Physics with tau leptons

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Physics Seminar
8th April 2005

Motivation

WHY talk about τ's?:

- prompted by recent paper reading of τ discovery
- **Phys. Rev. Lett. 35, 1489-1492 (1975)**

  http://prola.aps.org/abstract/PRL/v35/i22/p1489_1

Evidence for Anomalous Lepton Production in e^+-e^- Annihilation*

M. L. Perl, G. S. Abrams, A. M. Boyarski, M. Breidenbach, D. D. Briggs, F. Bulos, W. Chinowsky, J. T. Dakin,† G. J. Feldman, C. E. Friedberg, D. Fryberger, G. Goldhaber, G. Hanson, F. B. Heile, B. Jean-Marie, J. A. Kadyk, R. R. Larsen, A. M. Litke, D. Lüke,‡ B. A. Lulu, V. Lüth, D. Lyon, C. C. Morehouse, J. M. Paterson, F. M. Pierre,§ T. P. Pun, P. A. Rapidis, B. Richter, B. Sadoulet, R. F. Schwitters, W. Tanenbaum, G. H. Trilling, F. Vannucci,‖ J. S. Whitaker, F. C. Winkelmann, and J. E. Wiss

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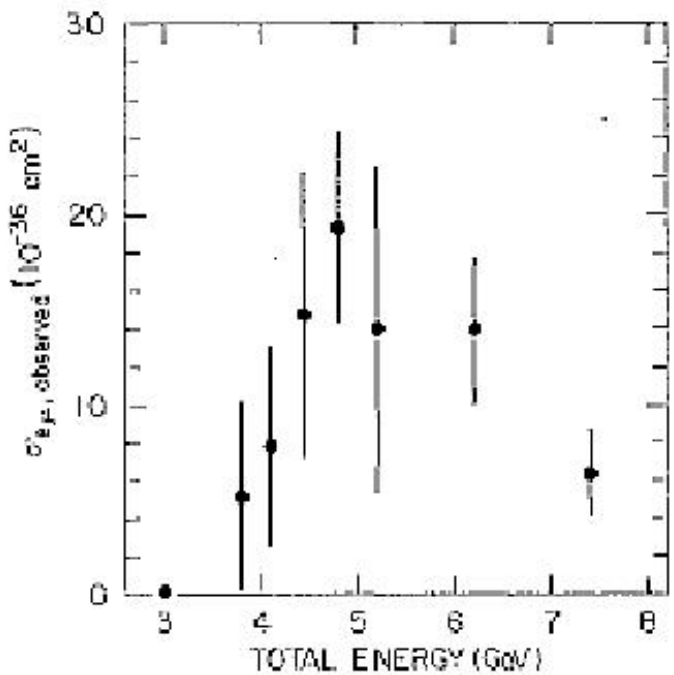
(Received 18 August 1975)

We have found events of the form $e^+ + e^- \to e^\pm + \mu^\mp$ + missing energy, in which no other charged particles or photons are detected. Most of these events are detected at or above a center-of-mass energy of 4 GeV. The missing-energy and missing-momentum spectra require that at least two additional particles be produced in each event. We have no conventional explanation for these events.

