Tau Reconstruction and Detector Optimization

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Characteristics of tau in LC

- Tau in LC
  - Usually highly boosted
    - Except low-energy τs for BSM study
  - Very confined bunch of particles
    - Separation of decay modes is challenge
    - e/μ/π separation is also critical
    - Extracting kinematics on 'tau-rest frame' – precise direction measurement is needed
  - Various decay
    - Intensive efforts needed for analysis

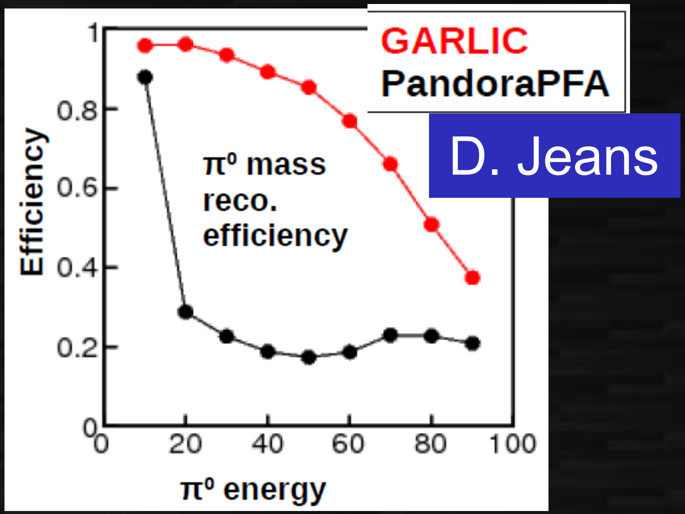
Final state	Branching fraction
$e^- \bar{\nu}_e \nu_\tau$	$17.85 \pm 0.05\%$
$\mu^- \bar{\nu}_\mu \nu_\tau$	$17.36 \pm 0.05\%$
$\pi^- \nu_\tau$	$10.91 \pm 0.07\%$
$\rho^- \nu_\tau$ $(\rho^- \to \pi^- \pi^0)$	$25.52 \pm 0.10\%$
$a_1^- \nu_\tau$ $(a_1^- \to \pi^- \pi^0 \pi^0)$	$9.27 \pm 0.12\%$
$a_1^-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

Tau: physics target for ILD

- Higgs → $\tau\tau$
  - Branching ratio
  - CP violation (by impact param and angular info)
    - Many decay modes should be studied: lot of effort
- Precise measurement of ff production
  - Including tau polarization measurement
- BSM – stau? (low energy)
- Treatment of tau as background
  - 'Tau tagger' is essential
- etc.

Reconstruction tools (1)

- PFA of tau is different from that of jets
  - High-energy low-multiplicity (but concentrated) particles
  - Photon counting (→ π^0) is as important as energy resolution
  - Garlic is better than Pandora
    → how to combine if we also need to reconstruct jets?
    (eg. qqH → $qq\tau\tau$)



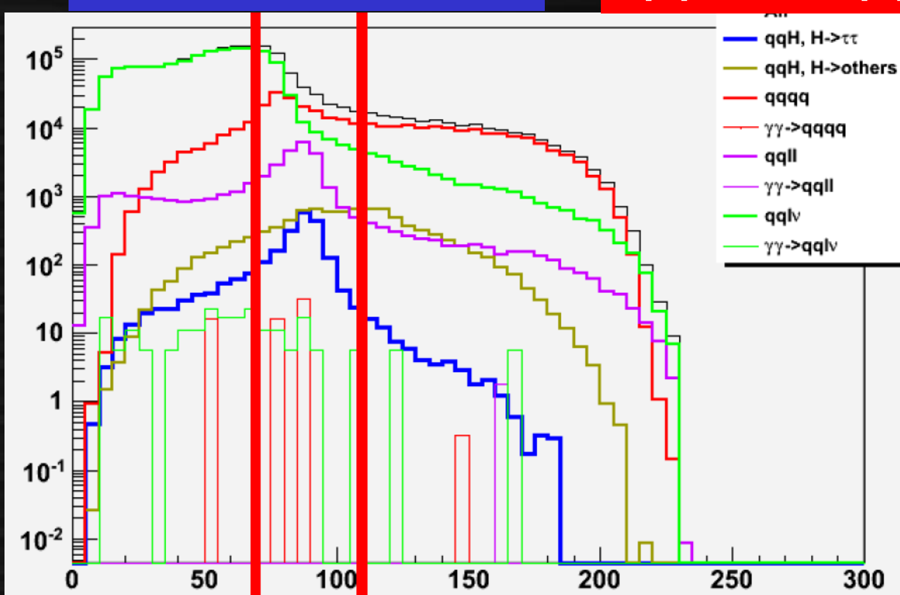
Reconstruction tools (2)

