Tau reconstruction for reduced ECAL size

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Outline:

- Tau decay modes
- Analysis procedures
- Comparison between ILD models (baseline vs reduced radius)

High granularity calorimeter for ILD workshop
LLR, Feb 2015

Tau decay modes

Tau jet reconstruction: a crucial key for an estimation of detector performance.
Tau jet is compact.

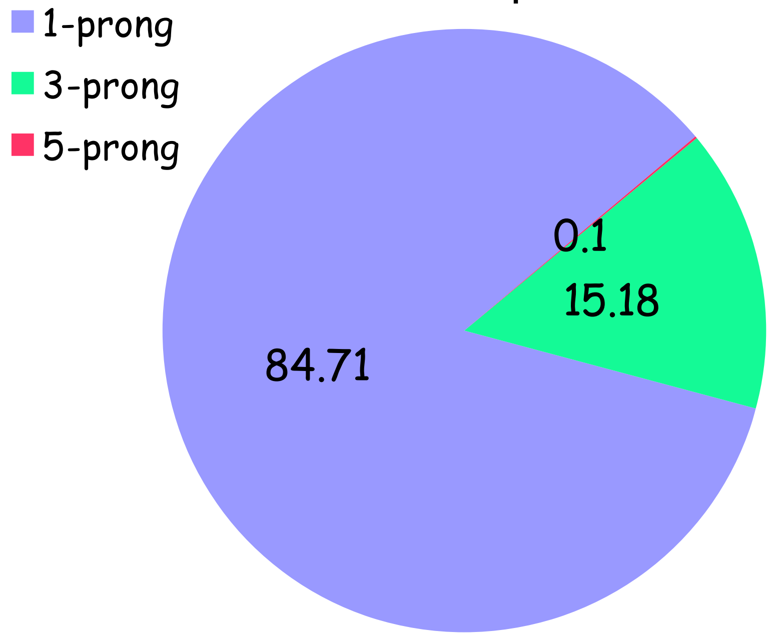
Topologically: 3 decay modes (1,3,5-prong)

1-prong: single charged pion and any number of π^0
3-prong: $\pi^+\pi^-\pi^+$

Final state	Branching fraction
$e^-\bar{\nu}_e\nu_\tau$	$17.85 \pm 0.05\%$
$\mu^-\bar{\nu}_\mu\nu_\tau$	$17.36 \pm 0.05\%$
$\pi^-\nu_\tau$	$10.91 \pm 0.07\%$
$\rho^-\nu_\tau$ $(\rho^- \to \pi^-\pi^0)$	$25.52 \pm 0.10\%$
$a_1^-\nu_\tau$ $(a_1^- \to \pi^-\pi^0\pi^0)$	$9.27 \pm 0.12\%$
$a_1^-\nu_\tau$ $(a_1^- \to \pi^-\pi^+\pi^-)$	$8.99 \pm 0.06\%$
24 other modes	10.10%

Branching fraction of main decays

7 tracks: very infrequent



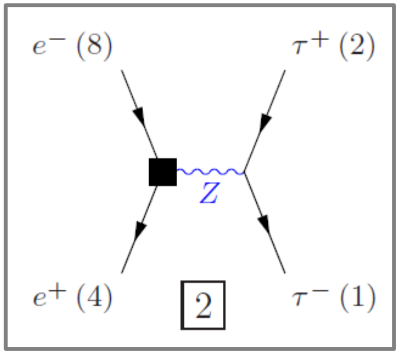
This analysis:
consider only 1-prong decay

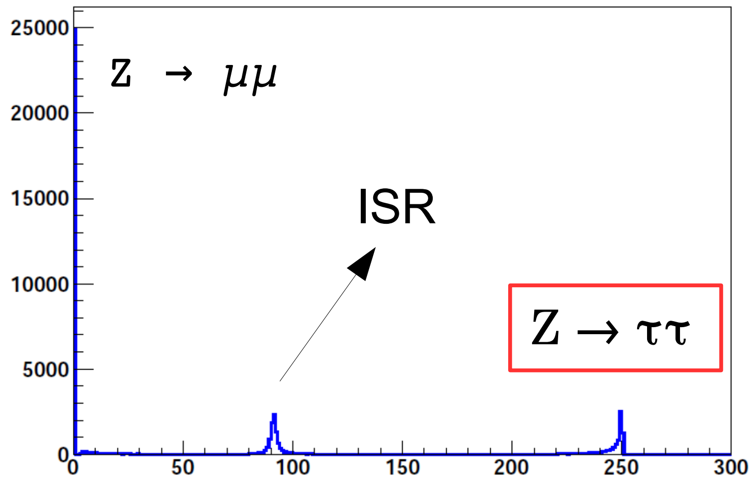
$\pi^-\nu_\tau$	0 photon
$\rho^-\nu_\tau$ $(\rho^- \to \pi^-\pi^0)$	2 photons
$a_1^-\nu_\tau$ $(a_1^- \to \pi^-\pi^0\pi^0)$	4 photons

Samples

DBD generators $e^+e^- \rightarrow Z \rightarrow \tau^-\tau^+$
at 250 GeV C.M. energy
(mixed with $e^+e^- \rightarrow Z \rightarrow \mu^-\mu^+$
→ preselection of τ events using generator informations)

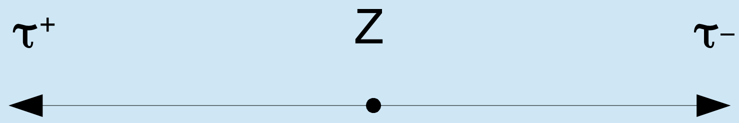
τ energy ~ 125 GeV



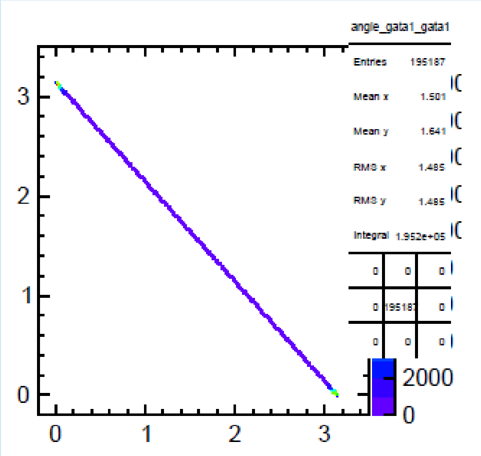


Tau-tau invariant mass

- Two independent Tau-decay are used (double statistics)