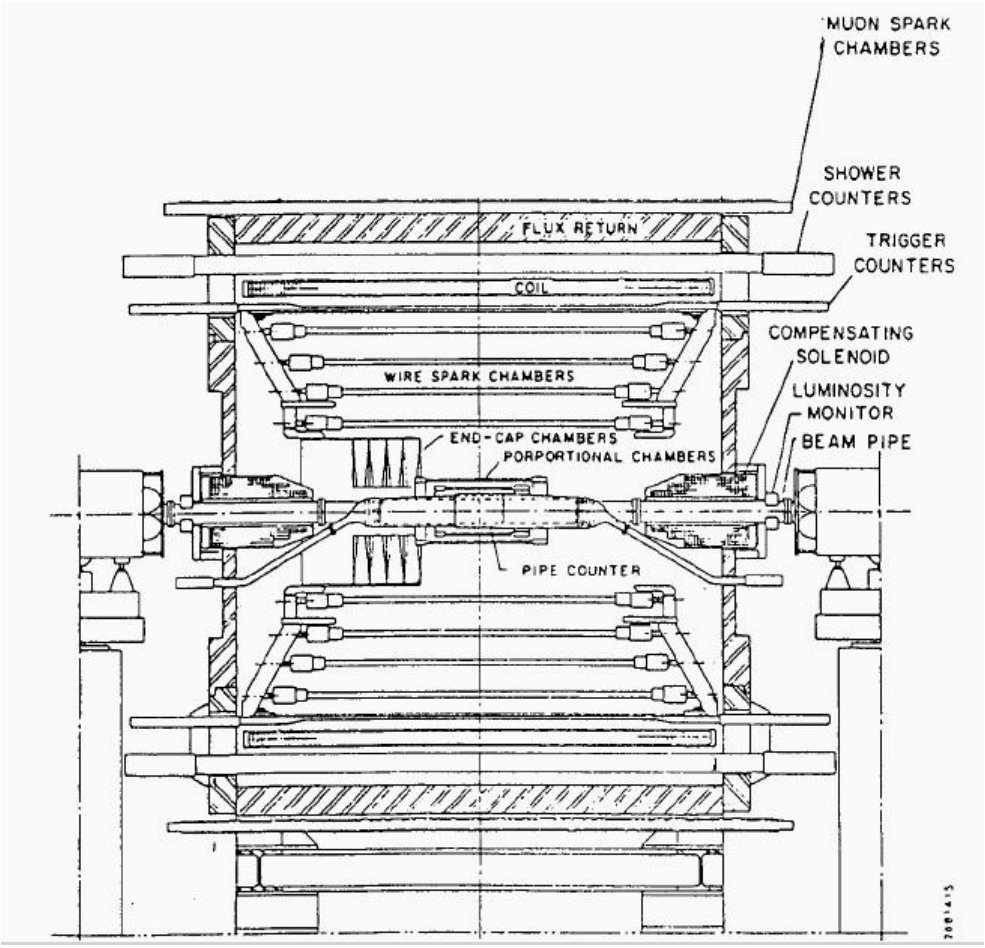
discovery discussion

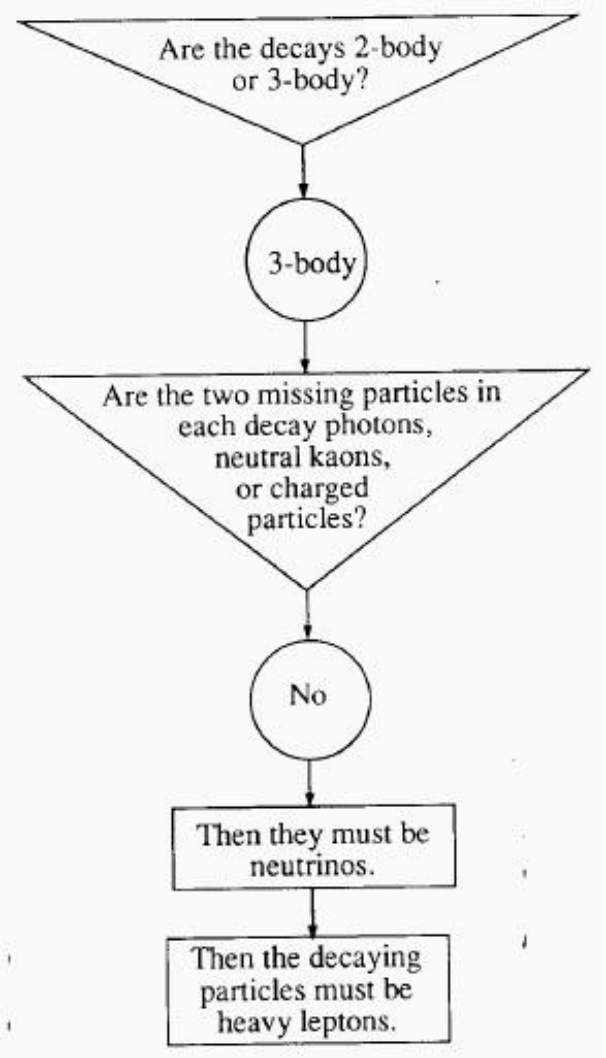
- controversial paper (note: first sign of 3rd family)
- $\sim 20\%$ fake rate for each e, μ (from ≥ 3 prong)
- 24 $e\mu$ events observed, expected 4.7 ± 1.2
- overall pretty solid



- interesting sociology
- people thought it was charm
- today:
  would you believe evidence for a 4th family?