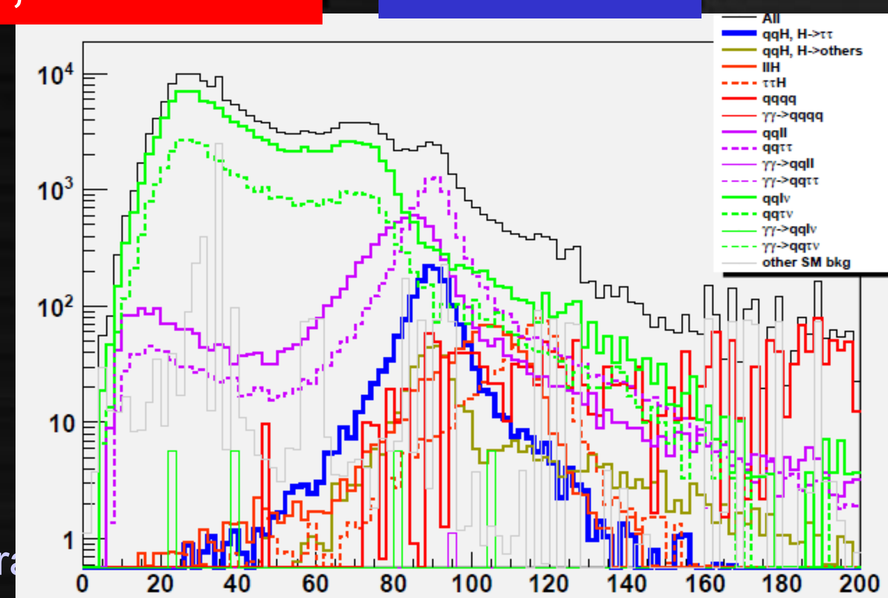
- Tau finder – key algorithm to separate tau
  - Normal jet clustering is usually not good
- Dedicated Tau finders
  - TaJet finder (tuned for qqH → qqττ)
  - DELPHI tau finder (for low energy tau)
  - Others?

Durham clustering

qqH → qqττ, 250 GeV

TaJet finder

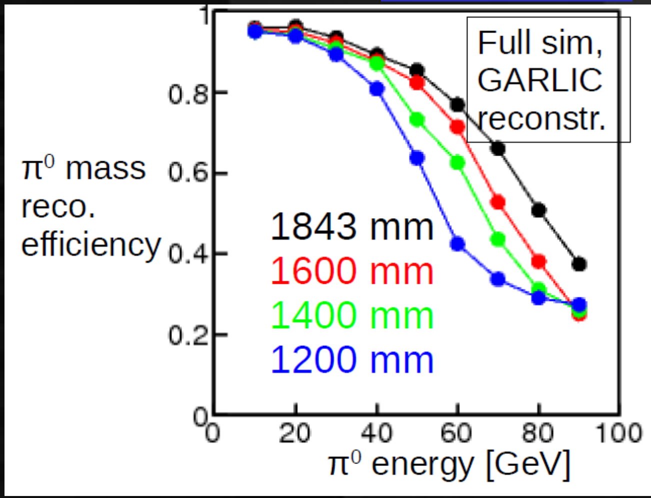




Tau and Detector Optimization

- Radius
  - Particle separation
  - Isolation of tau from jets (also B field affects)
- Pixel size
  - Particle separation
    - Ultra-high granular pixels at first layers of ECAL may help (eg. MAPS)
- Photon energy resolution
  - meson ($\pi^0/\rho/a_1$) reconstruction
- Impact parameter resolution
  - For angular analysis of CP violation

