SUSY measurements with tau leptons in ATLAS

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(slides show private work and not official ATLAS results)

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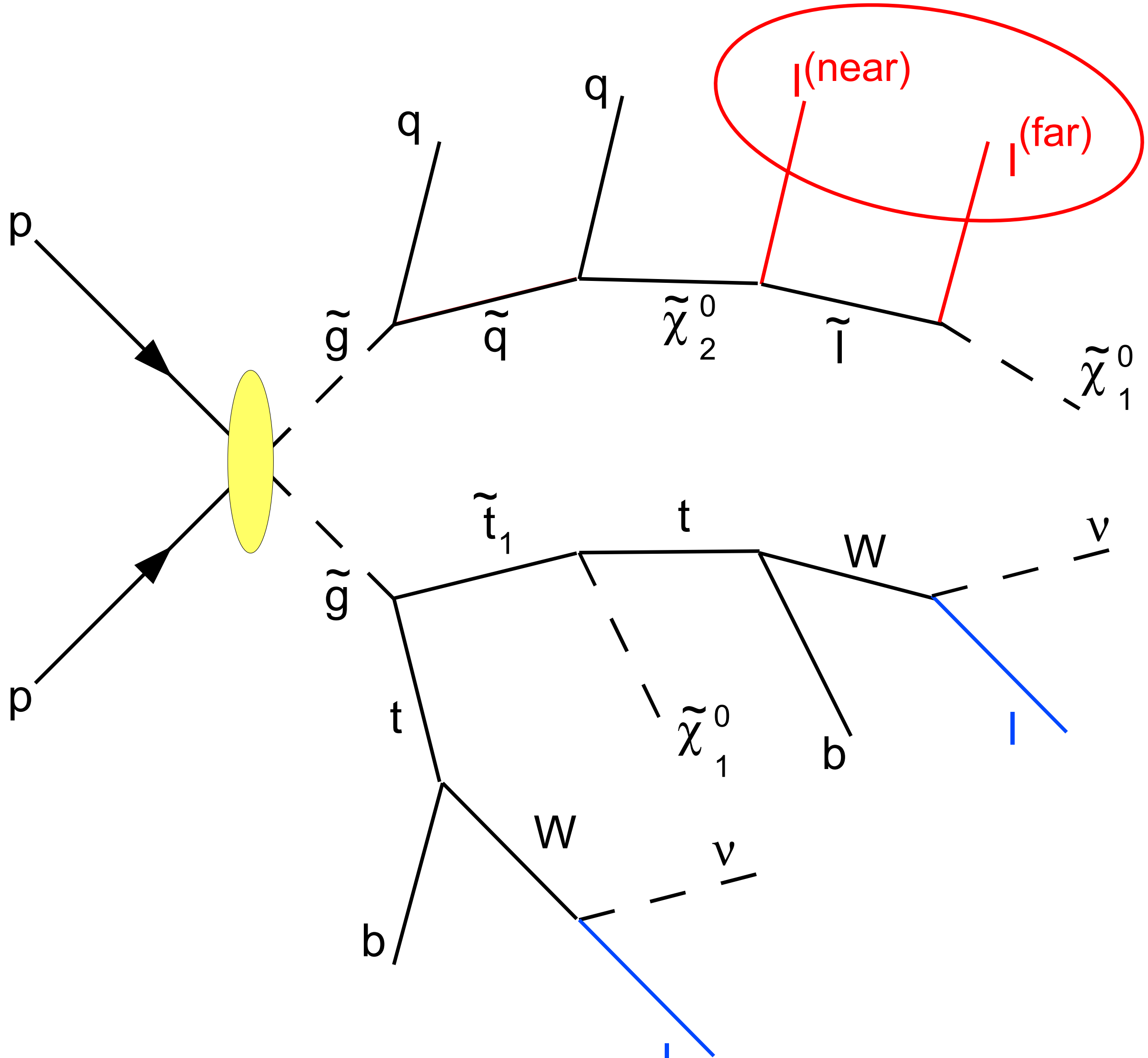
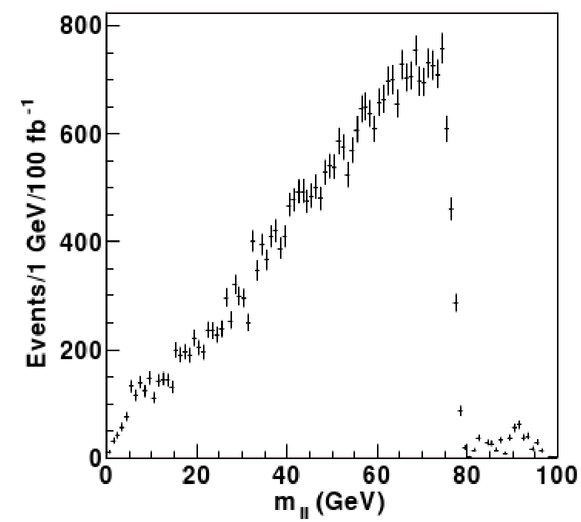
SUSY mass measurements at the LHC

No mass peaks due to ≥ 2 escaping LSPs (in R parity conserving SUSY)



Invariant mass of ll pair:



Endpoint of mass spectrum sensitive to involved SUSY masses:

$$\left(m_{ll}^2\right)^{\mathrm{edge}} = \frac{\left(m_{\tilde{\chi}_2^0}^2 - m_{\tilde{l}_R}^2\right)\left(m_{\tilde{l}_R}^2 - m_{\tilde{\chi}_1^0}^2\right)}{m_{\tilde{l}_R}^2}$$

In this talk consider case: l = τ

Why struggling with taus?

