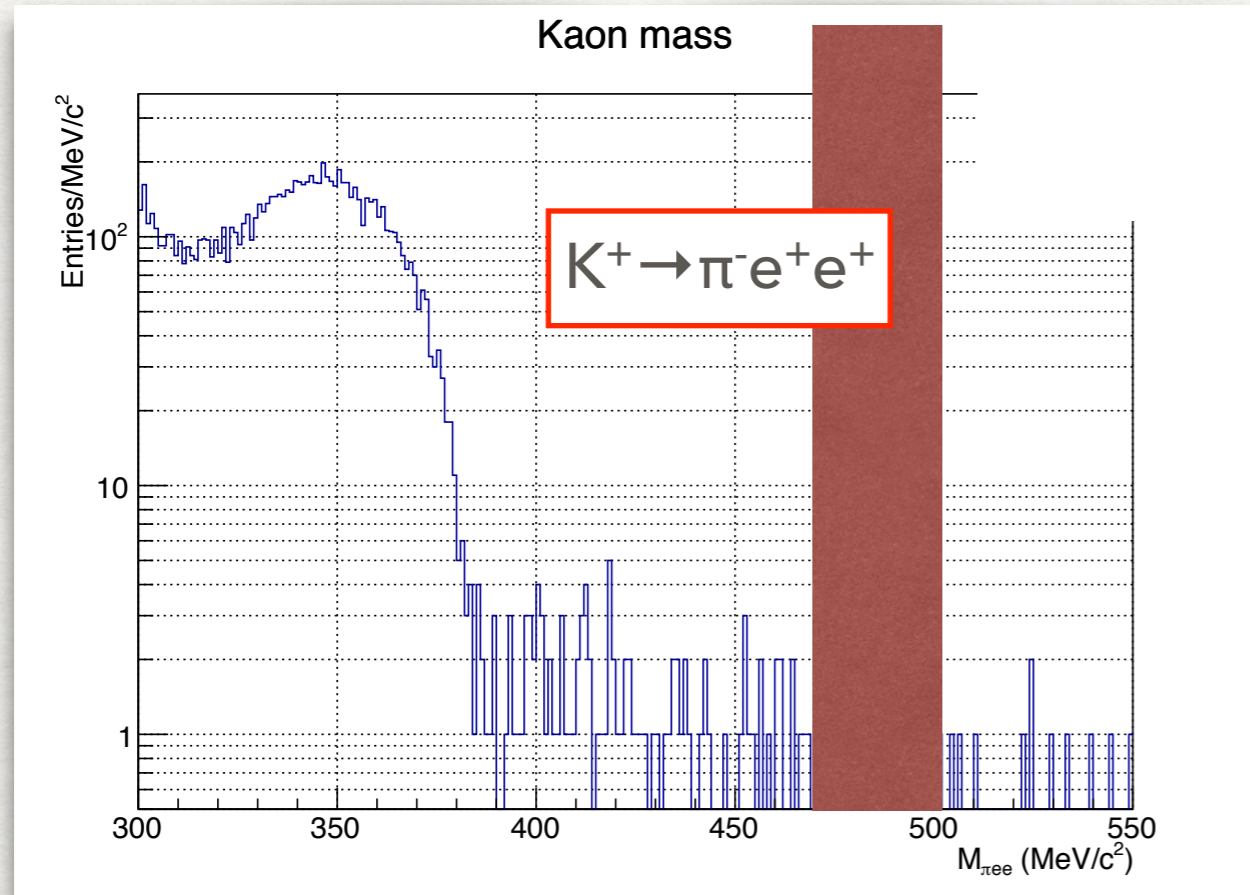
Particle identification. SELECTION 22: Lowest energy positrons in RICH (if $P < 30$ GeV, other in LKr, π^- in RICH for Non-SM decay. e^+/e^- with $P < 30$ GeV in RICH, other in LKr, π^+ in RICH for SM decay.

	Non SM	SM
Generated decays	588000	292000
Good tracks	76312	40554
$73 < \text{Total Momentum} < 77$ GeV/c	73292	38955
$\text{piee } P_y < 30$ MeV/c (to be tuned)	73224	38922
e1+ found	61797	34410
e2+ found (e-)	56169	24959
π^- found (π^+)	31126	16633
$M_{ee} > 140$ MeV/c ²	not applied	11789
$104 < Z_{\text{vertex}} < 180$ m (to be tuned)	30508	11506
Total cell energy > 20 GeV	29532	11198
Candidates($488 < M_{\text{piee}} < 500 = \pm 3\sigma$)	28795	10951
Acceptance	0.0489711	0.0375034

SELECTION

SM AND NON-SM MODES

Particle identification. SELECTION 22: Lowest energy positrons in RICH (if $P < 30$ GeV, other in LKr, π^- in RICH for Non-SM decay. e^+/e^- with $P < 30$ GeV in RICH, other in LKr, π^+ in RICH for SM decay.