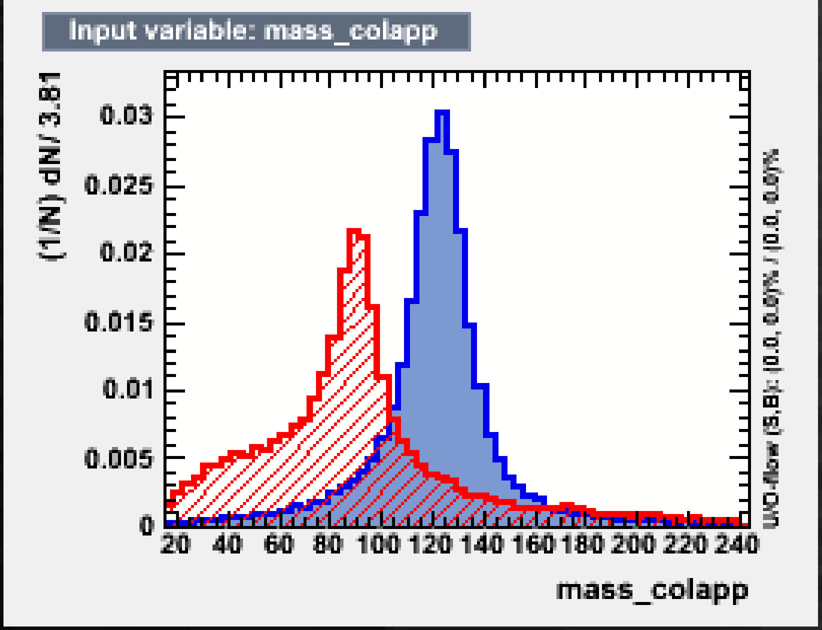
D. Jeans



Analysis: H → ττ

S. Kawada

Analysis condition
- PandoraPFA (no Garlic)
- DBD geometry
- TaJet finder
- Collinear approx. (only on qqH, llH)
- No reconstruction of tau decay products



Mττ @ qqH 250 GeV

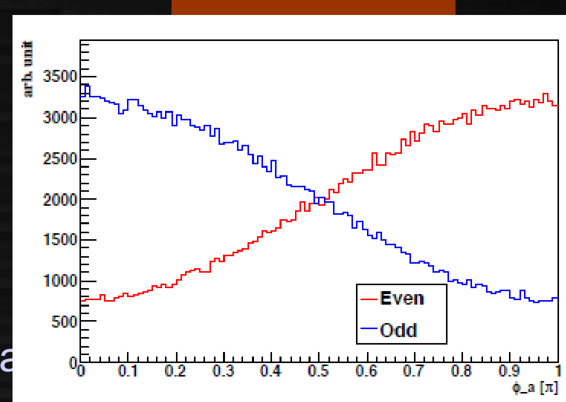
$\frac{\Delta(\sigma \times \mathrm{BR})}{(\sigma \times \mathrm{BR})}$	$q\bar{q}h$	e^+e^-h	$\mu^+\mu^-h$	$\nu\bar{\nu}h$	Combined
250 GeV, 250 fb^{-1}	3.4%	14.4%	11.3%	32.4%	3.2%
500 GeV, 500 fb^{-1}	4.6%	25.2%	17.8%	6.9%	3.7%