Taus:

rapid decay ($c\tau$ = 87 μm) into several, partly invisible particles

Electrons/muons:

stable (on time scales relevant for detection)

$\Rightarrow$ p_T of taus cannot be reconstructed due to escaping neutrinos

(not even tricks like collinear approximation help in RPC SUSY due to escaping LSPs)

Nevertheless there are good reasons to study SUSY with tau probes:

- obtain stau mass information with relying on GUT relations
- lightest slepton in models with high scale unification
- in mSUGRA large L-admixture in $\tilde{\tau}_1$ causes larger coupling to wino-like χ_2^0

$\}$ #(τ) = 1-10 #(e/μ)

- many other models (with large tan β, GMSB with stau NLSP, RPV SUSY with stau LSP, SUSY with LFV, ...) in which taus may play important role
- only lepton that grants access to polarisation information

Tau decays

- leptonic decays: 35 %
- hadronic decays: 65 %
  - 1-prong: 50 %
    - $\pi\nu$: 12 %
    - $\rho\nu$: 26 %
    - $a_1\nu$: 8 %
    - non-resonant decays: 4 %
  - 3-prong: 15 %

Tau ID in ATLAS only aims at hadronic decay modes

leptonic decay modes can hardly be distinguished from primary leptons

Di-tau invariant mass spectrum

In case of taus the ineluctable energy loss due to neutrinos makes endpoint measurement more difficult.

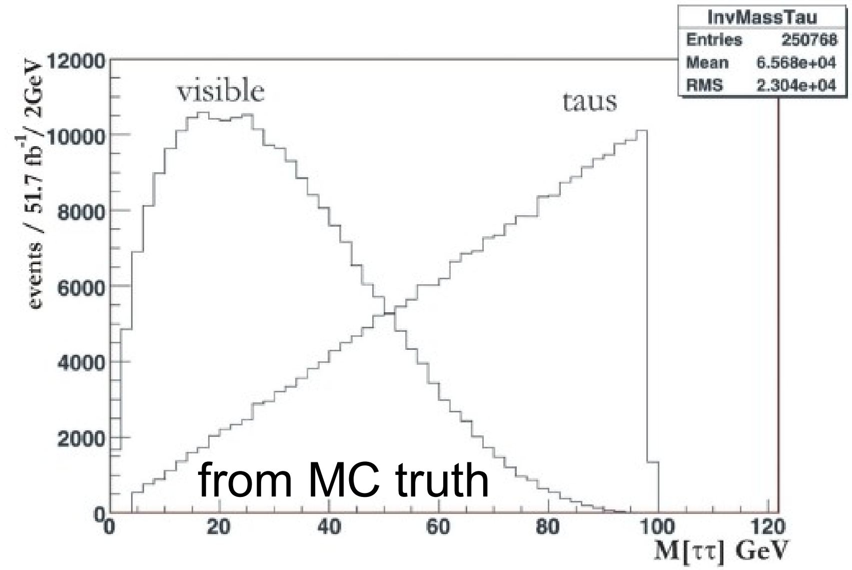
Inflexion point method:
Fit (log-normal) distribution

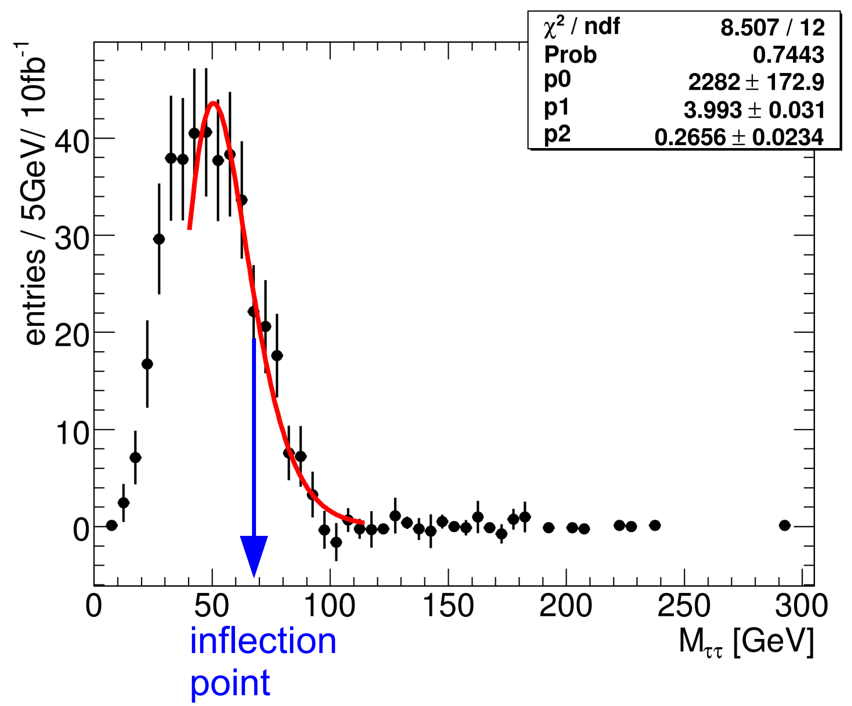
$$f = \frac{p_0}{x} \cdot \exp\left(-\frac{1}{2p_2^2}(\ln(x) - p_1)^2\right)$$

to mass spectrum and use inflection point of trailing edge as endpoint sensitive observable.