Candidates ($488 < M_{\pi ee} < 500 \text{ MeV}/c^2$)

716

$M_{\pi ee} < 488 \parallel M_{\pi ee} > 500 \text{ MeV}/c^2$

31107

SELECTION

SM AND NON-SM MODES

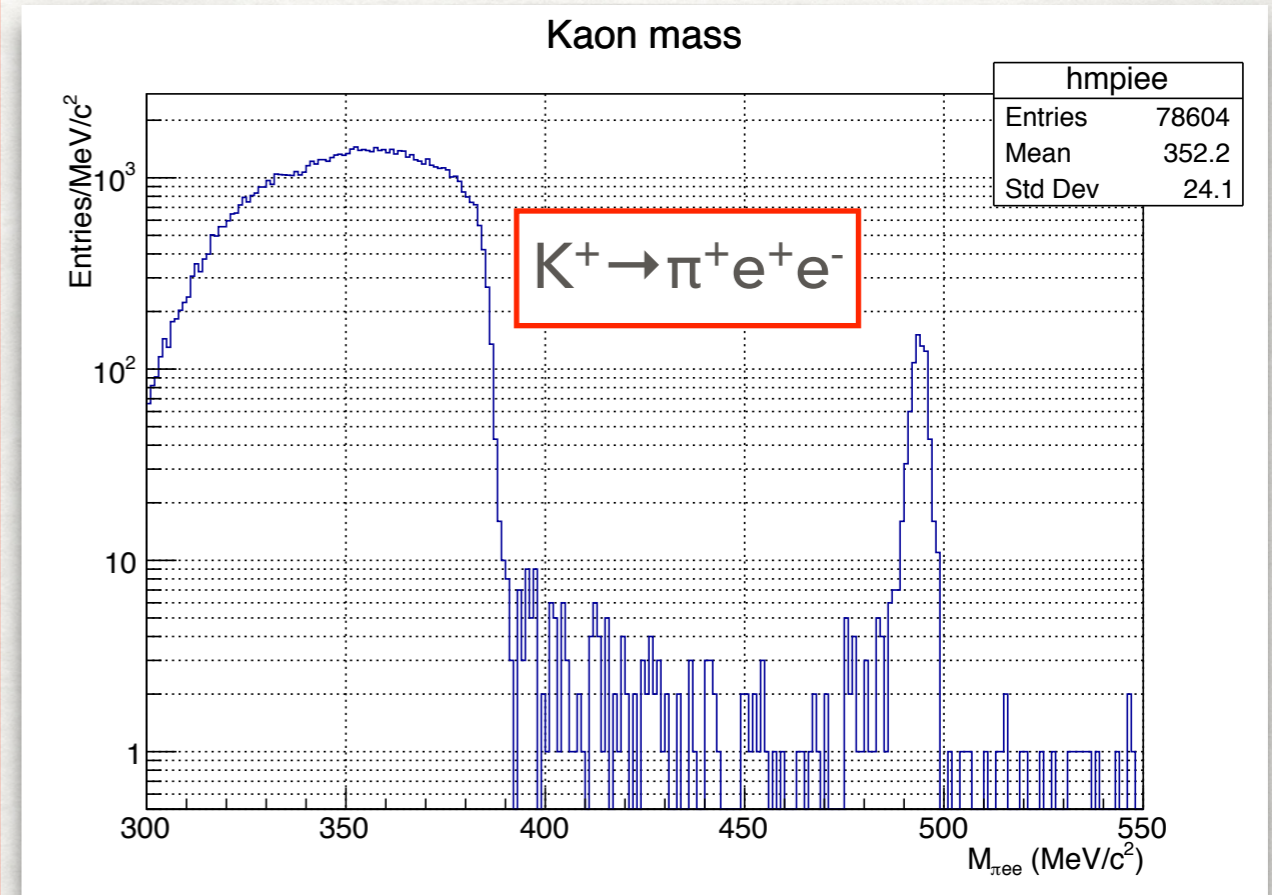
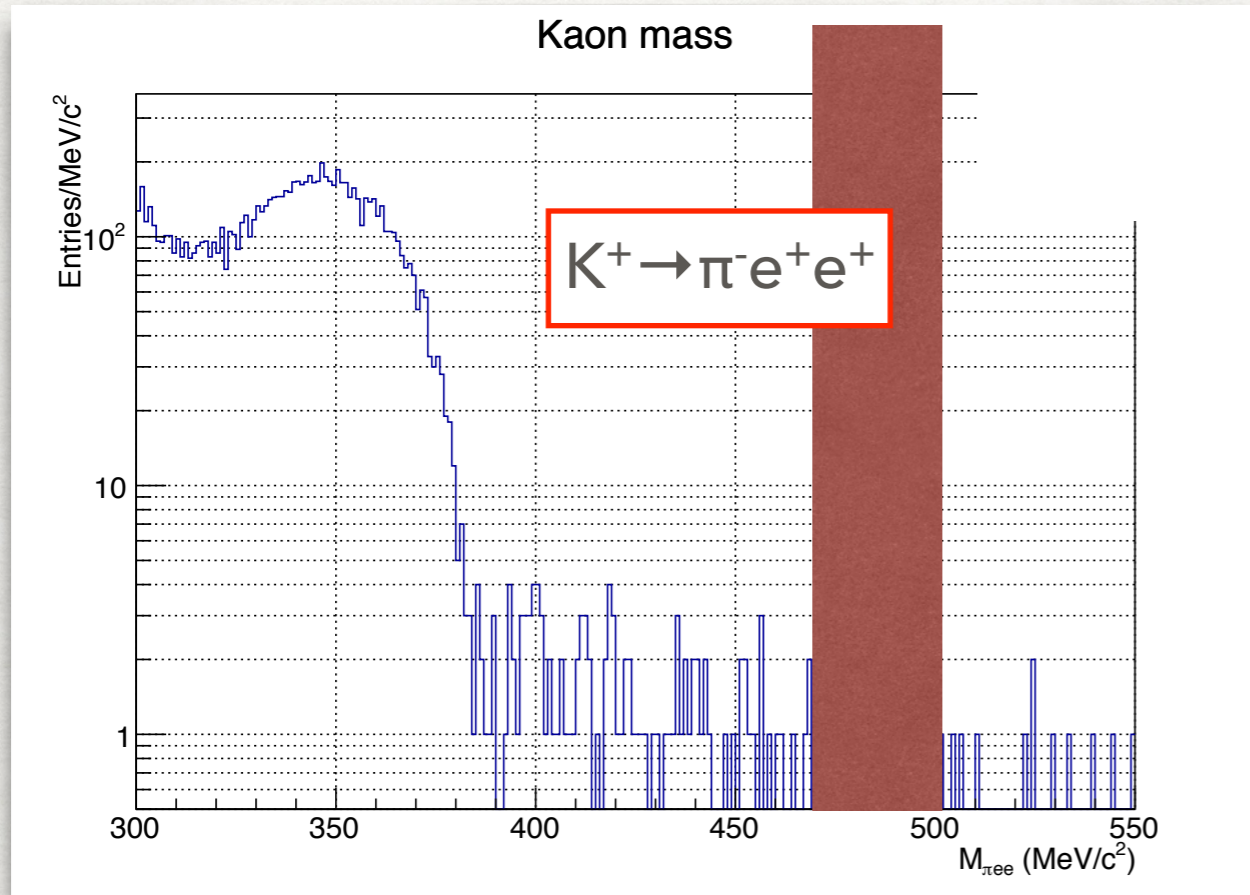
Particle identification. SELECTION 24: All particles identified in RICH if $P < 30 \text{ GeV}$, else in LKr

	Non SM	SM
Generated decays	588000	292000
Good tracks	76312	40554
$73 < \text{Total Momentum} < 77 \text{ GeV}/c$	73292	38955
$\text{piee } P_y < 30 \text{ MeV}/c$ (to be tuned)	73224	38922
e1+ found	61797	34869
e2+ found (e-)	56169	25201
pi- found (pi+)	30282	17367
$M_{ee} > 140 \text{ MeV}/c^2$	not applied	12310
$104 < Z_{\text{vertex}} < 180 \text{ m}$ (to be tuned)	29709	12028
Total cell energy $> 20 \text{ GeV}$	29130	11733
Candidates($488 < M_{\text{piee}} < 500 = \pm 3\sigma$)	28394	11463
Acceptance	0.0482891	0.0392568