discovery discussion





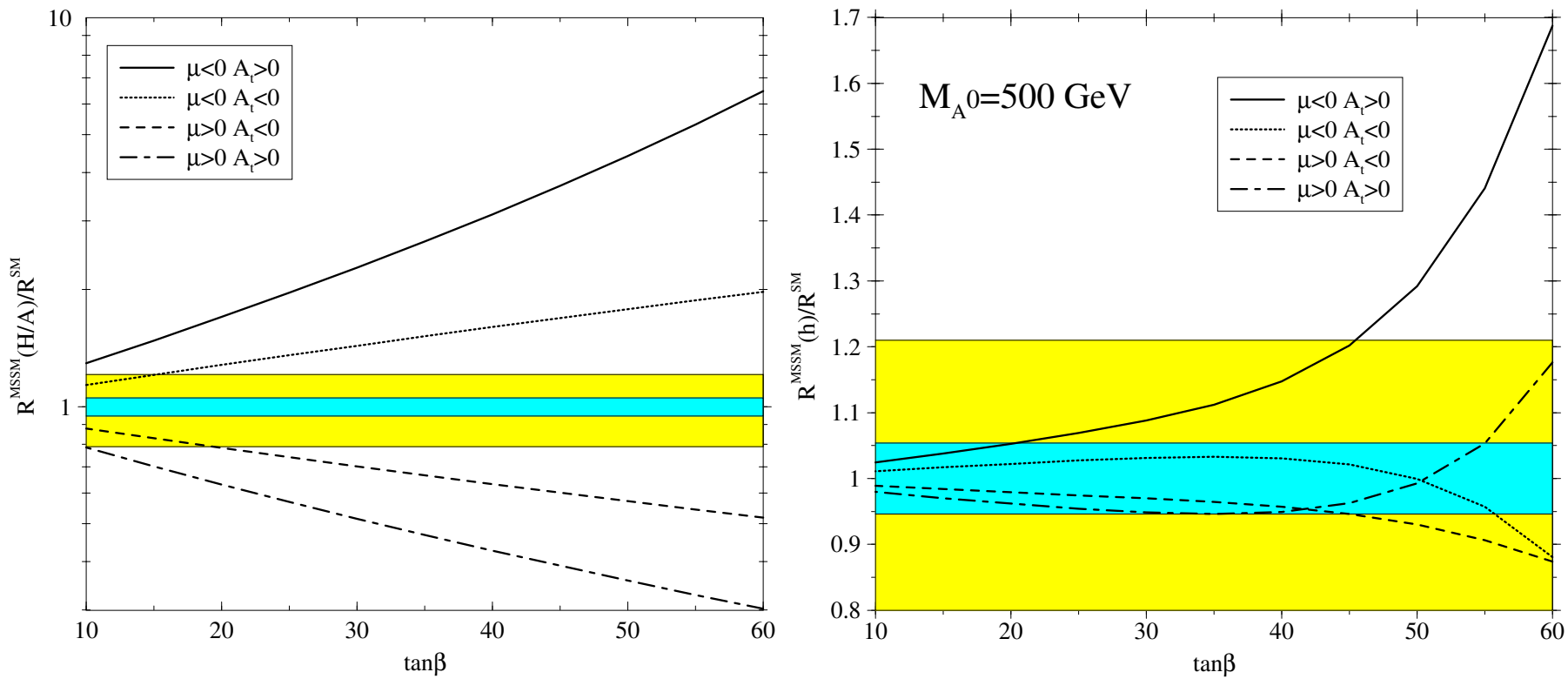
τ-Physics at ATLAS

Motivations:

- $\mathrm{A} \rightarrow \tau^+\tau^-$ (see Marjories Talk)
- in general couplings to τ enhanced in SUSY by $\tan\beta$
- also SM Higgs: $\mathrm{H} \rightarrow \tau^+\tau^-$
- proposal to use $R = \frac{H \rightarrow b\bar{b}}{H \rightarrow \tau^+\tau^-}$ to distinguish between models (hep-ph/0106027)

τ-Physics at ATLAS

- in SM $R = \frac{H \to b\bar{b}}{H \to \tau^+\tau^-} \sim \frac{N_c m_b(Q)^2}{m_\tau^2}$
- neat idea, but hard ($\Longrightarrow H \to b\bar{b}$)



τ-Physics at ATLAS

Reconstruction

- active area $\Longrightarrow$ monthly tau meetings (Agenda: Physics/JetEtmiss/tau)
- ATHENA package: `tauRec`
- three algorithms: baseline, track-based, japanese
- soon ;-), ATL-COM-PHYS-2004-080, ATL-COM-PHYS-2004-069
- interesting CMS notes: CR-2004/05, 1997/039