The two tau's are back-to-back in the Z-rest frame

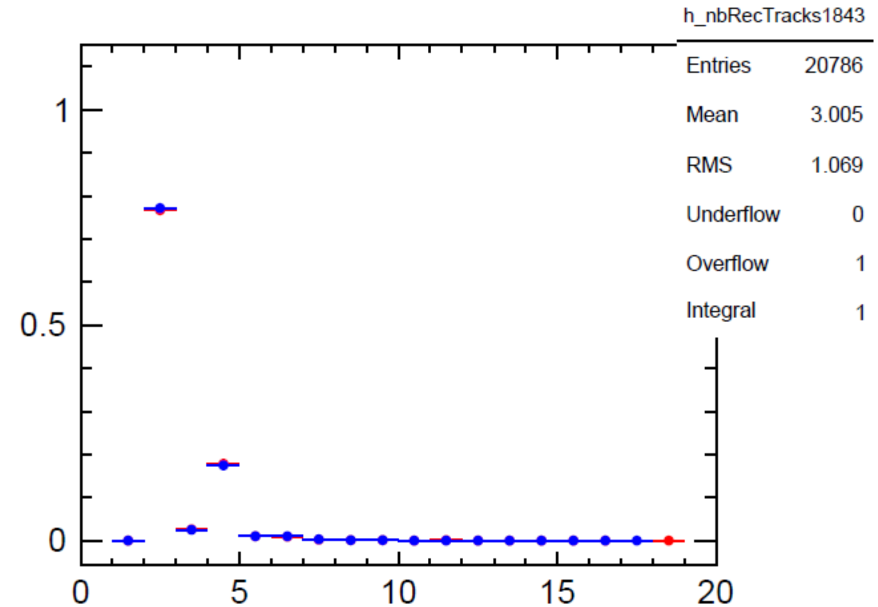


Angle cluster-tau1
Vs angle cluster-tau2

Simulation & reconstruction

Softwares
Ilcsoft v01-17-06, Mokka-08-04
Garlic v3.0.2

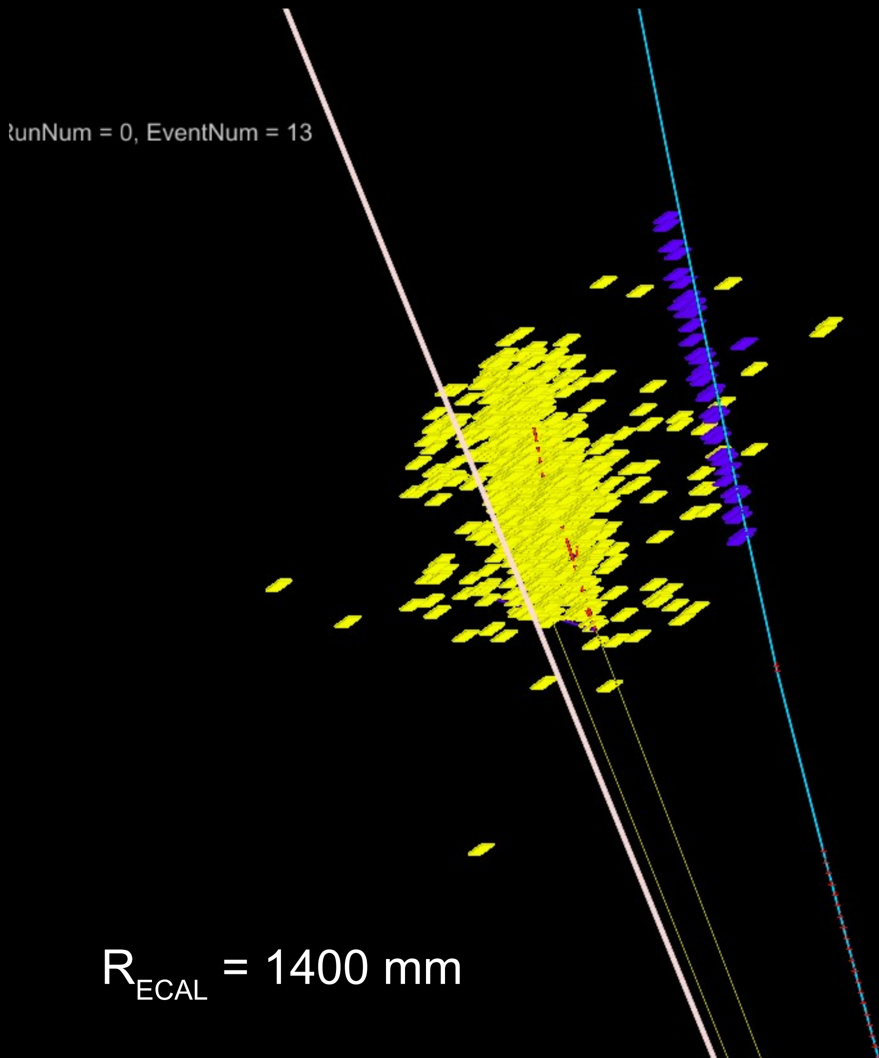
- Baseline ILD design (DBD): **SiW ECAL**, $\mathbf{R_{ECAL}^{inner} = 1843\ mm}$
- Alternative setup: $\mathbf{R_{ECAL}^{inner} = 1450\ mm}$
- Reduced TPC radius → ECAL, HCAL, Yoke, … radii are reduced
- Keep same aspect ratio: Radius/Length (→ for a reduced radius, the length is reduced as well)
- Other configurations unchanged (cell size, thicknesses)



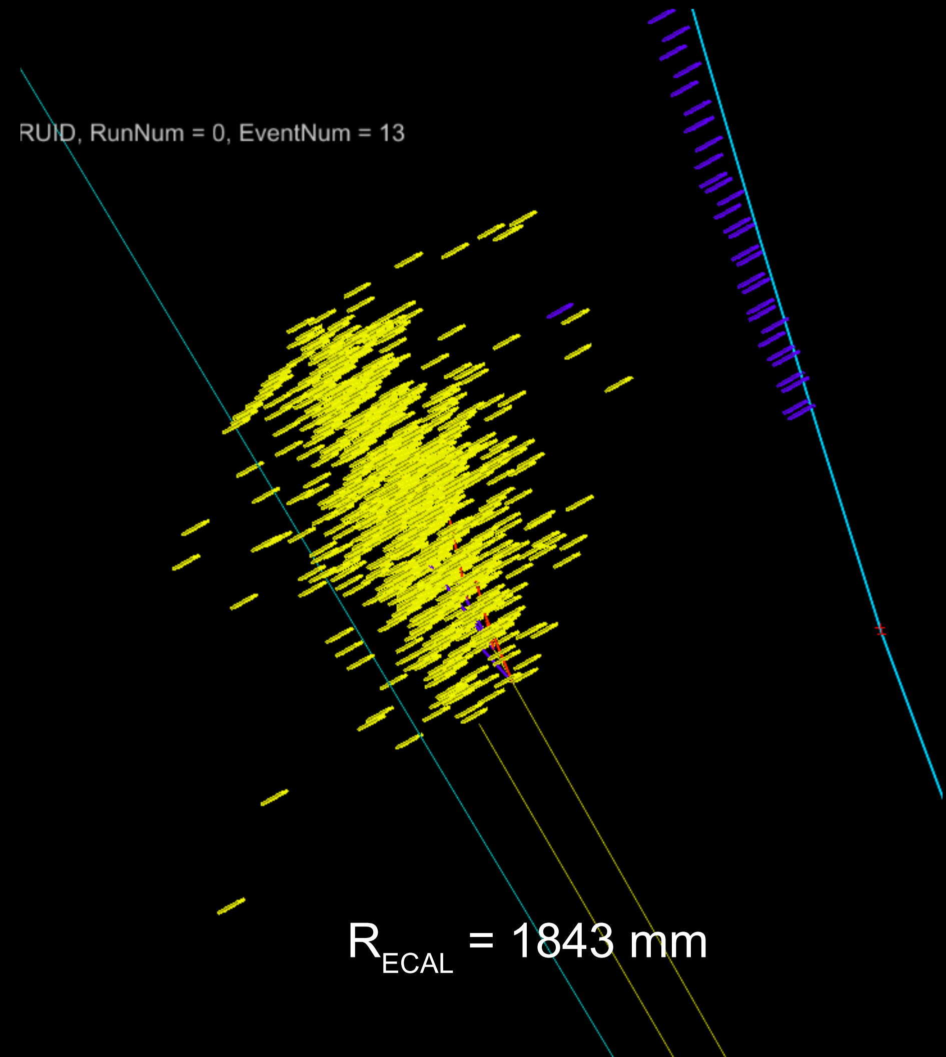
Nb of reconstructed tracks with baseline ILD and with reduced TPC radius
→ **no difference**

- Garlic (v3.0.2) is used for photon reconstruction
- however its cuts are not used but some simple cuts based on track-cluster distance & cluster energy
- Strategy:
  - preselection based on MC info: choose only **1-prong** decays
  - $|\cos(\theta)|^{tau} < 0.7$
  - photon in tau direction within 0.5 rad (to be optimised)
  - sample with only **one track** in tau direction

Example (1)