CMS 3 ab^{-1}: 2-5%

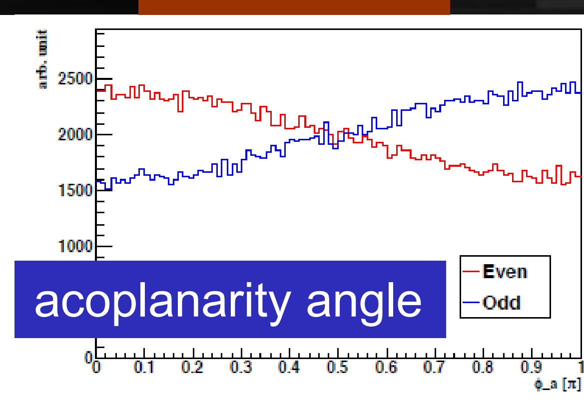
Analysis: Higgs CP

- Identifying CP-even and CP-odd mixing of Higgs
  - CP odd (H →) ZZ couples **only with loop**
    - More difficult to see the non-SM Higgs mixing
  - (H →) ττ is **directly coupled** to CP-odd Higgs
- Complicated analysis to identify CP mixing
  - **Clear separation of Higgs decay mode**
    - Angular parameters differ by decay modes
  - **Kinematics of tau-rest frame critical**
    - cannot perfectly reconstruct kinematics of taus using impact parameters with momentum of decay products Ta

ττ → πνπν



ττ → eννπν



acoplanarity angle

Analysis: $e^+e^- \rightarrow \tau\tau$

H. Tran

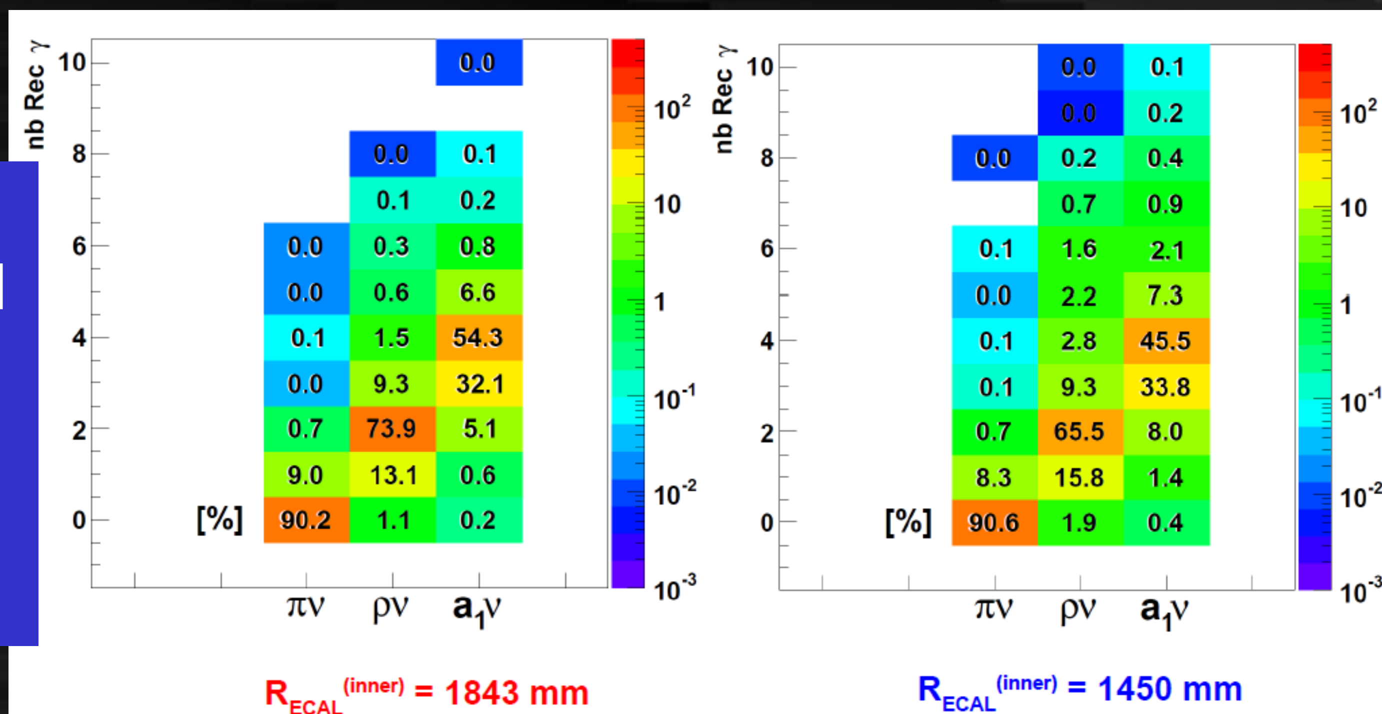
Analysis condition

- 250 GeV CM energy
- Garlic v3.0.2 (no jets)
- Compare performance of various radius with constant aspect ratio
- SiECAL