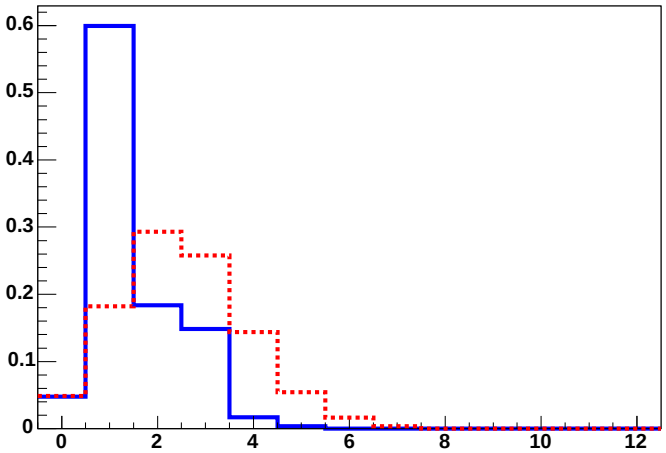
Basic τ reconstruction

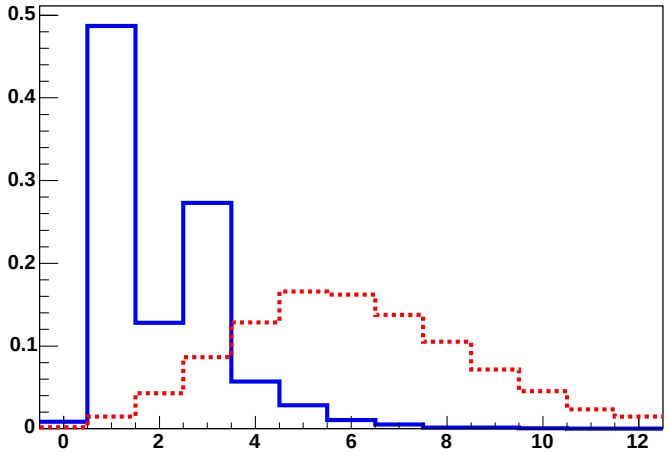
Decay modes	TAUOLA-CLEO
$\tau \to e\nu_e\ \nu_\tau$,	17.8 %
$\tau \to \mu\nu_\mu\ \nu_\tau$	17.4 %
$\tau \to \pi^\pm\nu_\tau$	11.1 %
$\tau \to \pi^0\pi^\pm\nu_\tau$	25.4 %
$\tau \to \pi^0\pi^0\pi^\pm\nu_\tau$	9.19 %
$\tau \to \pi^0\pi^0\pi^0\pi^\pm\nu_\tau$	1.08 %
$\tau \to \pi^\pm\pi^\pm\pi^\pm\nu_\tau$	8.98 %
$\tau \to \pi^0\pi^\pm\pi^\pm\pi^\pm\nu_\tau$	4.30 %
$\tau \to \pi^0\pi^0\pi^\pm\pi^\pm\pi^\pm\nu_\tau$	0.50 %
$\tau \to \pi^0\pi^0\pi^0\pi^\pm\pi^\pm\pi^\pm\nu_\tau$	0.11 %
$\tau \to K^\pm X\nu_\tau$	3.74 %
$\tau \to (\pi^0)\pi^\pm\pi^\pm\pi^\pm\pi^\pm\pi^\pm\nu_\tau$	0.10 %
others	0.03 %

- $\tau \longrightarrow l\nu\bar{\nu}$
- $\tau \longrightarrow \pi^+ + n\pi^0\nu$
  one prong
- $\tau \longrightarrow \pi^+\pi^-\pi^+ + n\pi^0\nu$
  three prong
- everything else
  negligible

Basic τ reconstruction

- start with either Calo cluster or seed track
- $N_{trk} = 1, 3$; $|Q| = 1$





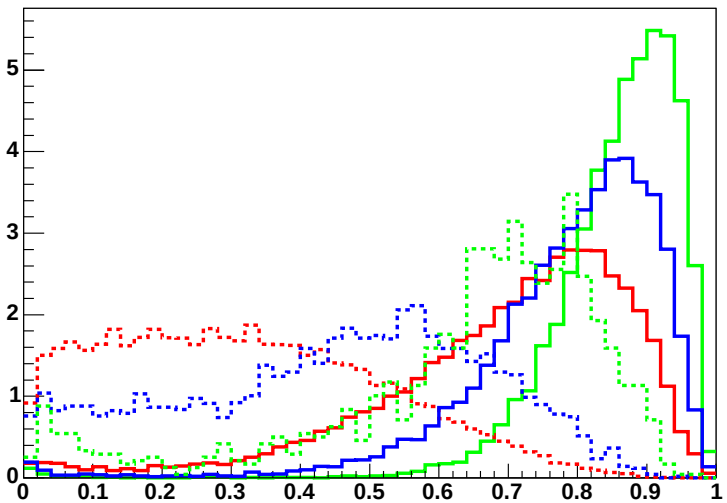
Number of tracks with $p_T > 2\mathrm{GeV}$,