SELECTION

SM AND NON-SM MODES

Particle identification. SELECTION 24: All particles identified in RICH if $P < 30 \text{ GeV}$, else in LKr



Candidates ($488 < M_{\text{piee}} < 500 \text{ MeV}/c^2$)

700

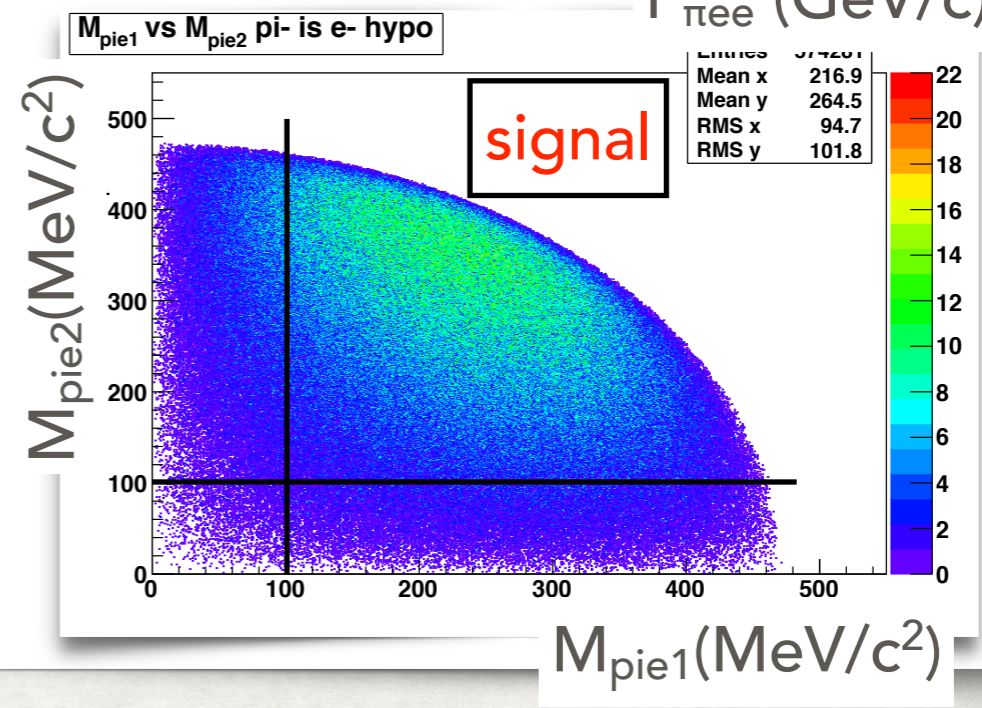
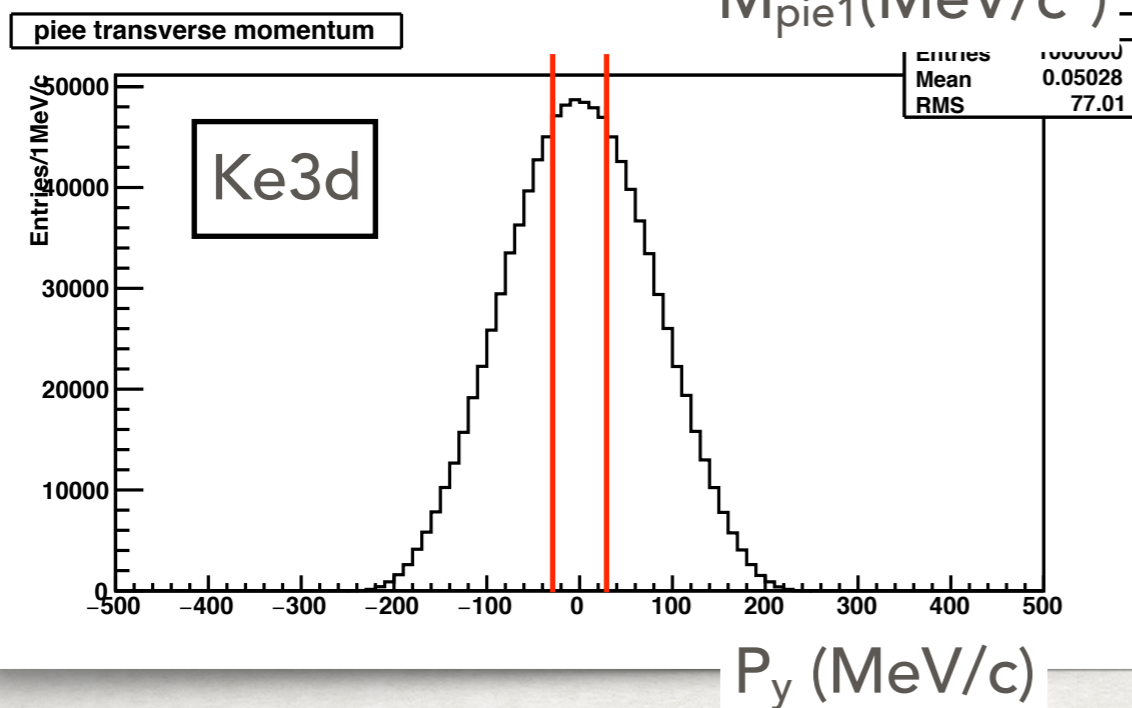
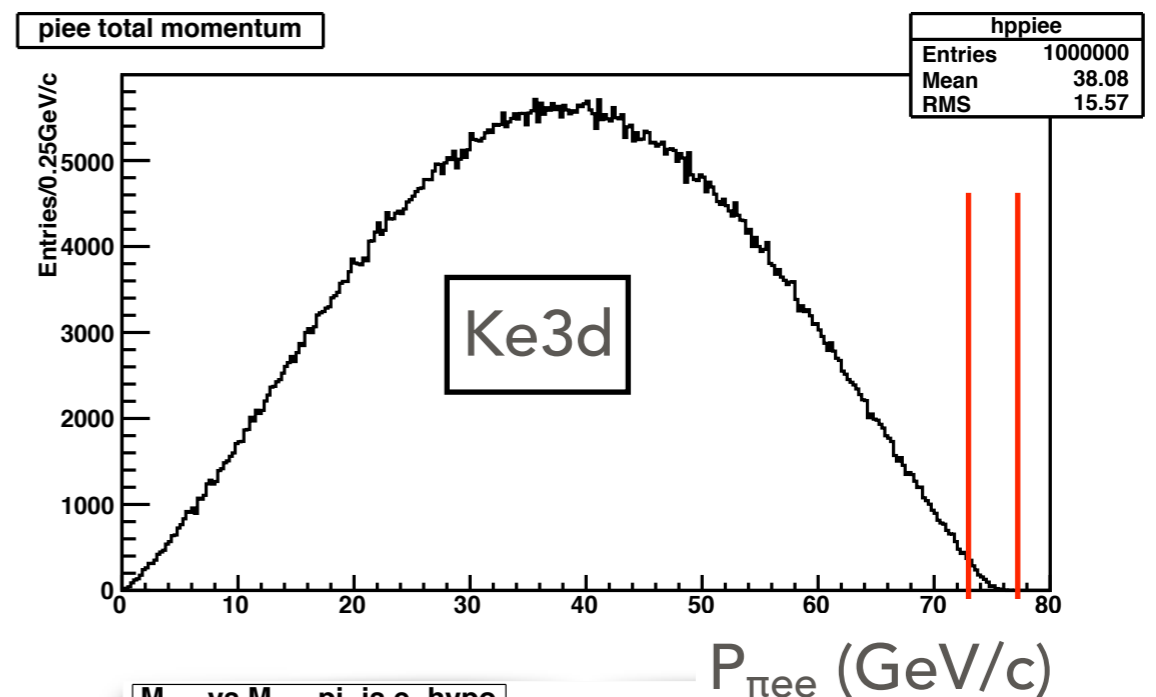
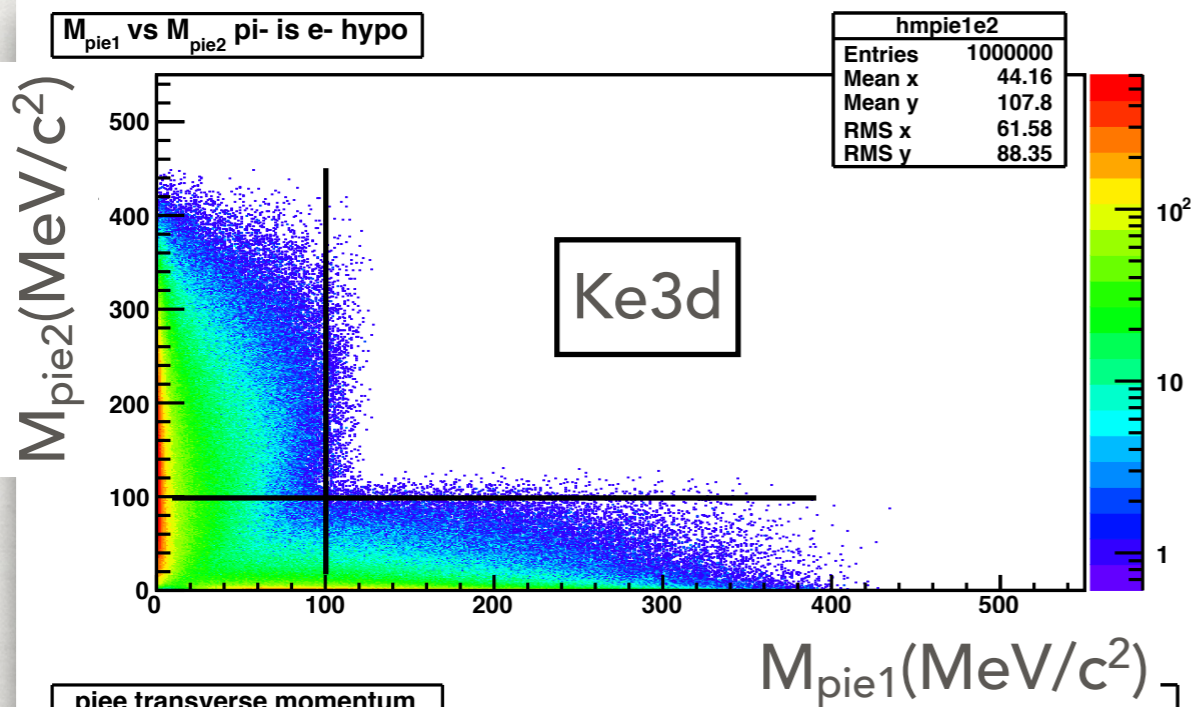
$M_{\text{piee}} < 488 \parallel M_{\text{piee}} > 500 \text{ MeV}/c^2$