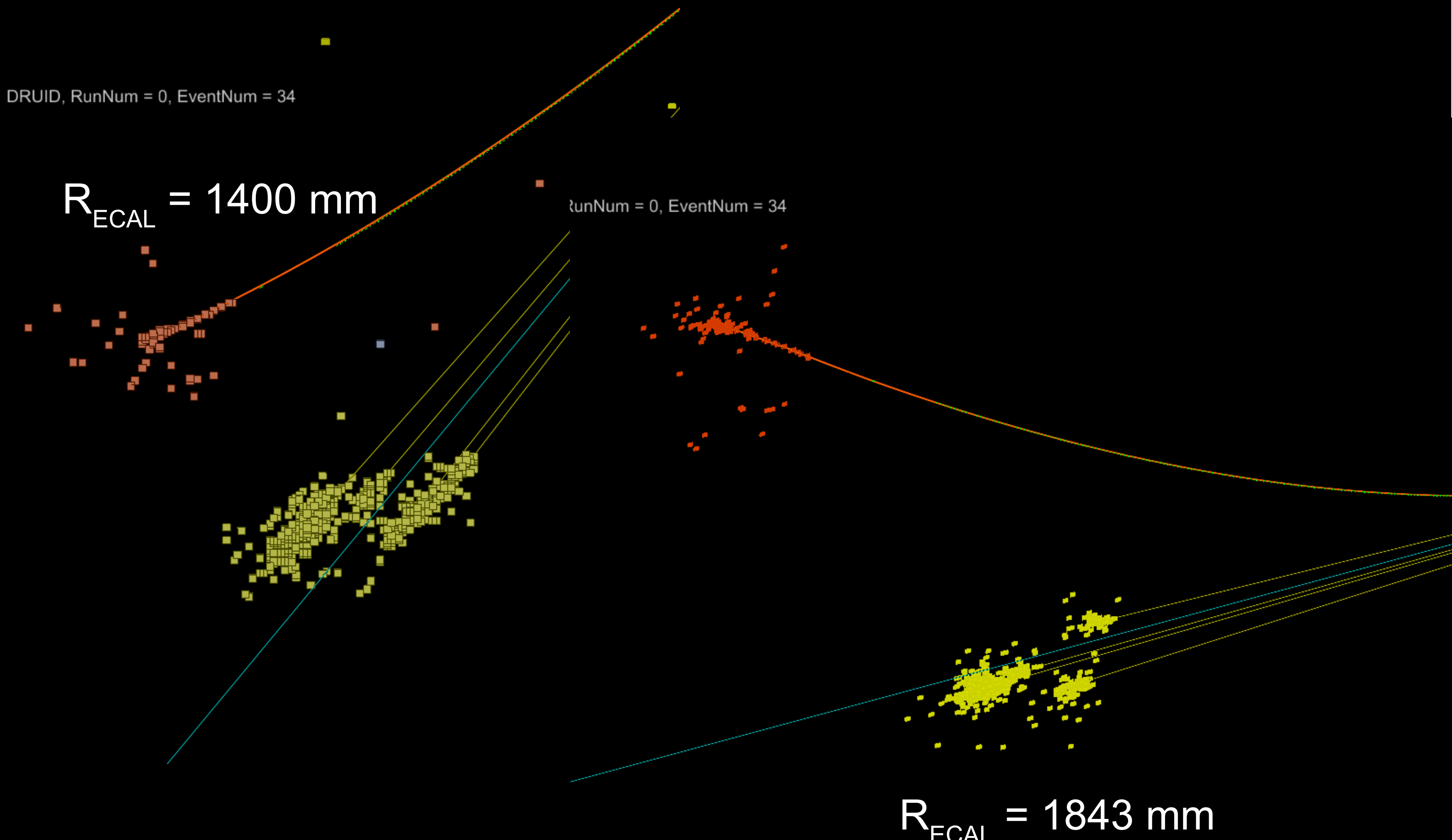


R_{ECAL} = 1400 mm



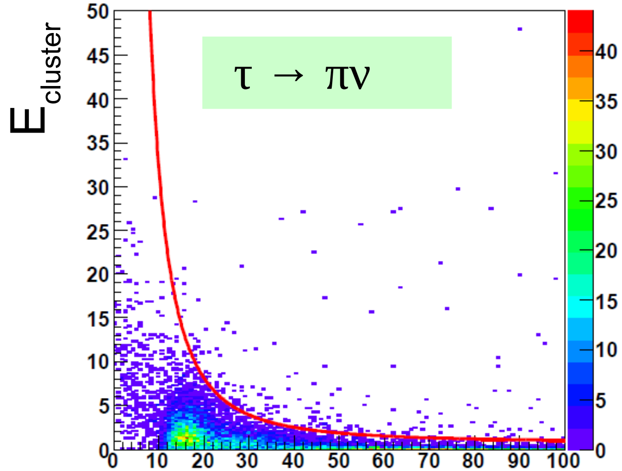
R_{ECAL} = 1843 mm

Example (2)

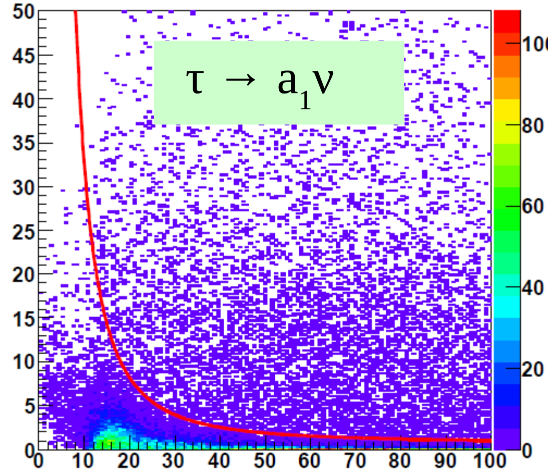

DRUID, RunNum = 0, EventNum = 34
R_{ECAL} = 1400 mm
unNum = 0, EventNum = 34
R_{ECAL} = 1843 mm

Photon selection:

photonE vs distance to track



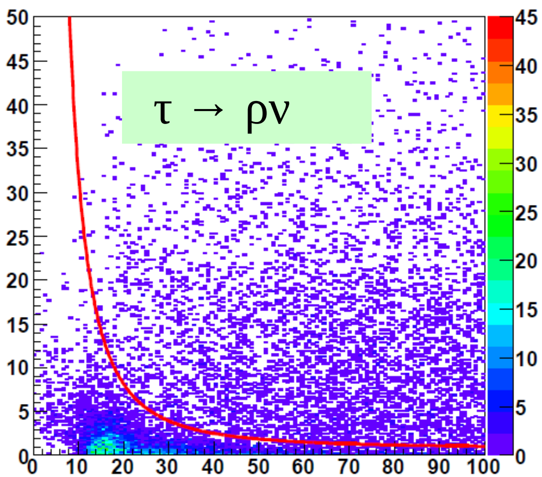
Cluster-track distance



Cluster-track distance

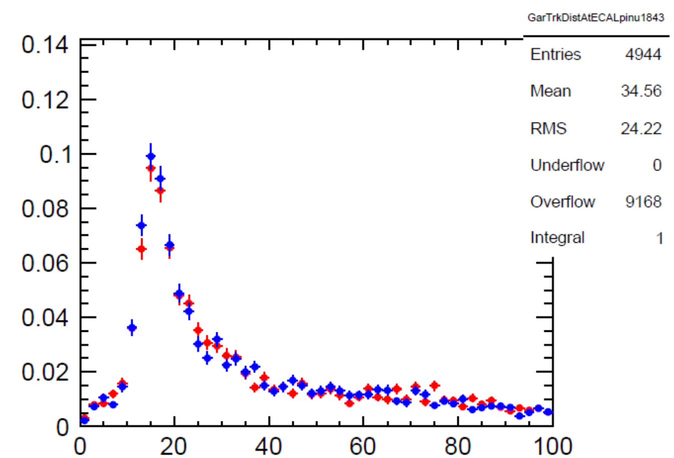
Aim to remove fake clusters at low energy or from pion

For the moments:
All cuts are the same for
ECAL**(R=1843)**
and ECAL**(R=1450)**



Cluster-track distance

$E > 4e3/d^2 + 0.5$
d : distance track-cluster

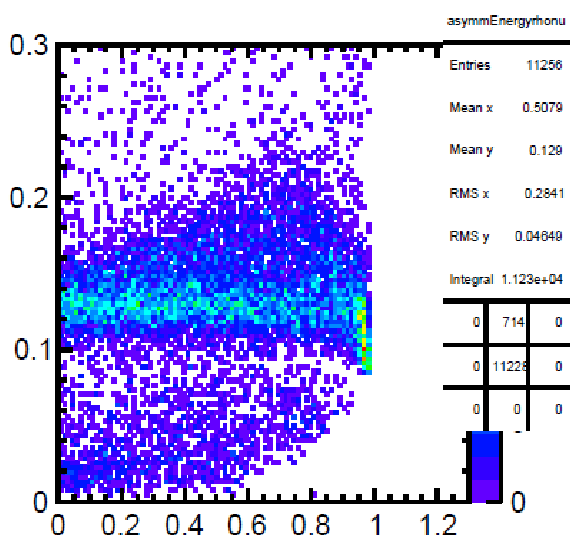


Comparison track-cluster distance at ECAL surface
1843 vs 1450

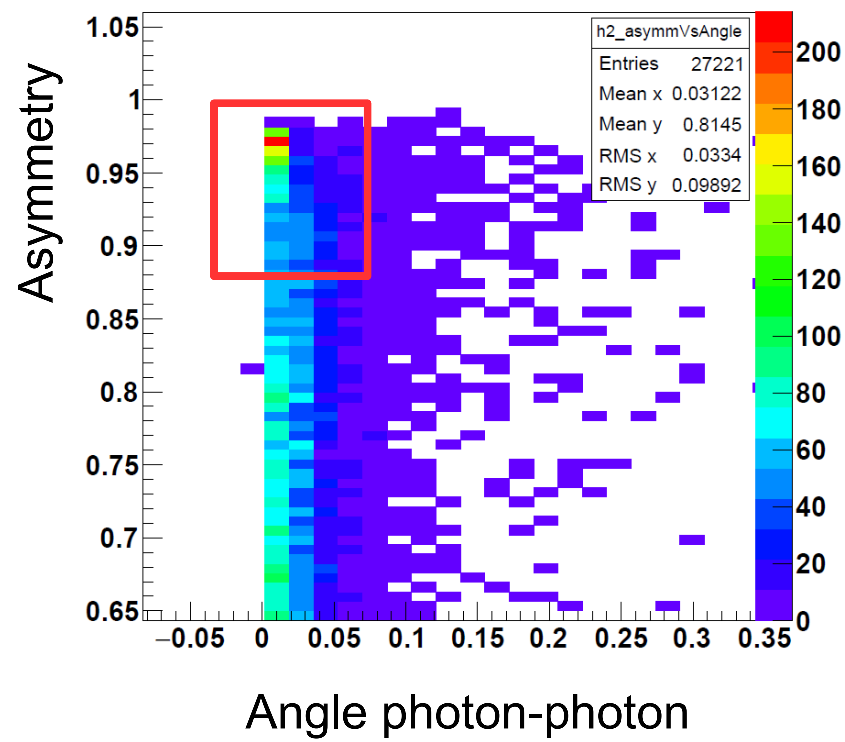
Photon selection: fake EM clusters

- Fake clusters created from interaction of with detector
- “Asymmetry” of energy very close to 1

$$\text{Asymmetry} = |E_{\gamma 1} - E_{\gamma 2}| \,/\, (E_{\gamma 1} - E_{\gamma 2})$$