$20 < p_T(\tau) < 30\mathrm{GeV}$, $70 < p_T(\tau) < 130\mathrm{GeV}$

Basic τ reconstruction

Energy Fraction:

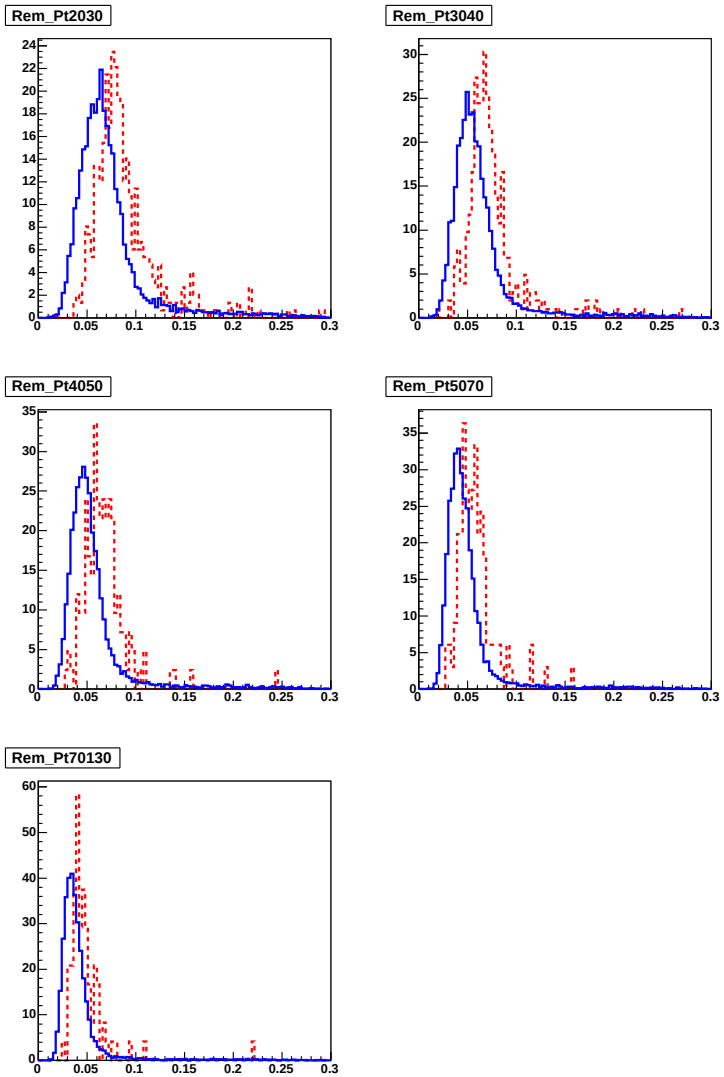
- utilize narrow jet feature
- $\mathrm{frac}E_T^{R12} = \frac{E_T(\Delta R<0.2)-E_T(\Delta R<0.1)}{E_T(\Delta R<0.2)}$
- $\mathrm{frac}E_T^{R12} < 0.2(\tau_{1P}); \mathrm{frac}E_T^{R12} < 0.4(\tau_{3P})$