Target: separation of 1-prong hardonic decay

$\pi^- \nu_\tau$	$10.91 \pm 0.07\%$
$\rho^- \nu_\tau \ (\rho^- \to \pi^- \pi^0)$	$25.52 \pm 0.10\%$
$a_1^- \nu_\tau \ (a_1^- \to \pi^- \pi^0 \pi^0)$	$9.27 \pm 0.12\%$

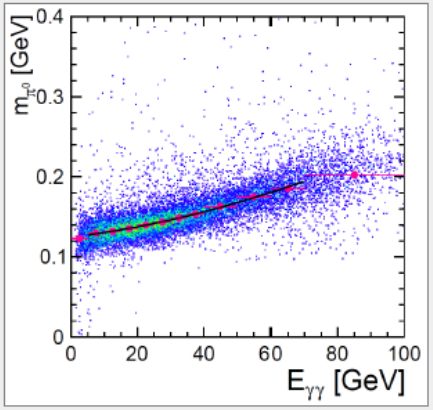
number of reconstructed photons with MVA photon selection

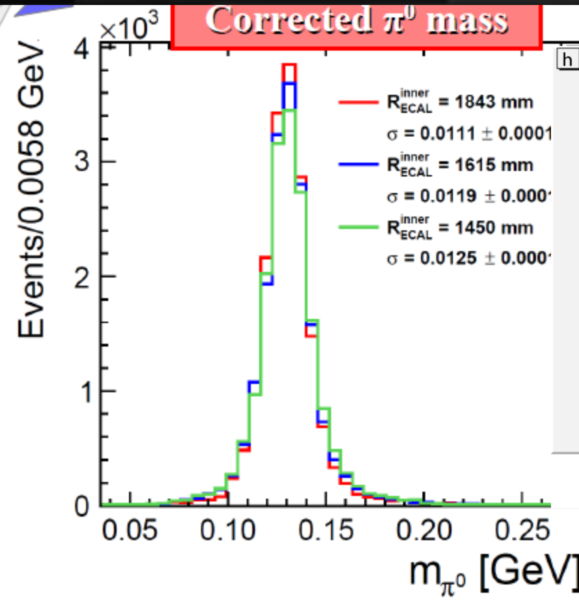


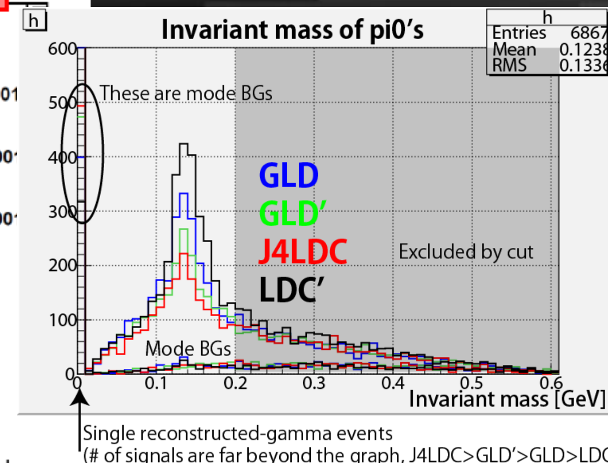
Analysis: $e^+e^- \rightarrow \tau\tau$

H. Tran