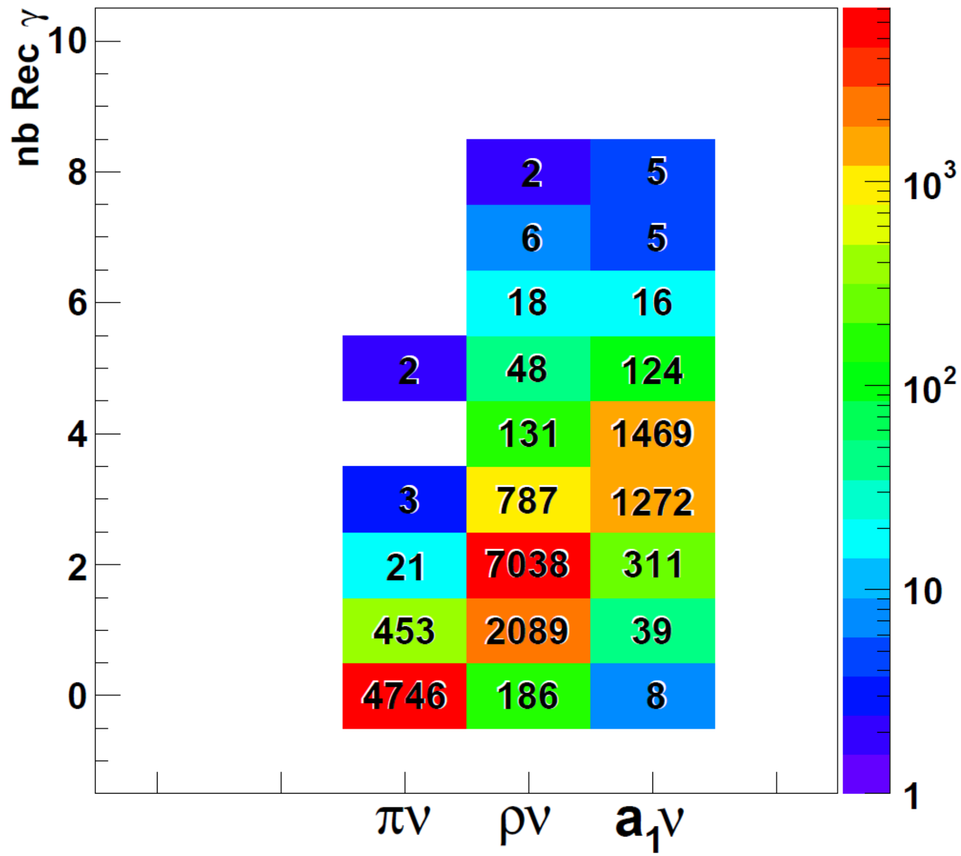


Example of photon invariant mass vs asymmetry

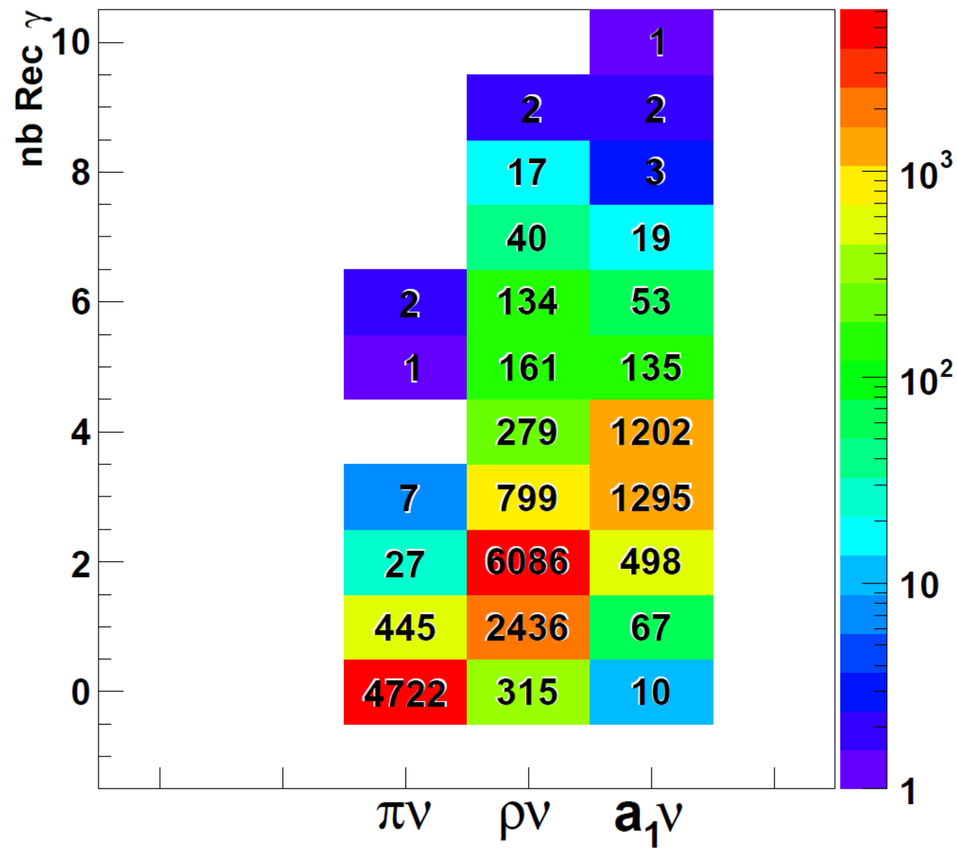


Choose to merge closest clusters with asymmetry close to 1.