$$F_{01} = \frac{E_T(\Delta R<0.1)}{E_T(\Delta R<0.4)}$$

20-30,40-50,70-130 GeV

Basic τ reconstruction



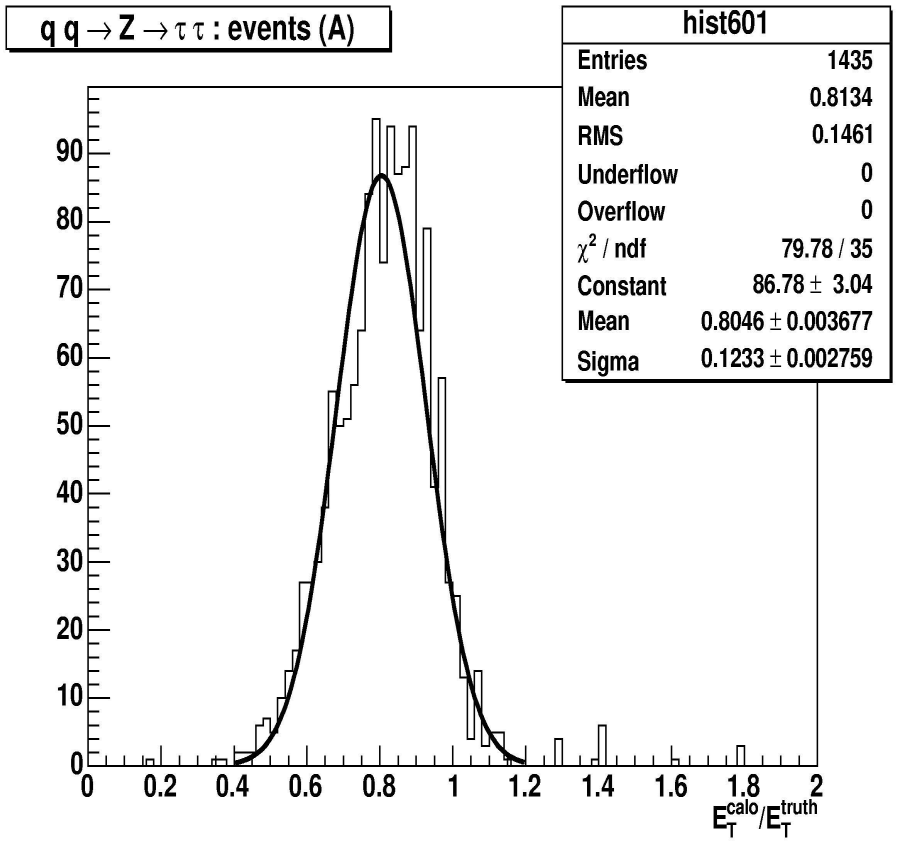
- utilize narrow jet feature
- electromagnetic radius
- $R_{EM} = \frac{\sum_{cells} \Delta R^{cell} . E_T^{cell}}{\sum_{cells} E_T^{cell}}$
- $R_{EM} \leq 0.08$

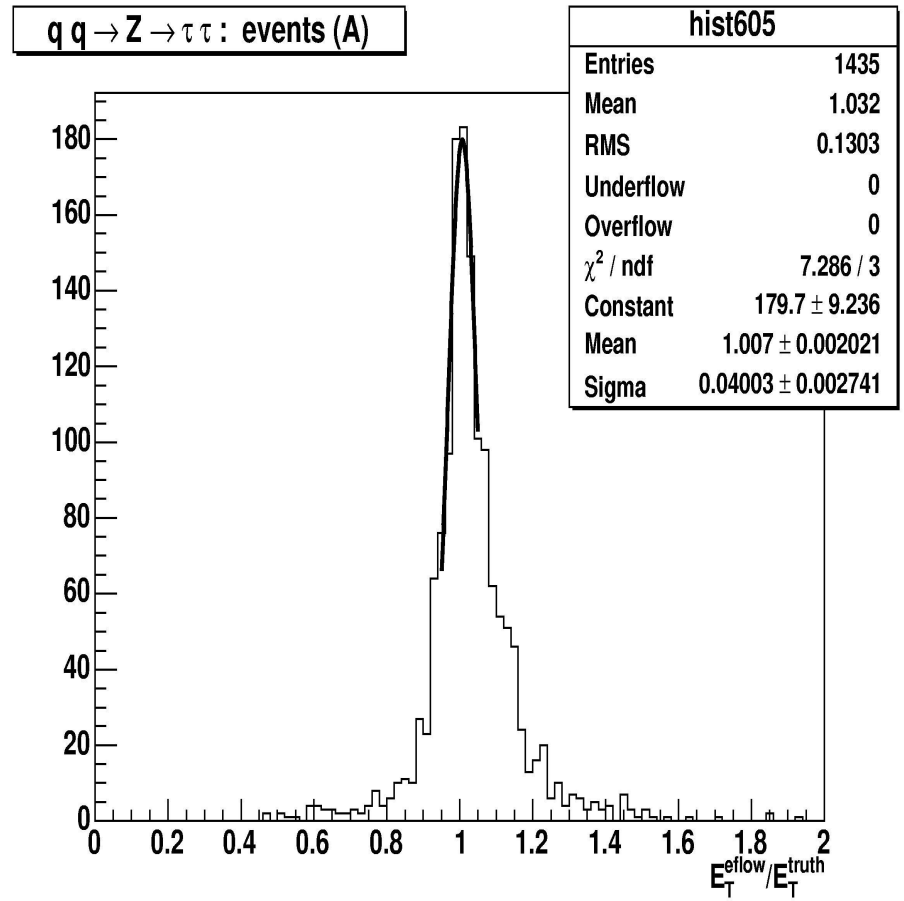
other ideas

Energy flow E_T^{eflow}

- tracks are much better measured than cal energy
- $\Longrightarrow$ replace $E_{charged}$ with $\sum p_T$
- classify towers with respect to combination of tracks, E_{EM} and E_{hadr}
- model and correct leakage
- $\Longrightarrow$ particular well suited for τ, underestimates E_{flow} for fakes
- $E_T^{eflow} = E_T^{EMCL} + E_T^{neuEM} + \sum p_T^{track} + resE_T^{chrgEM} + resE_T^{neuEM}$