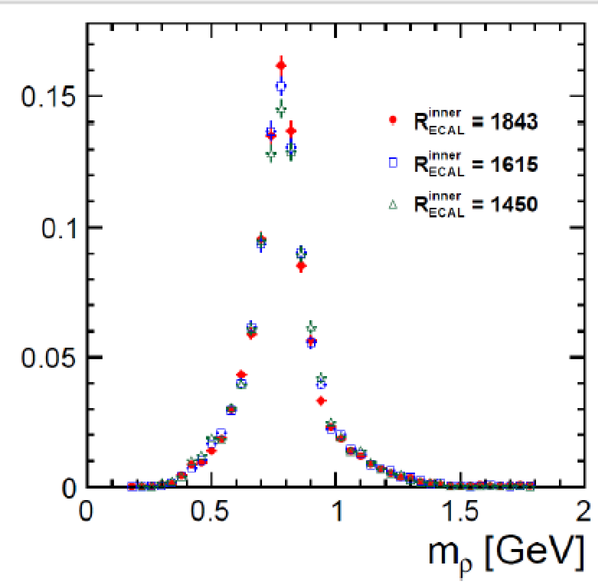
- Fit mass dependence on $\gamma\gamma$ energy with a parabola
- correct to mean value

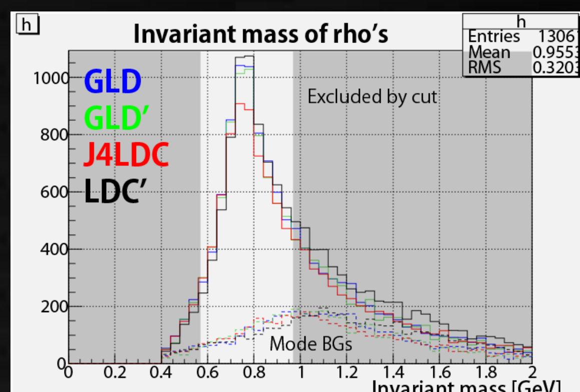






cf. 500 GeV, Pandora
1cm pixel except LDC'





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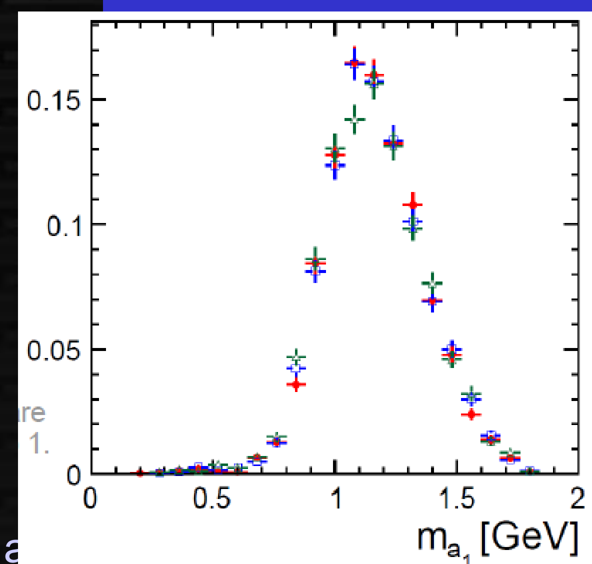

Analysis: $e^+e^- \to \tau\tau$

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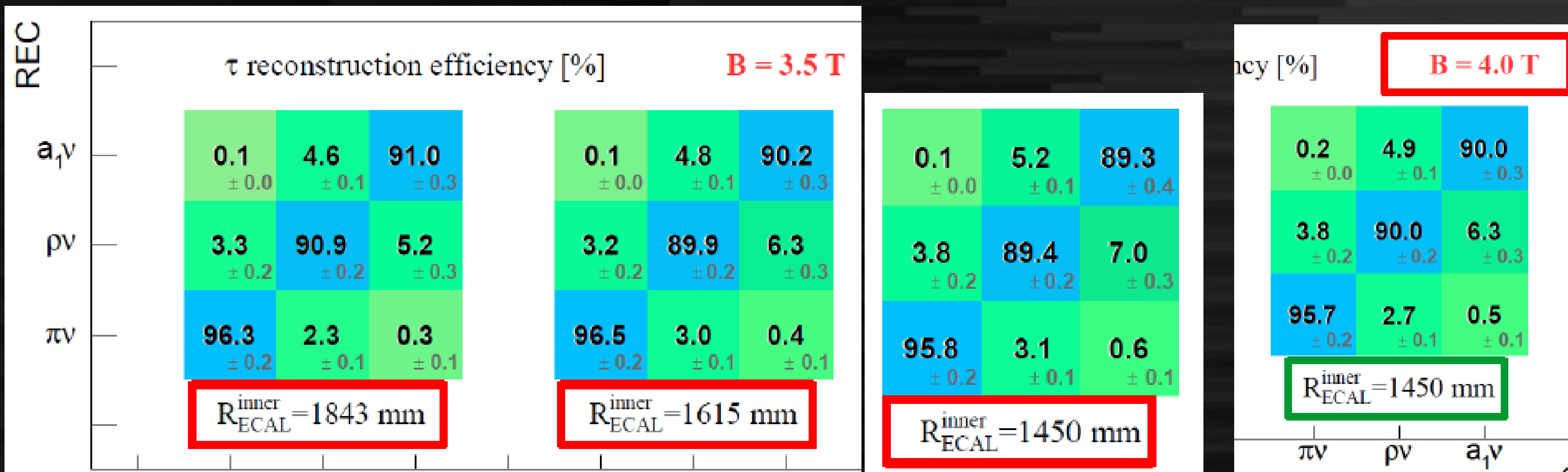