Needs calibration: inflection point vs. endpoint

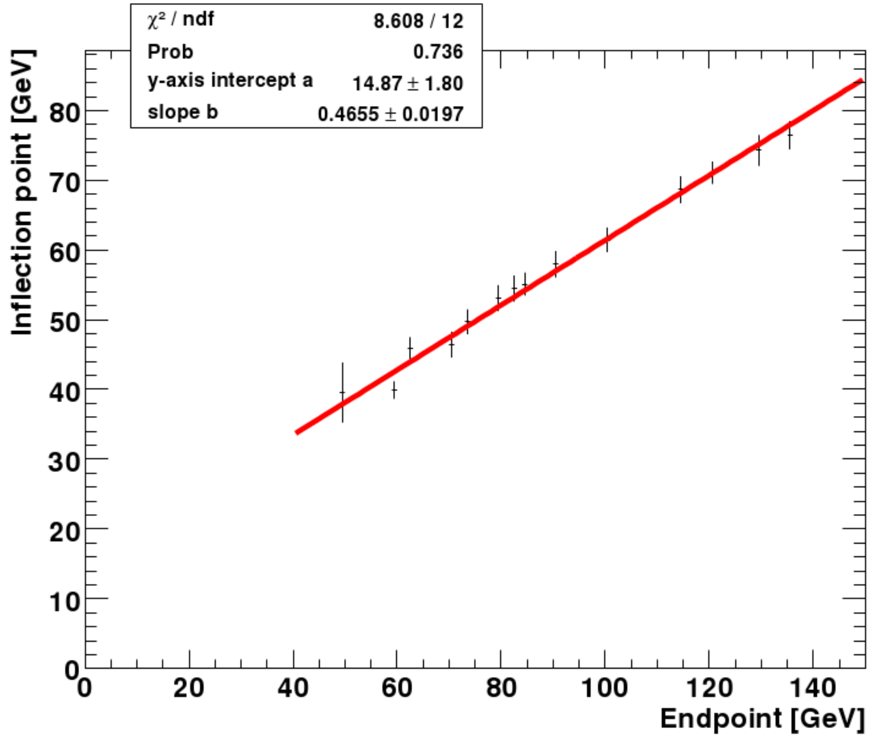
Study for ATLAS mSUGRA bulk point SU3:
tan β = 6, M_0=100 GeV, $M_{1/2}$=300 GeV, A_0=-300 GeV, sign(μ)=+1



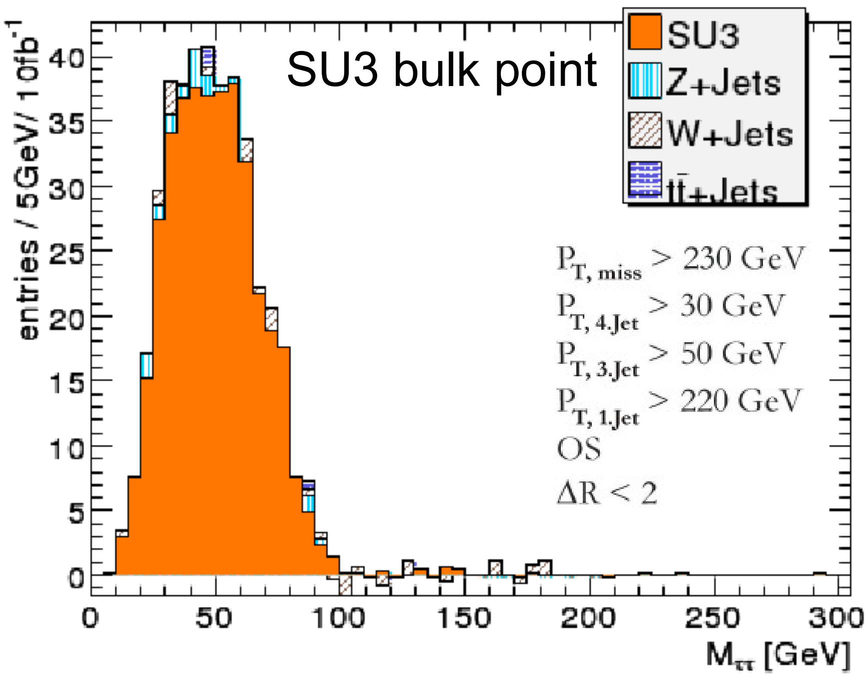


Inflection point technique

Vary endpoint by changing SUSY masses in MC and compare with corresponding inflection point:



OS-SS mass spectrum (10 fb^{-1}):



Precision on endpoint position for 10 fb^{-1}:

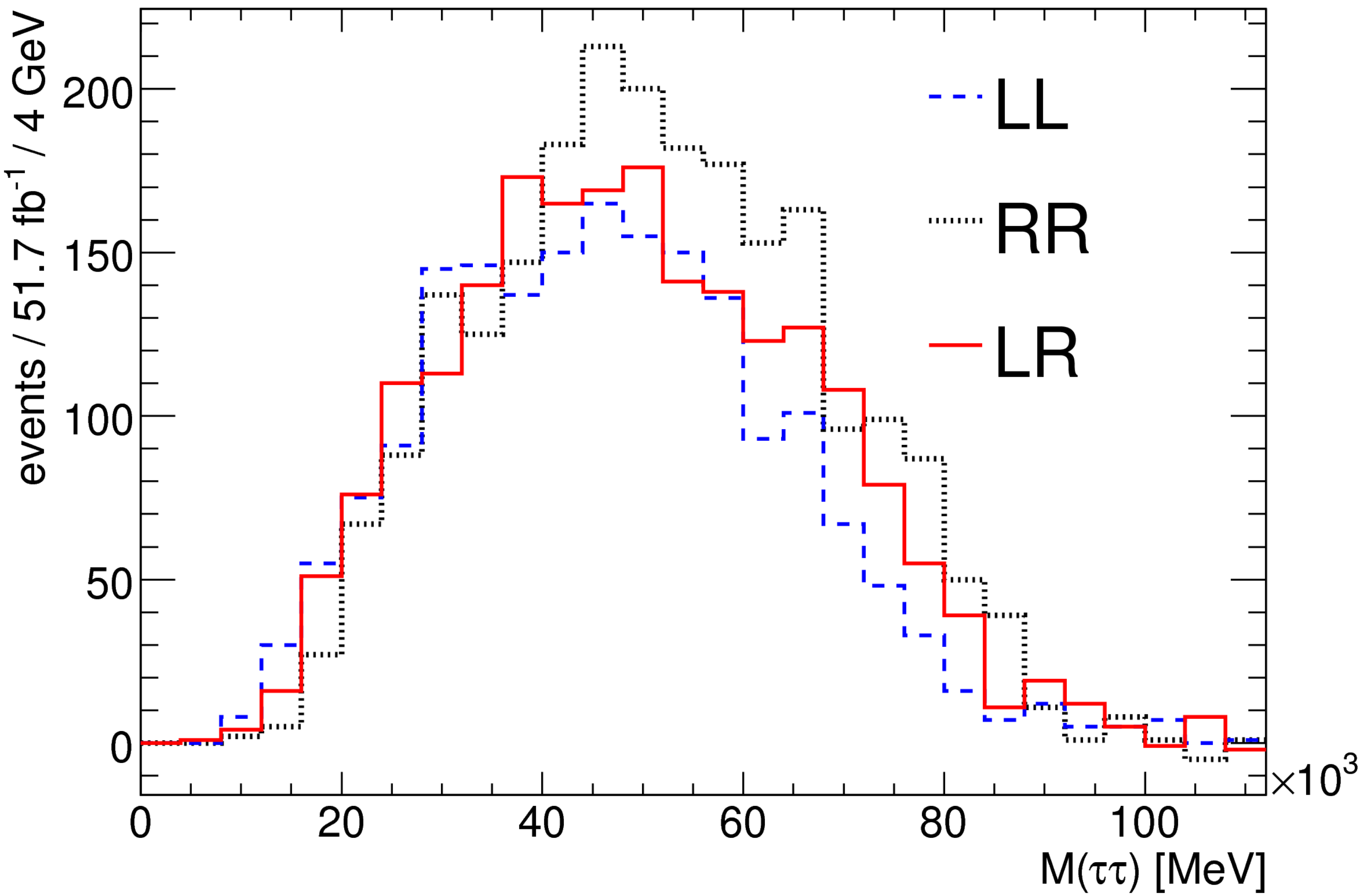
105 GeV ± 4 GeV (stat)

Expectation: 98 GeV

(for mSUGRA bulk point SU3)

Polarisation dependence of di-tau spectrum

Inflection point (but not endpoint!) also depends on polarisation of taus:



Inflection point varies by ±3-4 GeV due polarisation effects
(> statistical uncertainty of ±2 GeV for 10 fb^{-1})

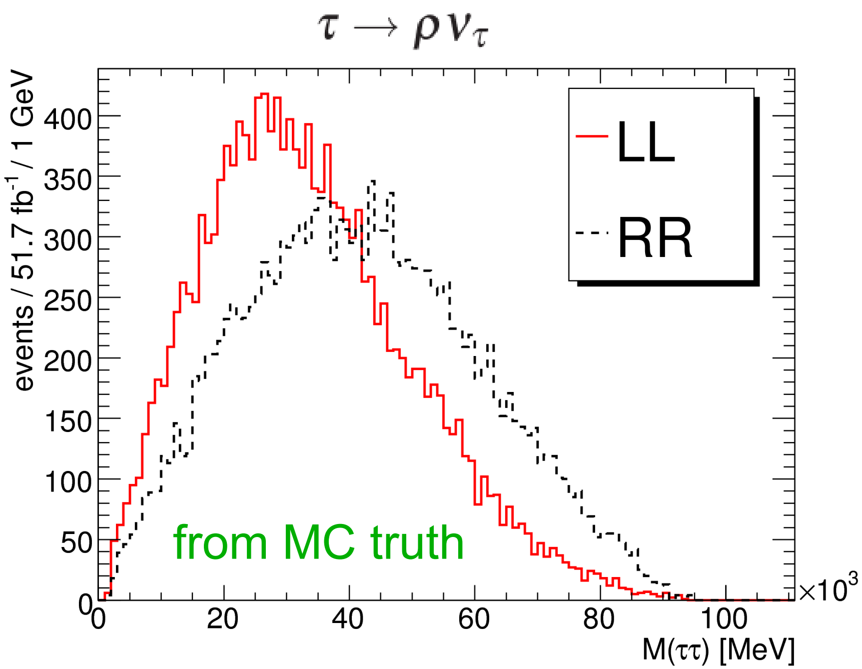
Disentangling masses and polarisation

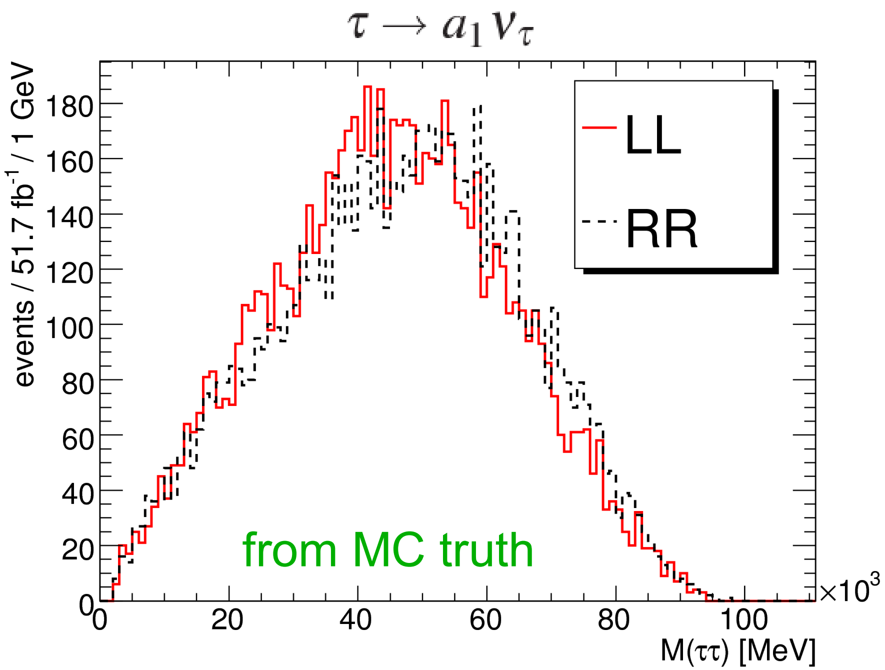
Spectra for different polarisations differ in shape.