Number of reconstructed photons



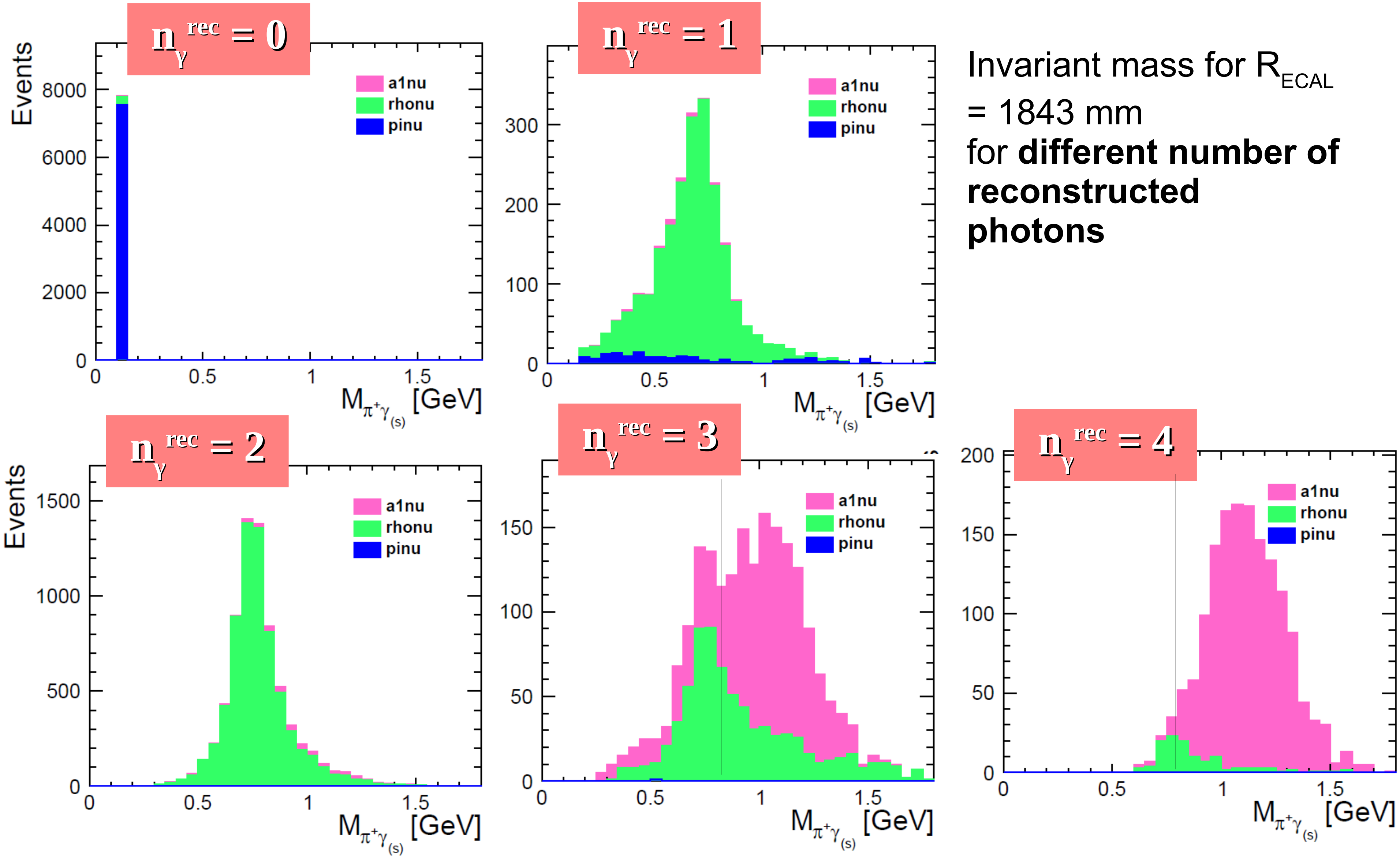
$R_{ECAL}^{(inner)}$ = 1843 mm



$R_{ECAL}^{(inner)}$ = 1450 mm

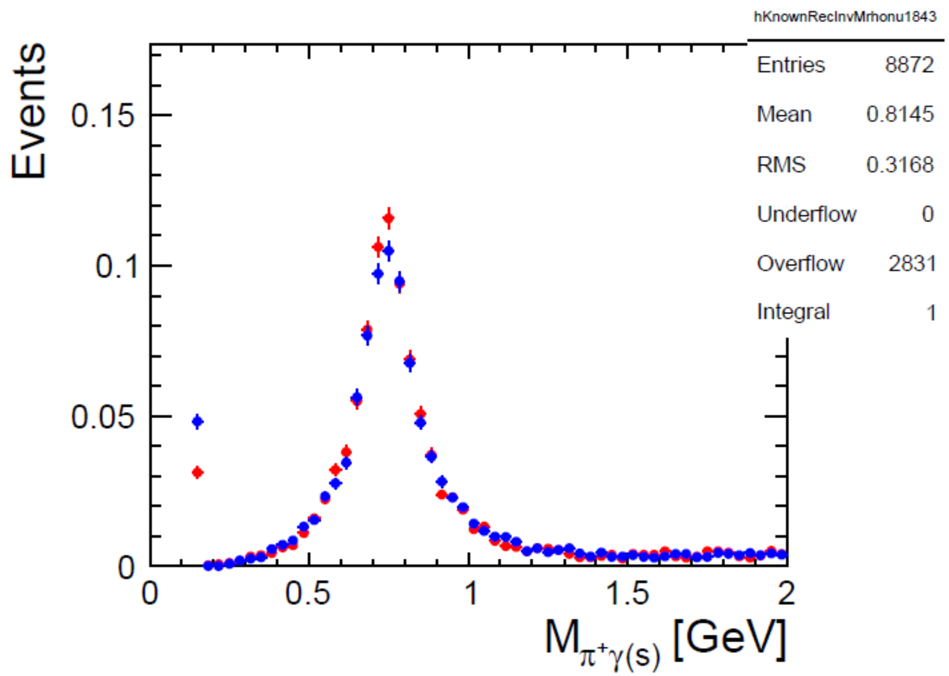
Decay mode known from MC info.
Look at samples with different number of reconstructed photons.
If everything is fine: **πν**: 0 photon, **ρν**: 2 photons, **a_1ν**: 4 photons.

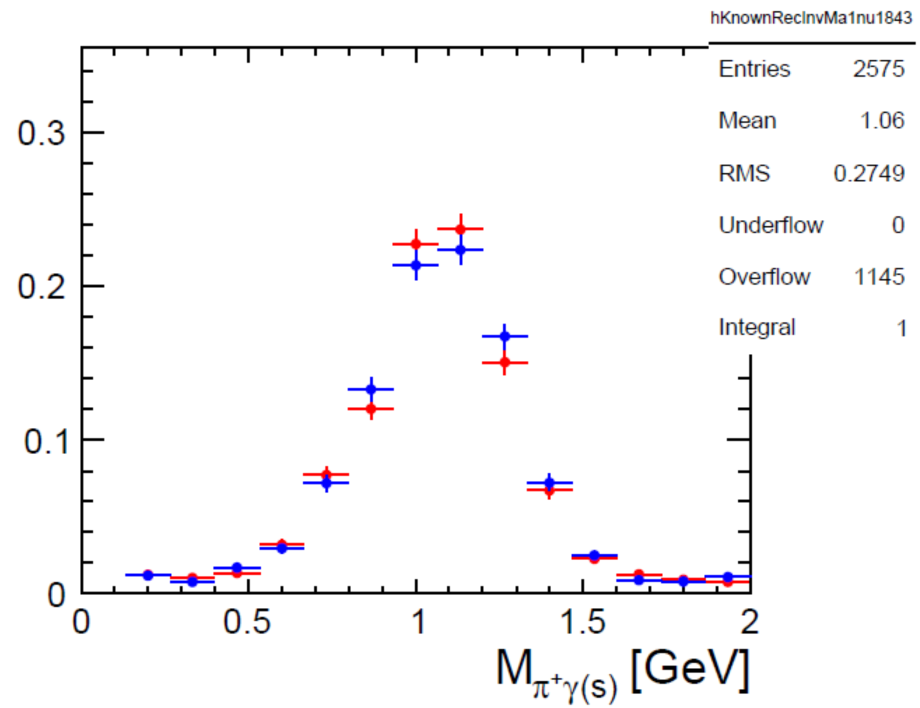
Invariant mass $\pi^+\gamma(s)$: key for final state distinction



Invariant mass for R_{ECAL} = 1843 mm for **different number of reconstructed photons**

Comparison: R_{ECAL}=1843 vs R_{ECAL}=1450 mm





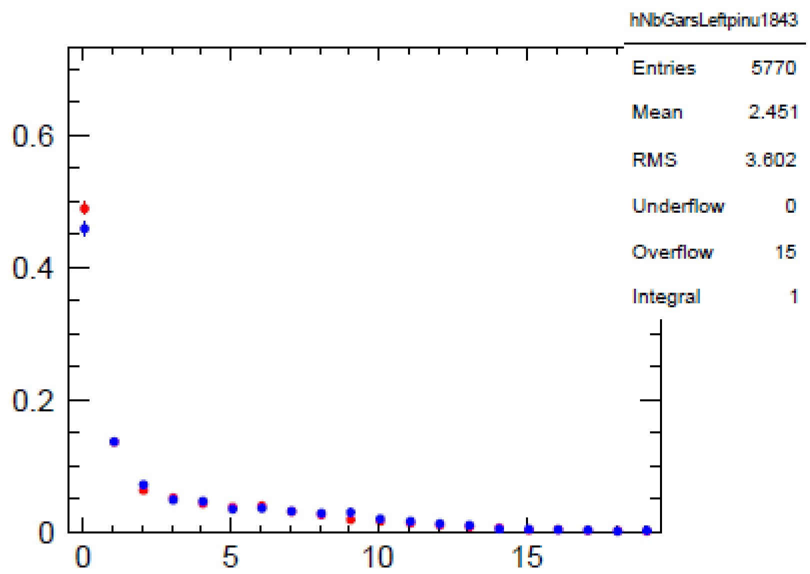
$R_{ECAL}^{(inner)}$ = 1843 mm

$R_{ECAL}^{(inner)}$ = 1400 mm

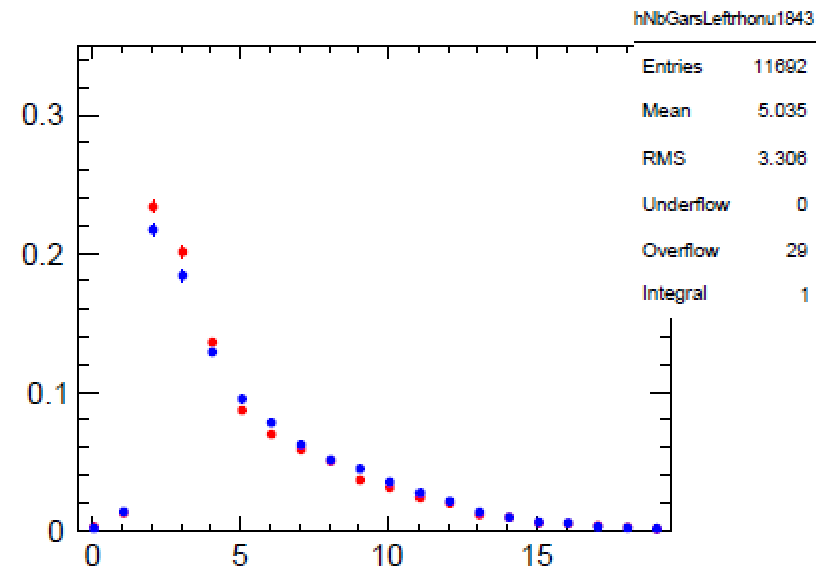
Reconstructed tau jet invariant mass for known decay modes.
Slight difference between radii 1843 and 1450 mm.
(Same cuts are used.)