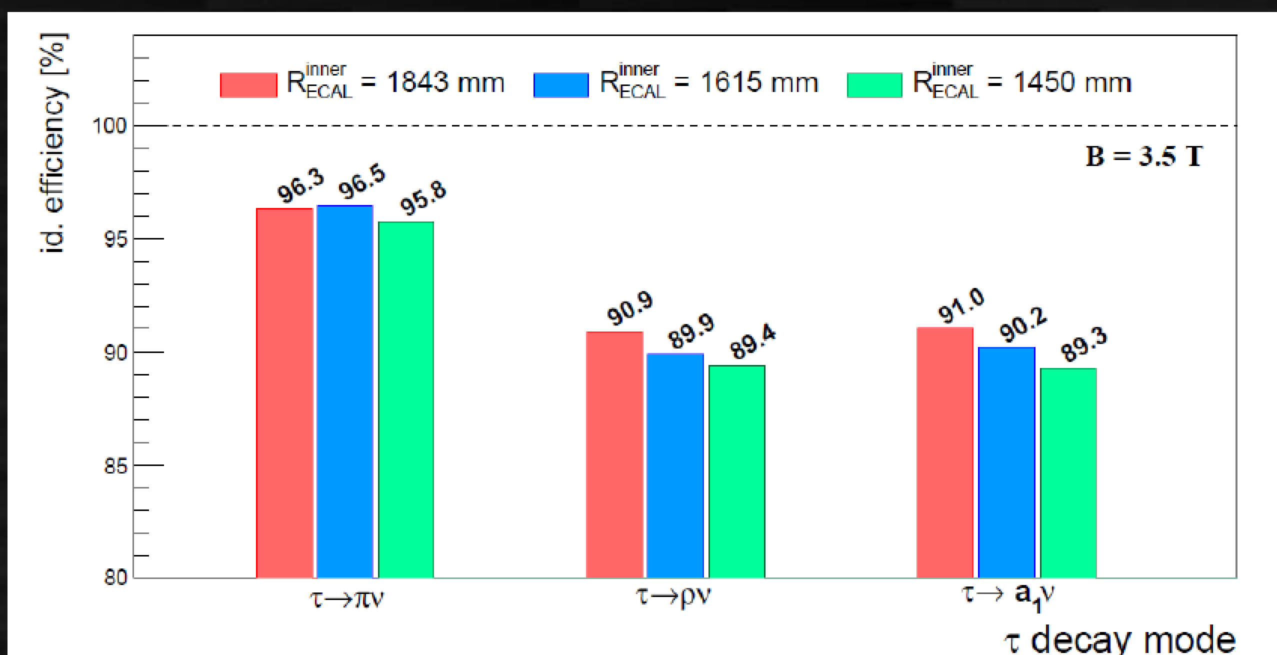

Final comments

- Detector challenge
  - Decay reconstruction for
    - Higgs CP (seems most important)
    - ff polarization – niche market physics??
    - others?
  - Low energy stau
    - Low energy track/photon reconstruction
- Other perspectives for calorimeter optimization than quark jets
- Analysis and software is critical
  - Optimization is not easy – same as quark jets