Unfortunately differences are almost completely washed out by detector effects.

⇒ Difficult to distinguish mass effects from polarisation effects.

To overcome this, different polarisation dependence of different tau decay modes may be exploited:





Polarisation provides information about stau mixing angle.

Polarisation of taus from stau decays

Technique on last slide only provides combined polarisation information from near and far tau. Also interesting to measure polarisation of particular taus.

Polarisation of taus from stau decay is a probe of the χ_1^0 composition and can be used to discriminate between different models of SUSY breaking

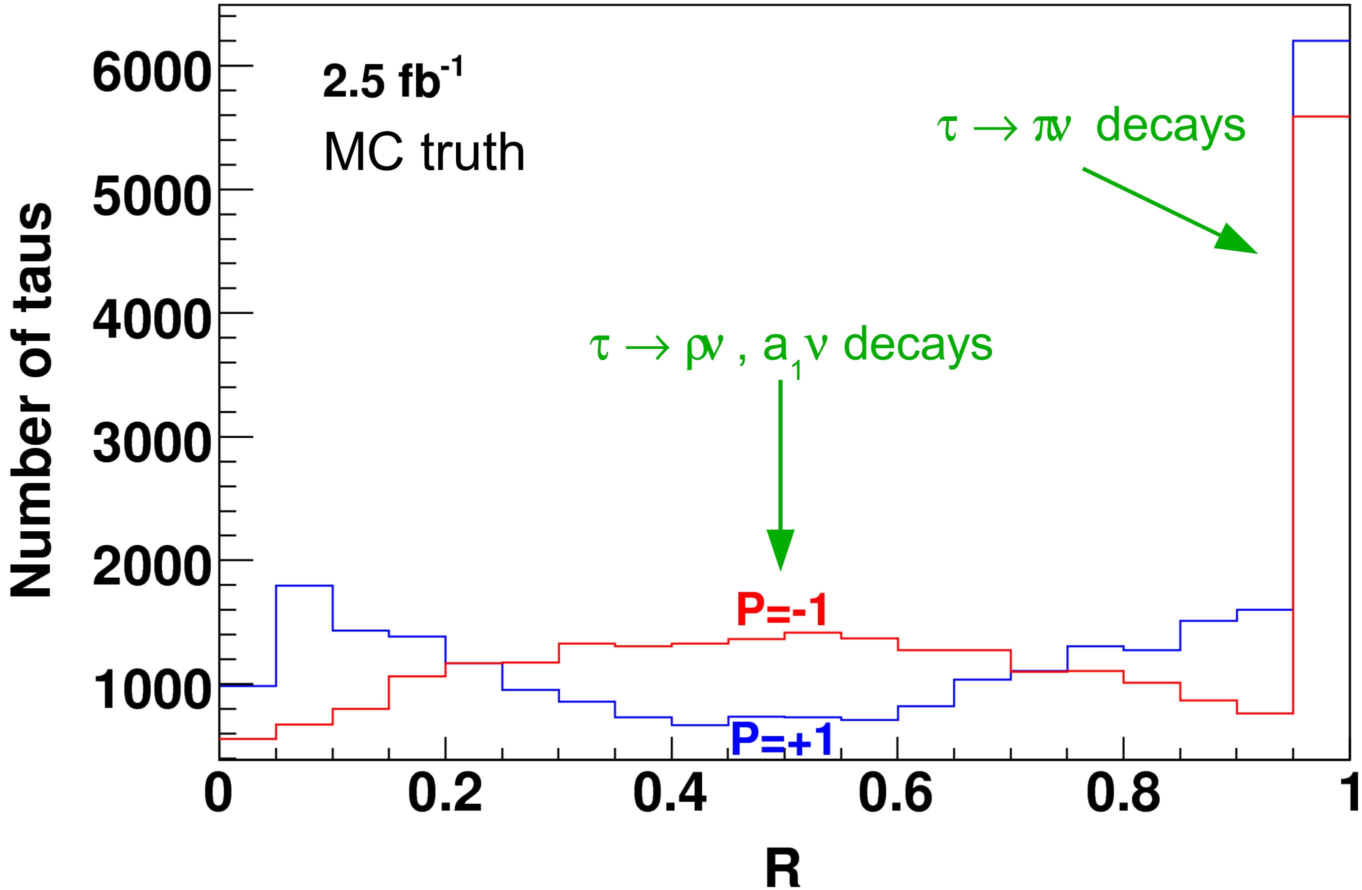
- Universal SUGRA models: $P_\tau \simeq +1$
- For most non-universal SUGRA models: $P_\tau \simeq \cos^2\theta_\tau - \sin^2\theta_\tau$
- AMSB models: $P_\tau \simeq -1$
- For many GMSB models: $P_\tau = \sin^2\theta_\tau - \cos^2\theta_\tau$