77904

SELECTION

FOR NON-SM ONLY

Particle identification. SELECTION 3: e1/e2 identified in RICH if $P < 30 \text{ GeV}$, else in LKr.
 No pi- ID, reject $K^+ \rightarrow e^+ \pi^0 \nu$ ($\pi^0 \rightarrow e^+ e^- \gamma$) decay by kinematics. Toy MC.



SELECTION

NON-SM ONLY

Particle identification. SELECTION 3: e1/e2 identified in RICH if $P < 30 \text{ GeV}$, else in LKr.
 No pi- ID, reject $K^+ \rightarrow e^+ \pi^0 \nu$ ($\pi^0 \rightarrow e^+ e^- \gamma$) decay by kinematics.

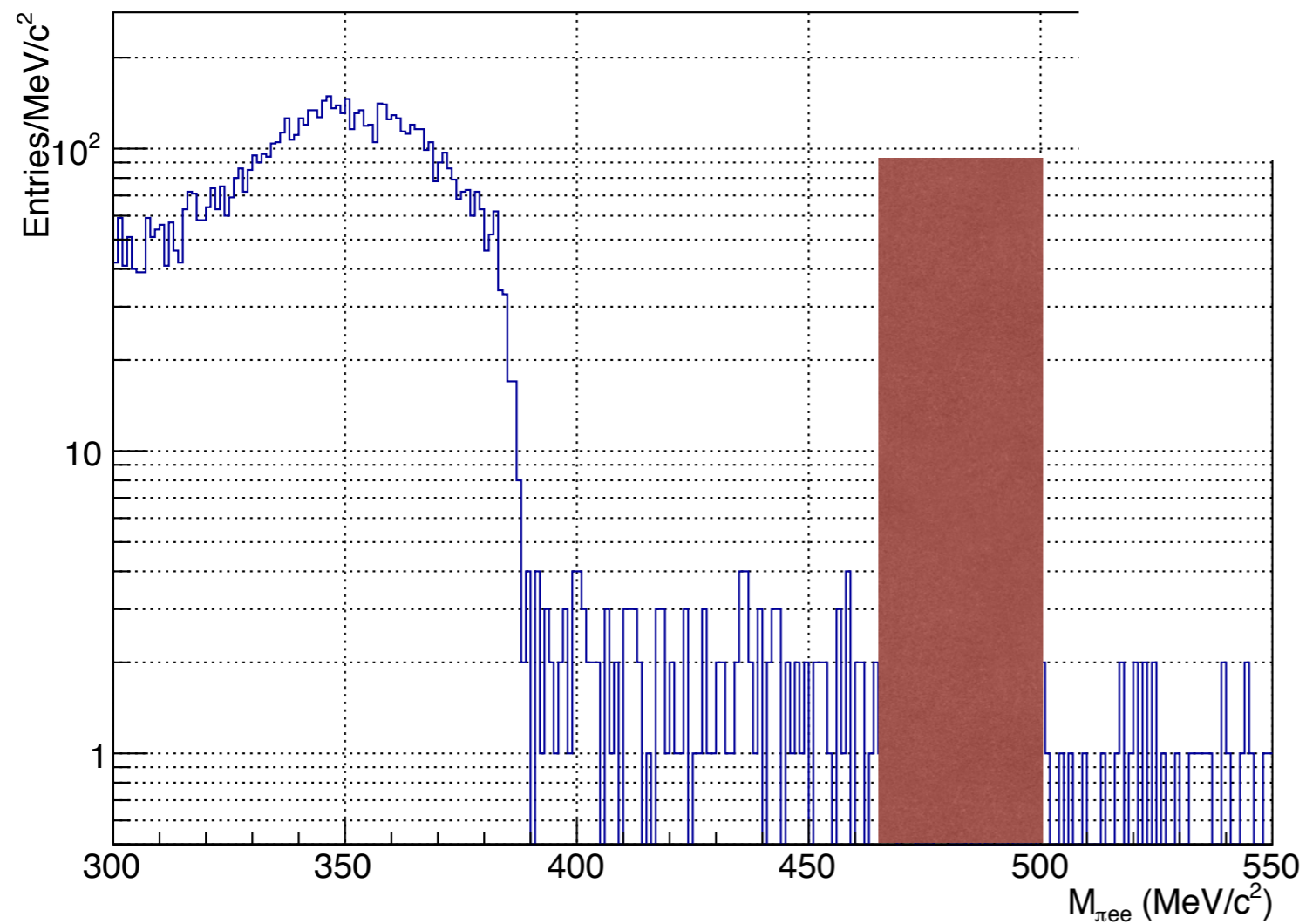
	Non SM
Generated decays	588000
Good tracks	76312
$73 < \text{Total Momentum} < 77 \text{ GeV}/c$	73292
piee $ \text{Pt} < 30 \text{ MeV}/c$ (to be tuned)	73224
e1+ found	61797
e2+ found (e-)	56169
$M_{\text{pie1}} > 100 \parallel M_{\text{pie2}} > 100 \text{ MeV}/c^2$ (to be tuned)	44203
$104 < Z_{\text{vertex}} < 180 \text{ m}$ (to be tuned)	43349
Total cell energy $> 20 \text{ GeV}$	42256
Candidates ($488 < M_{\text{piee}} < 500 = \pm 3\sigma$)	41270
Acceptance	0.0701871

SELECTION

NON-SM MODE

Particle identification. SELECTION 3: e1/e2 identified in RICH if $P < 30\text{GeV}$, else in LKr.
No pi- ID, reject $K^+ \rightarrow e^+ \pi^0 \nu$ ($\pi^0 \rightarrow e^+ e^- \gamma$) decay by kinematics.

Kaon mass



SELECTION: SUMMARY

SM AND NON-SM MODES

Selection	Non SM: candidates (acceptance)	SM: candidates (acceptance)
0	closed box (0.040)	667 (0.033)
1	closed box (0.043)	672 (0.032)
21	closed box (0.045)	531 (0.031)
22	closed box (0.049)	716 (0.038)
24	closed box (0.048)	700 (0.039)
3	closed box (0.070)	not applied

CONCLUSION

- Acceptance increased ~factor of 2 for non-SM mode
- Good signal resolution ~ 2 MeV/c
- Signal event sensitivity for non-SM decay based on the best acceptance selection is $\sim 10^{-10}$ for 2016 data sample (I used number of decayed kaons from Evgueni's talk on 1 March 2016).
- Several selections are introduced for SM mode with almost the same acceptance
- Next step: background study