Comparison: R_{ECAL}=1843 vs R_{ECAL}=1450 mm

Nb of rec photons : pinu



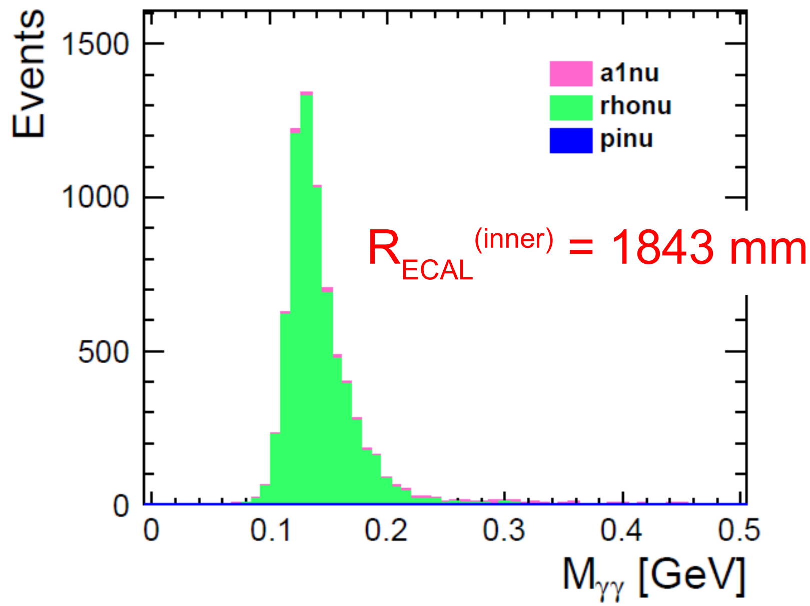
Nb of rec photons : rhonu

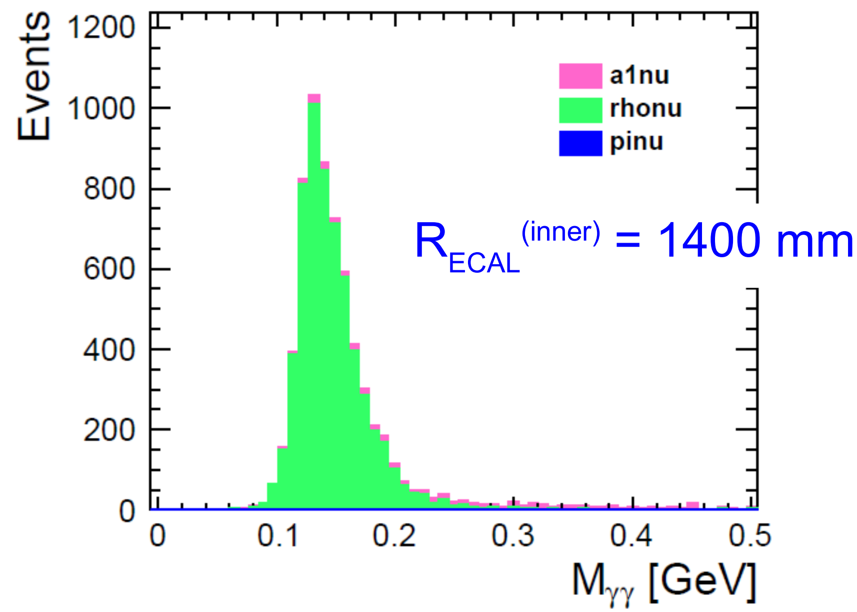


$R_{ECAL}^{(inner)}$ = 1843 mm
$R_{ECAL}^{(inner)}$ = 1400 mm

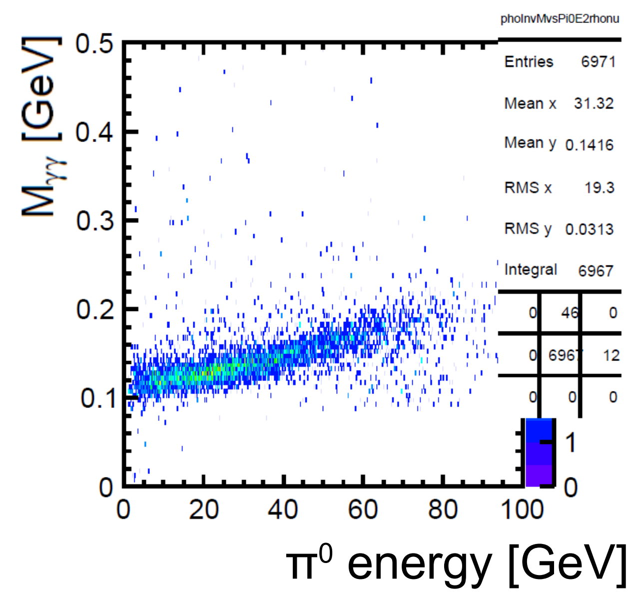
Reconstructed π^0 mass

R_{ECAL}=1843 vs R_{ECAL}=1450 mm

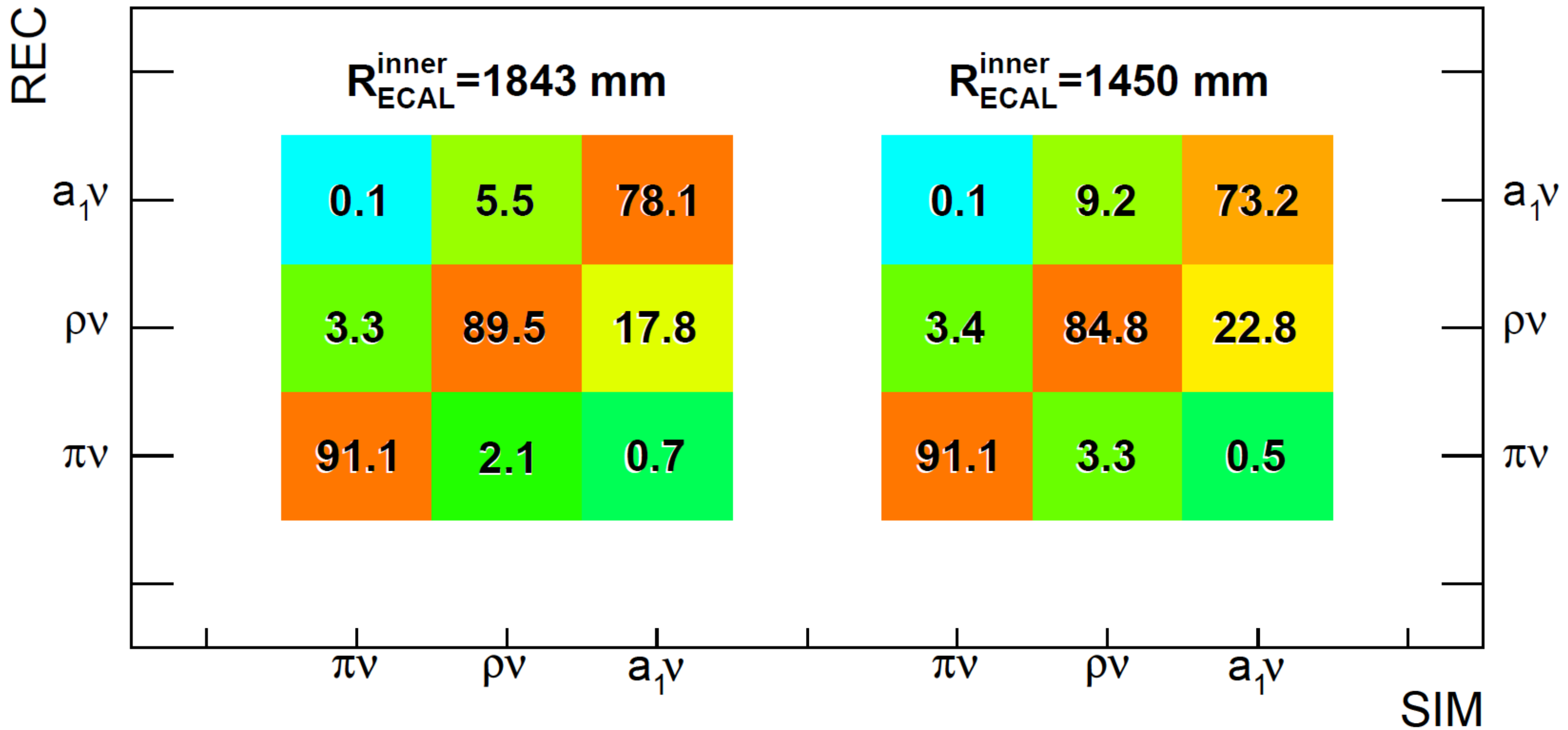




- Nice peak photon-photon (π^0) invariant mass
- tail due to high π^0 energies
- Good signal/background



Reconstruction efficiency



Tau final state reconstruction efficiency
shown in percent
for R_{ECAL} = 1843 and **R_{ECAL}=1450 mm**