Polarisation sensitive observable

As polarisation dependent observable Guchait and Roy proposed to use ratio of charged and total tau jet momentum *R* (hep-ph/0109096):

$$R = p_{\pi^\pm}/p_{\tau-\mathrm{jet}}$$

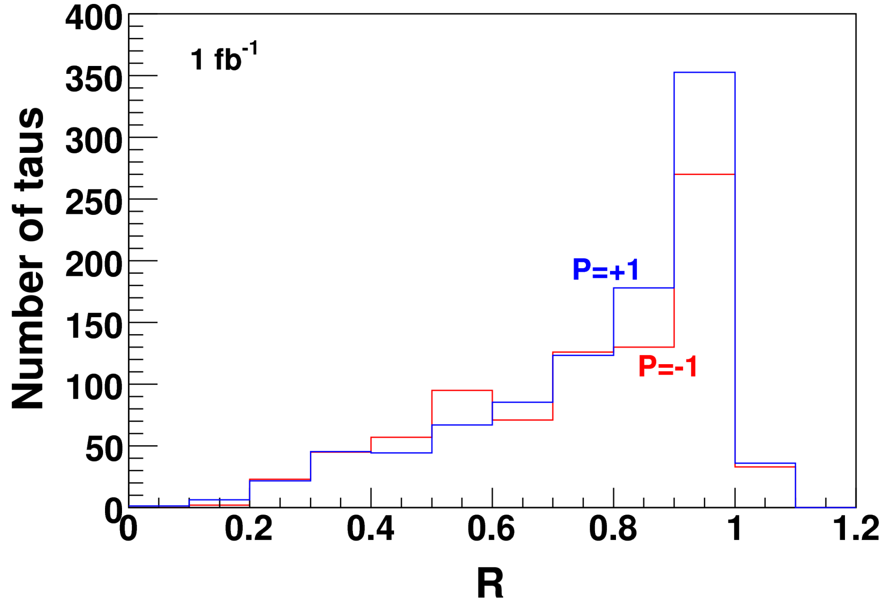
~ boost invariant



Reconstructed R distribution

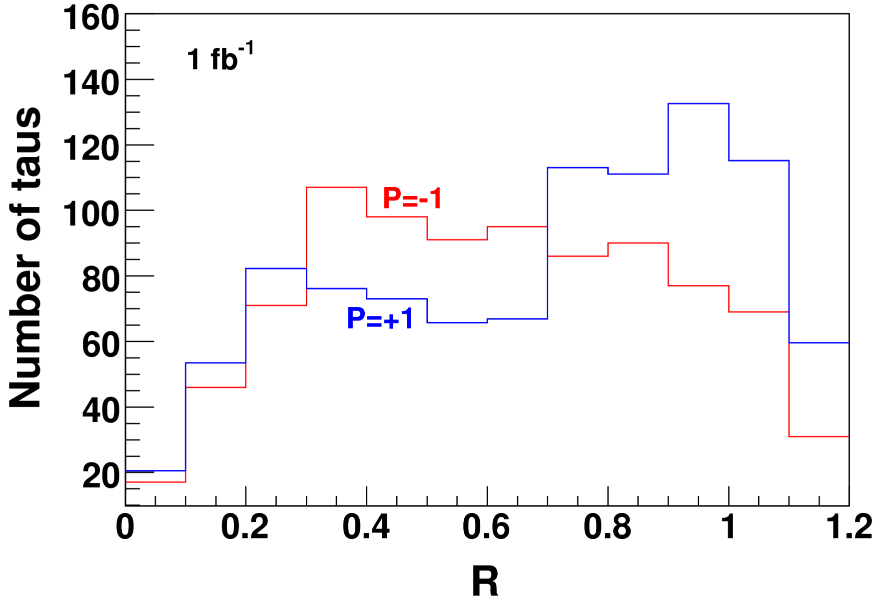
Presently two different tau reconstruction algorithms in ATLAS:

tau1p3p



- track seeded
- E from energy flow

tauRec



- calorimeter seeded
- E from calorimeter

Clearly there is separation power. More quantitative analysis ongoing.

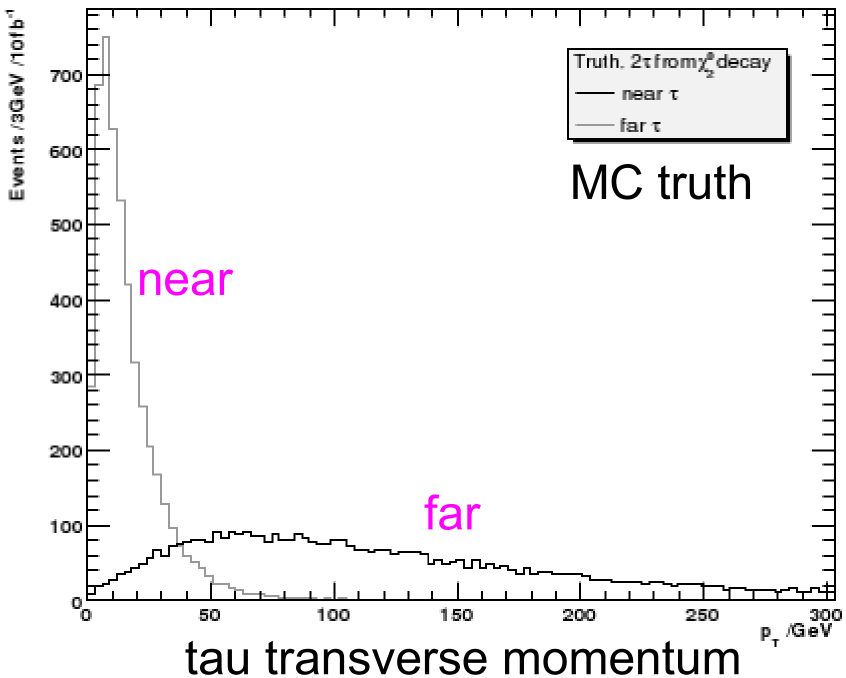
Neither of the two tau reconstruction algorithms seems ideal for this measurement.