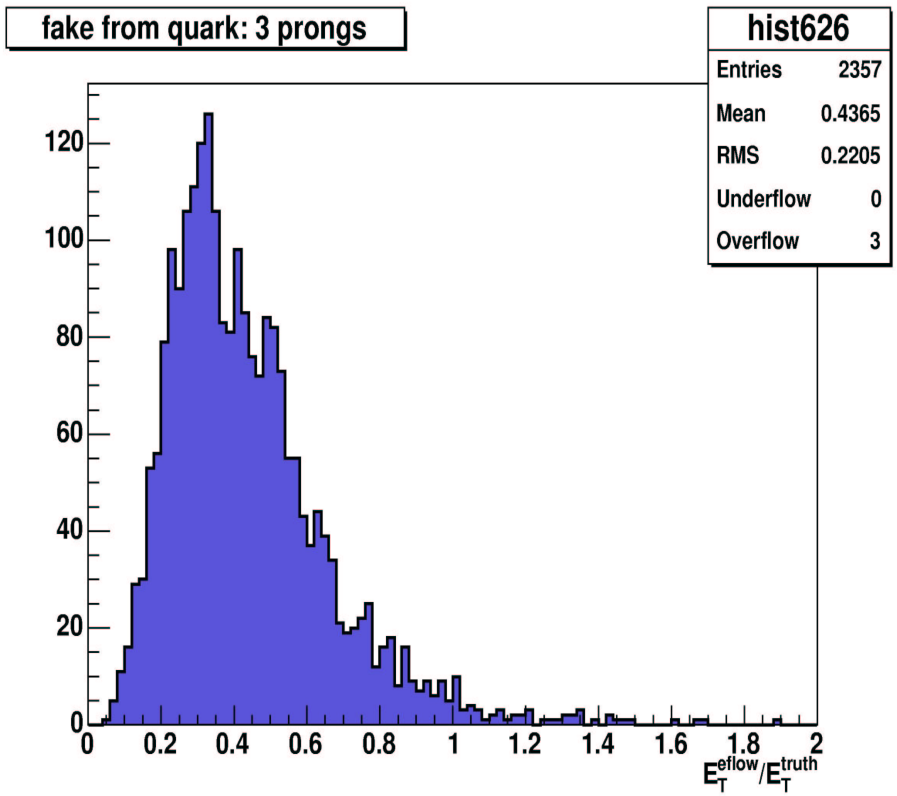
other ideas

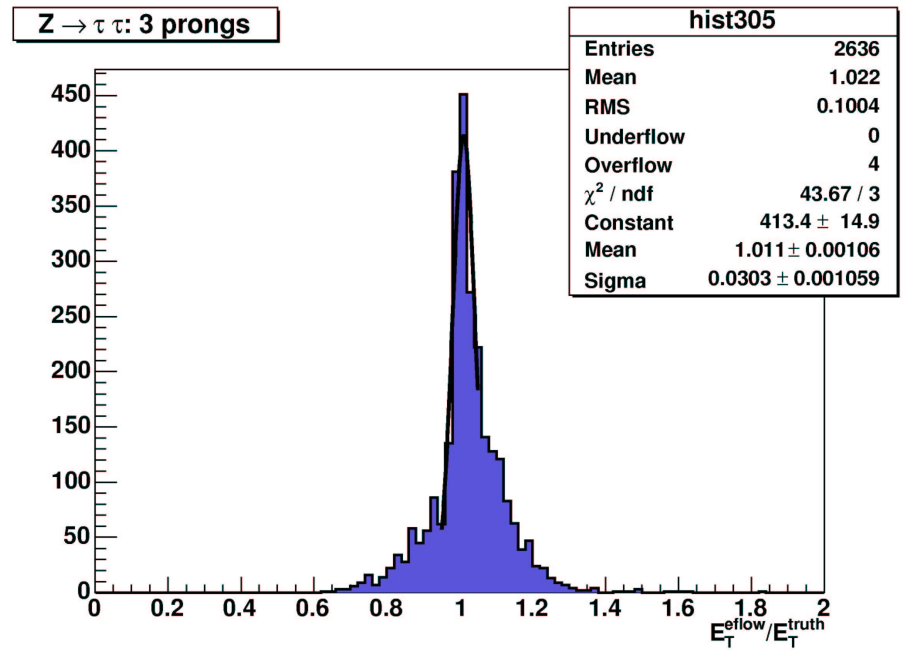




before and after E^{flow} correction

other ideas



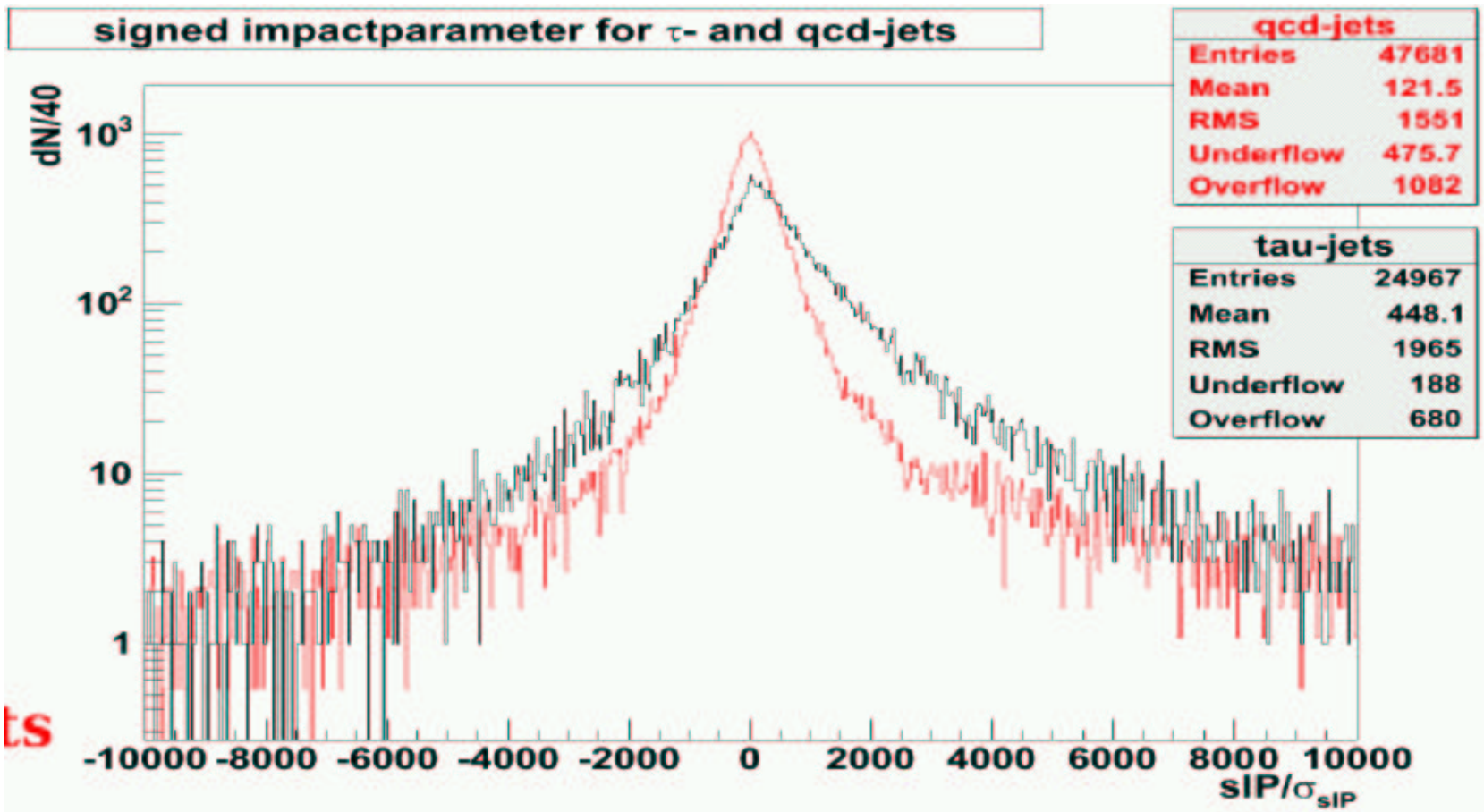


$\Longrightarrow$ underestimated for background only,

$\Longrightarrow$ effective higher E_T cut

other ideas

τ has lifetime $(c\tau \sim 90\mu m) \Longrightarrow$ impact parameter



Concluding remarks

- many more connected topics
- standard candle $\mathrm{Z} \rightarrow \tau\tau$
- use to calibrate calorimeter? pion test beam ...
- analysis that connects tracking and calorimetry
- τ is connected to search for new physics
- lots of activity ongoing, at least 3 active groups