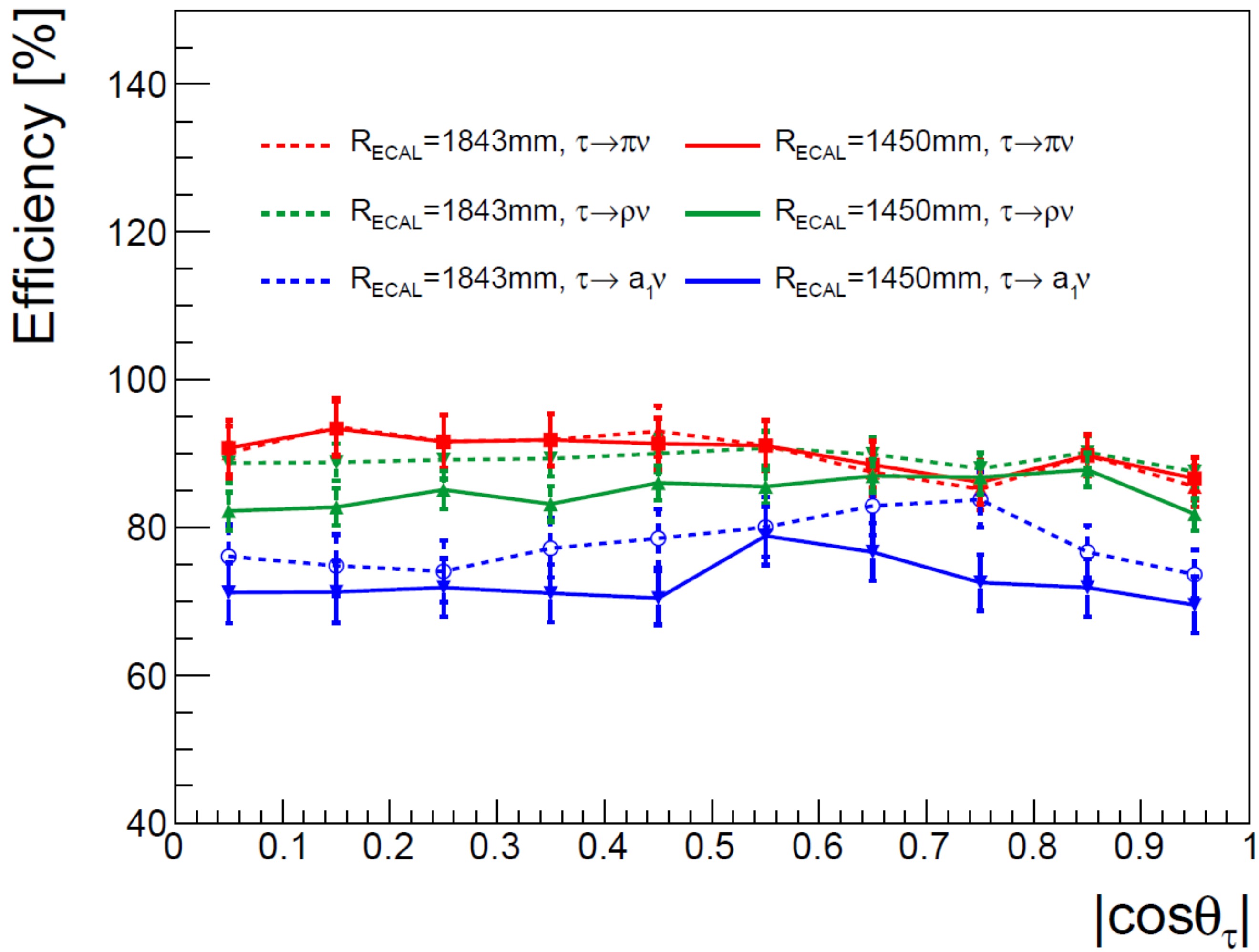
Slight difference in term of efficiency for two ECAL models.
This is due to tighter angle between photons for reduced radius
BUT also: cuts are determined for R=1843 for the moment!

Summary

- Tau decay mode reconstruction (***E_{tau} ~ 125 GeV*** *which is equivalent to taus in ZH, H → $\tau^+\tau^-$ at 500 GeV cms*) being investigated using Garlic v3.0.2 (ilcsoft v01-17-06).
- Nice mass peaks observed
- High reconstruction efficiency even with a reduced detector size
- Comparison between ILD with ECAL of radii 1843 and 1450 mm **shows slight difference! (up to 5% of in term of efficiency)**
- Next steps:
  - to look at ZH, H → $\tau^+\tau^-$ events (500 GeV)
  - optimise cuts (1843mm || 1450mm)