Tau reconstruction

SUSY can lead to extremely soft taus
(e. g. in co-annihilation region, AMSB).

In addition a more exclusive tau reco
than "tau ≈ narrow jet" is desirable
(e. g. for polarisation measurement)

SU1 co-annihilation point:

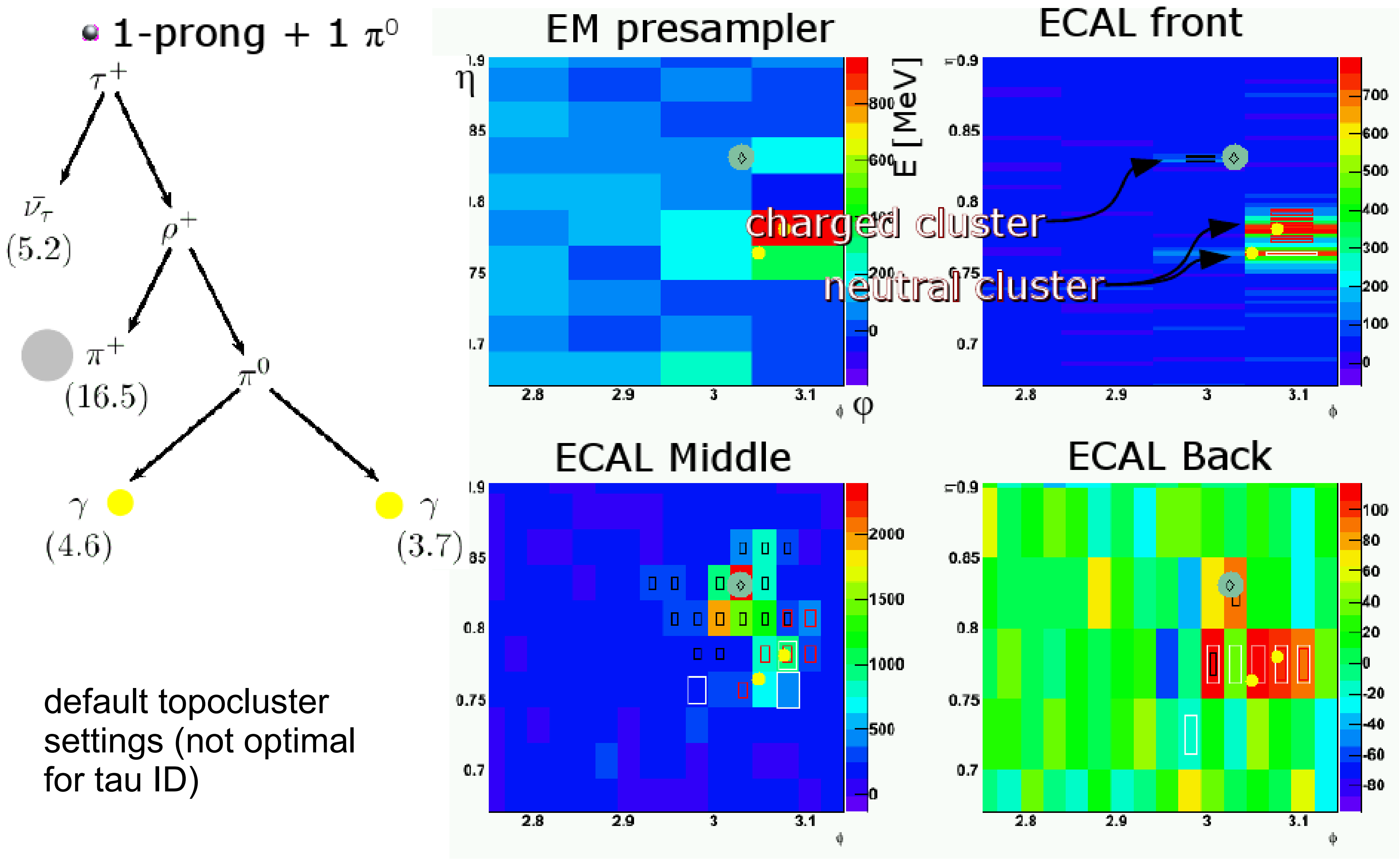


Topological clustering of calorimeter cells opened door towards particle based tau reconstruction (tau $= n\pi^{\pm} + m\pi^{0}$):

- use tau decay kinematics (mass constraints, etc.)
- fully exploit calorimeter granularity (shower profiles)

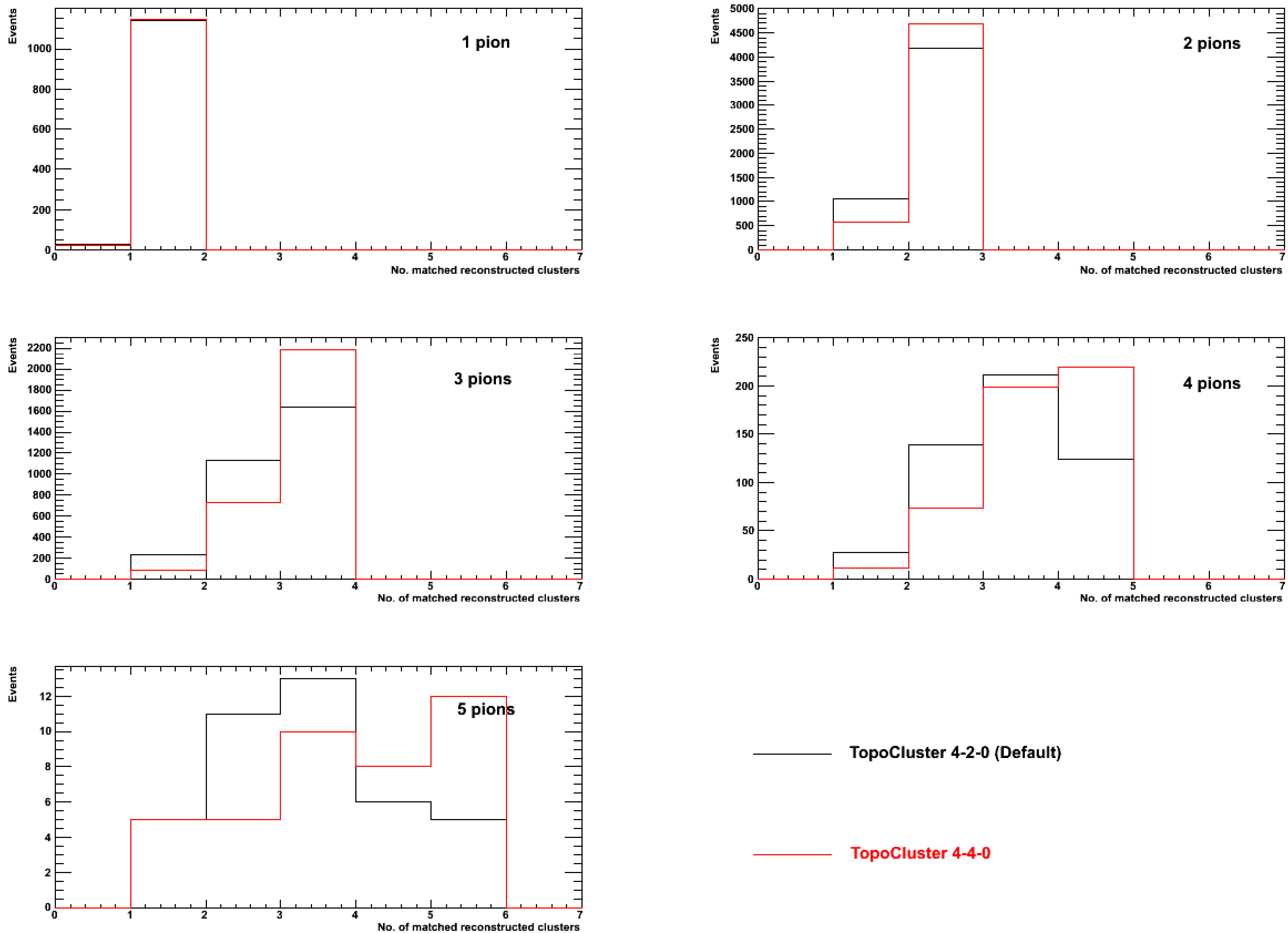
Topoclusters may allow to fulfil both wishes at once.

Tau in ECAL after topological clustering



default topocluster settings (not optimal for tau ID)

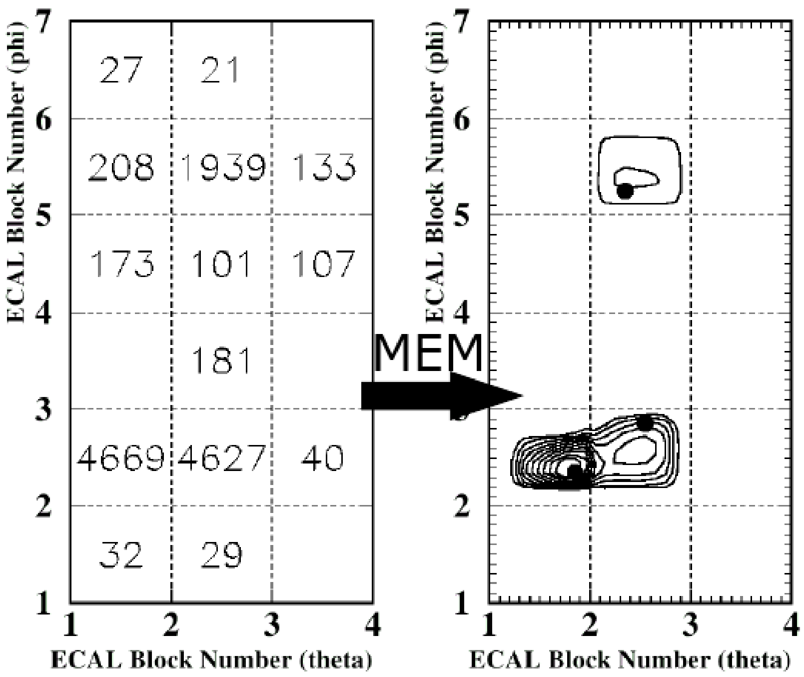
Variation of topocluster parameters



Maximum entropy method

Try to separate overlapping clusters and to increase spatial resolution of calorimeter with maximum entropy method (MEM).

Investigated in OPAL (M. Thomson, NIM A383 (1996) 553) and widely used in astronomy.



Precision below detector resolution possible by using known response of detector to (different types of) incident particles

→ with particle dependent response function MEM provides particle hypothesis

Summary

- Taus are very interesting probes for SUSY physics often providing complementary information not accessible in other measurements.
- Di-tau endpoint can be measured up to 4 % statistical precision with 10 fb^{-1} for considered bulk point.
- Tau polarisation has significant impact on endpoint measurement. Disentanglement may be done using different tau decay modes.
- Tau polarisation provides information on stau mixing angle and LSP composition.
- Work on fully exploiting tau decay kinematics and calorimeter granularity for tau ID under way.