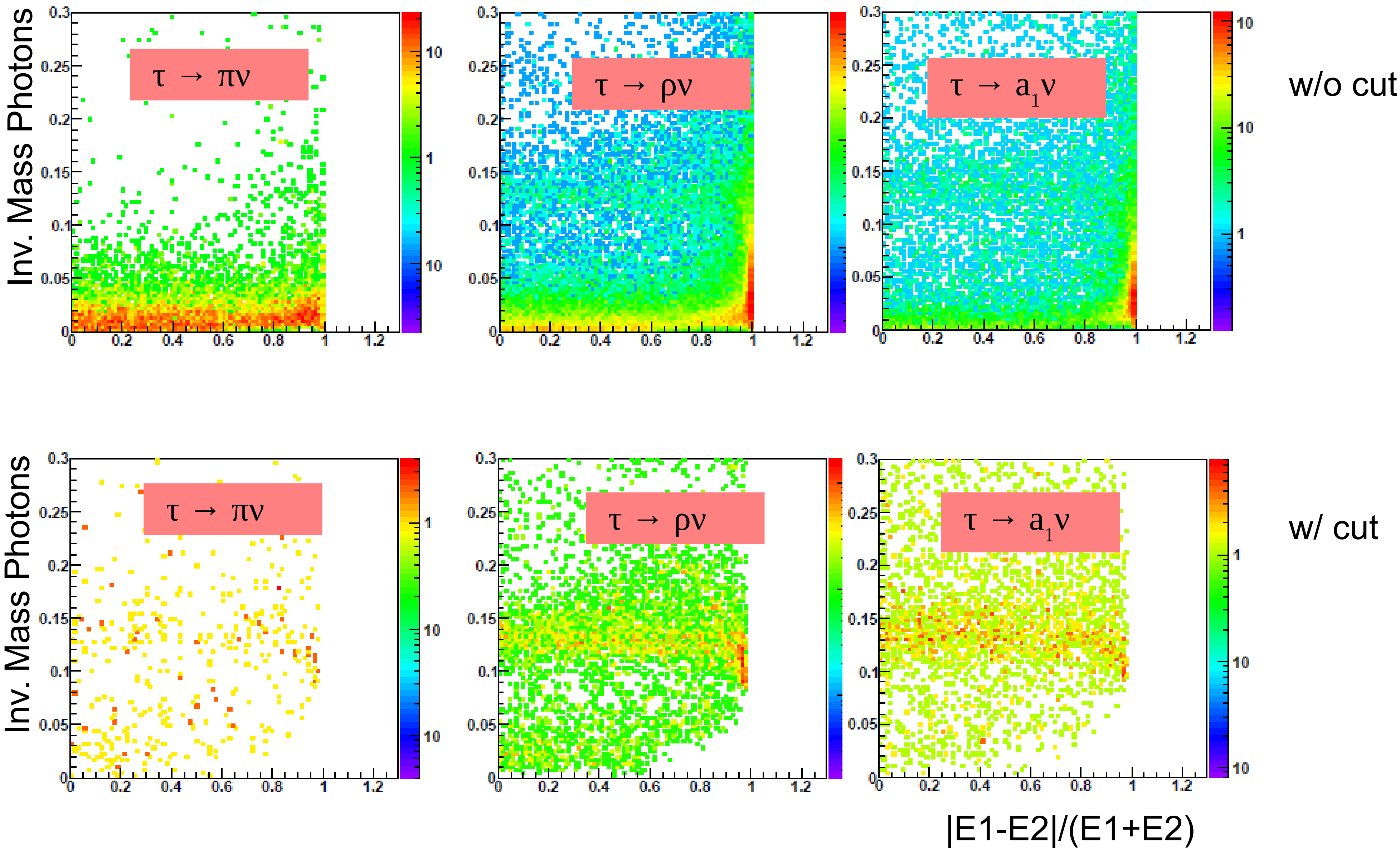
Backup

Rec efficiency vs cosTheta

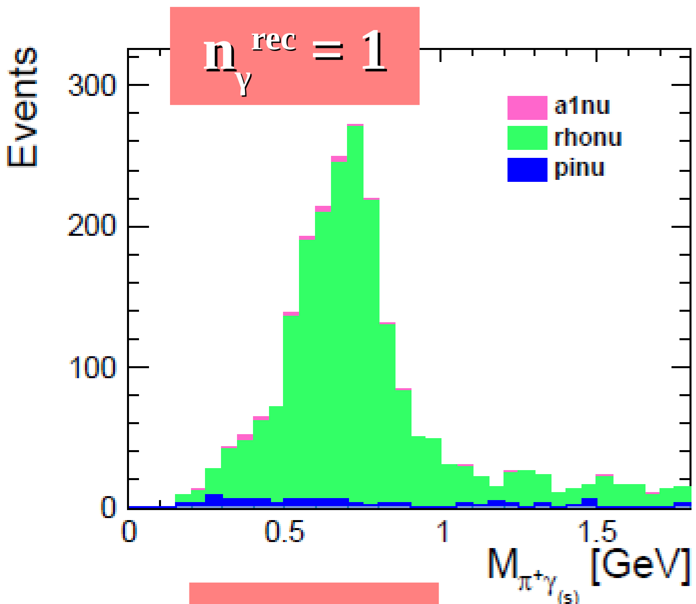


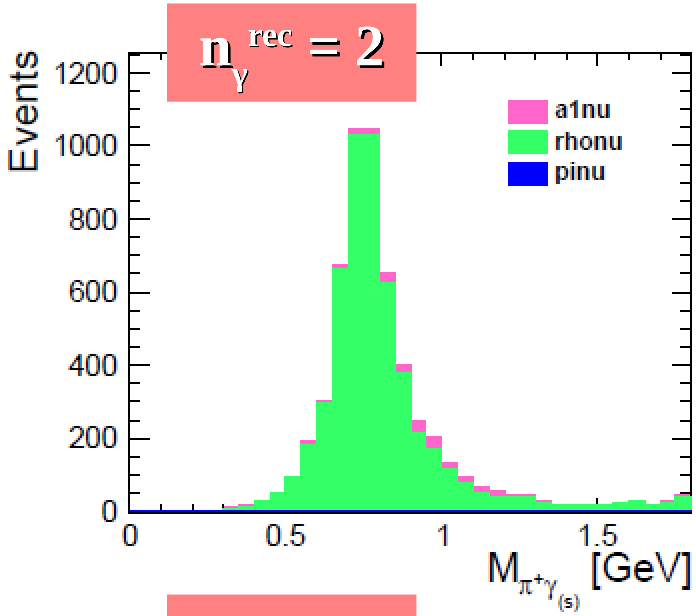
Slight dependence on |cosθ|

Effect of distance-energy cut

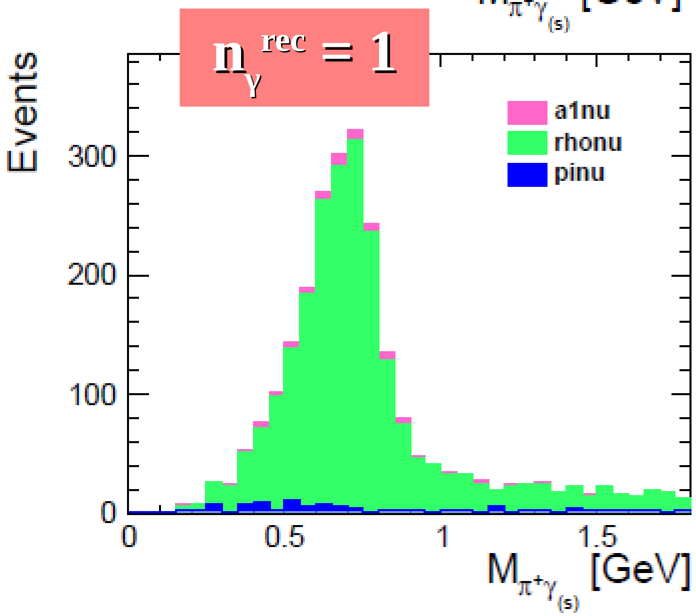


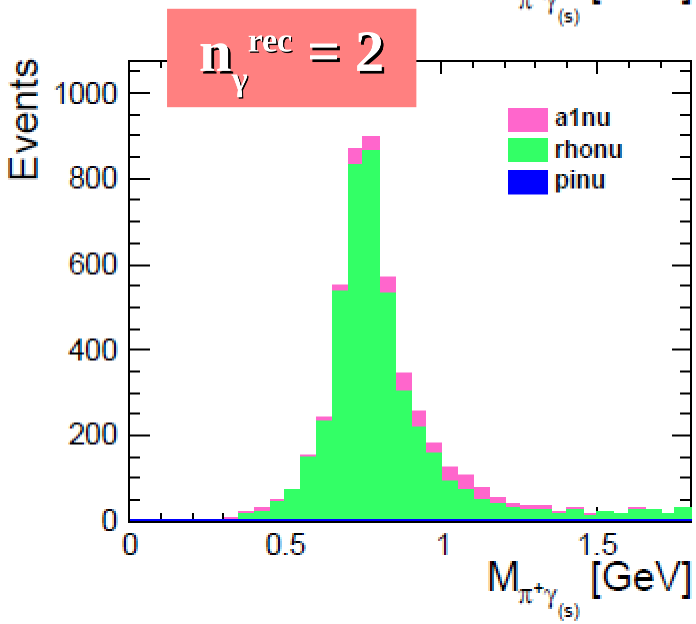
More comparison: 1843 vs 1450





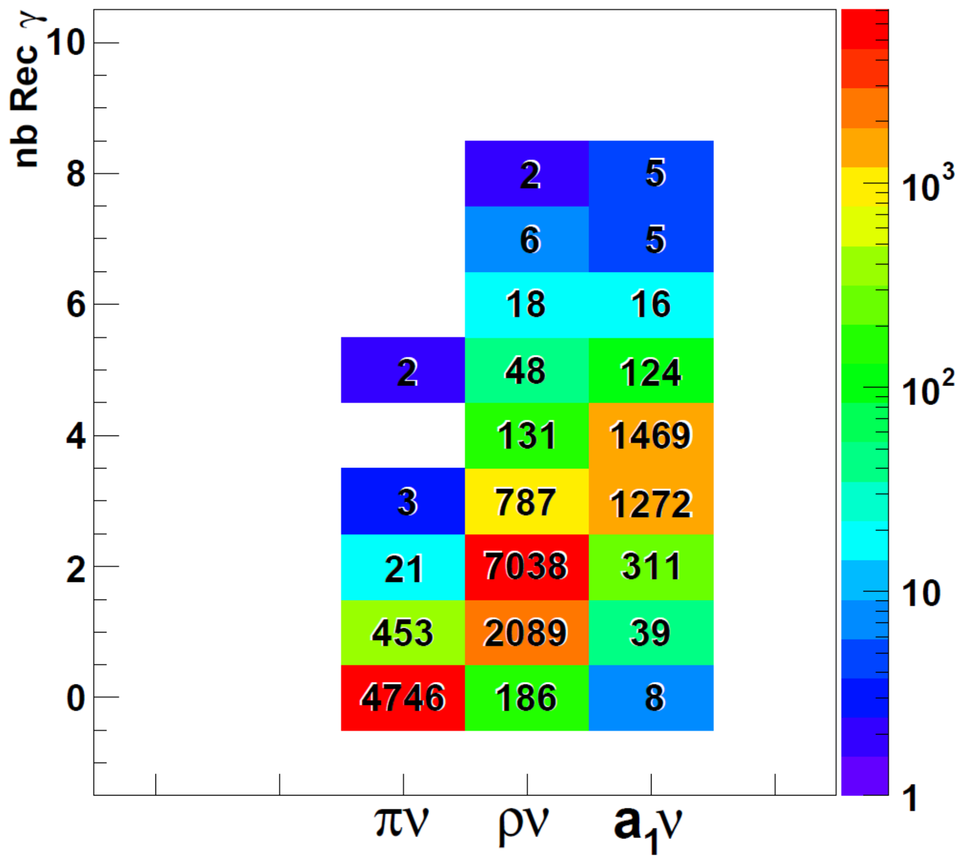
R = 1843 mm



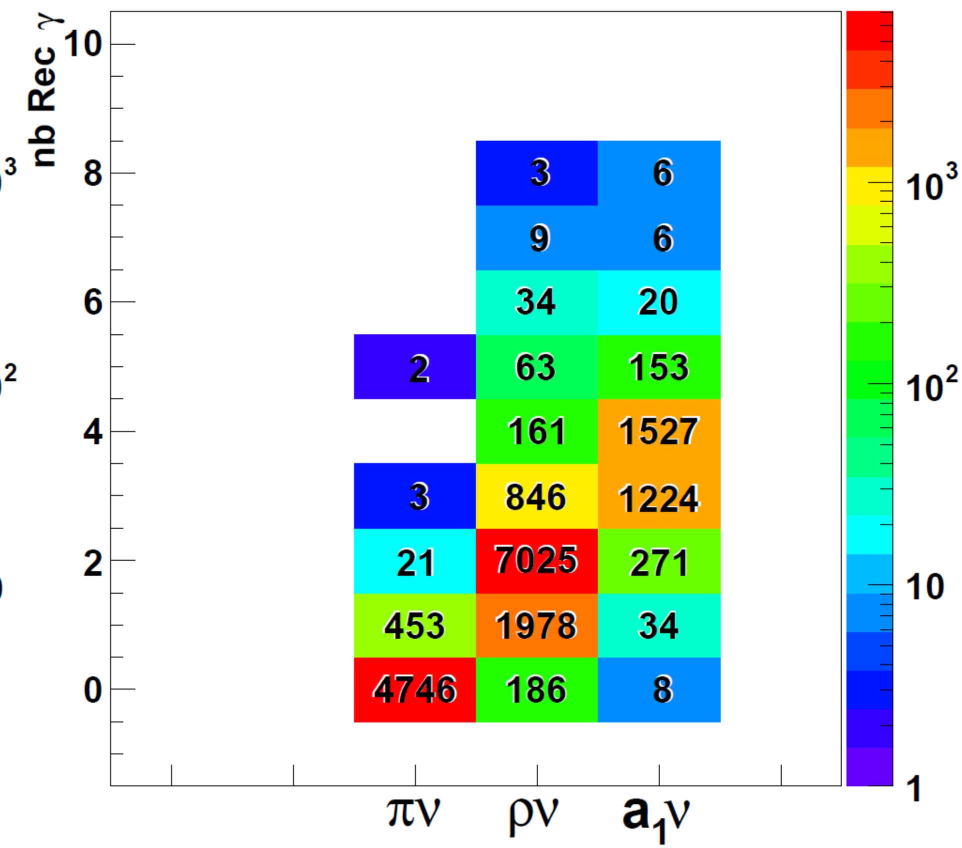


R = 1450 mm

Effect of merging



With merging



Without merging