Events with τ–Leptons at HERA

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for the H1 Collaboration

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Reminder: Isolated Lepton Searches at HERA-I

- Isolated Leptons in Events with Missing Transverse Momentum observed at HERA
- Excess in Electron / Muon channels for H1, in τ–Channel for ZEUS
- **Question:** What does H1 see in the τ–Channel?

1994-2000 *ep* 118 pb^{-1}	Electron obs. / exp.	Muon obs. / exp.	**Tau**
Full Sample	**11 / 11.54**	**8 / 2.94**	**?**
$P_T X > 25$ GeV	**5 / 1.76**	**6 / 1.68**	
$P_T X > 40$ GeV	**3 / 0.66**	**3 / 0.64**	

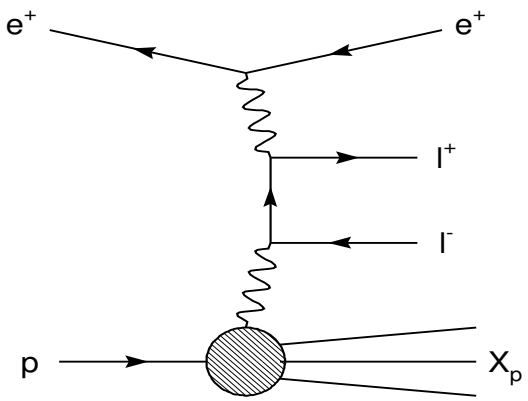
1994-2000 *ep* 130 pb^{-1}	Electron obs. / exp.	Muon obs. / exp.	Tau obs. / exp.
Full Sample	**24 / 20.6**	**12 / 11.9**	**3 / 0.40**
$P_T X > 25$ GeV	**2 / 2.9**	**5 / 2.75**	**2 / 0.20**
$P_T X > 40$ GeV	**0 / 0.94**	**0 / 0.95**	**1 / 0.07**

τ-Pairs in Elastic γγ-Processes

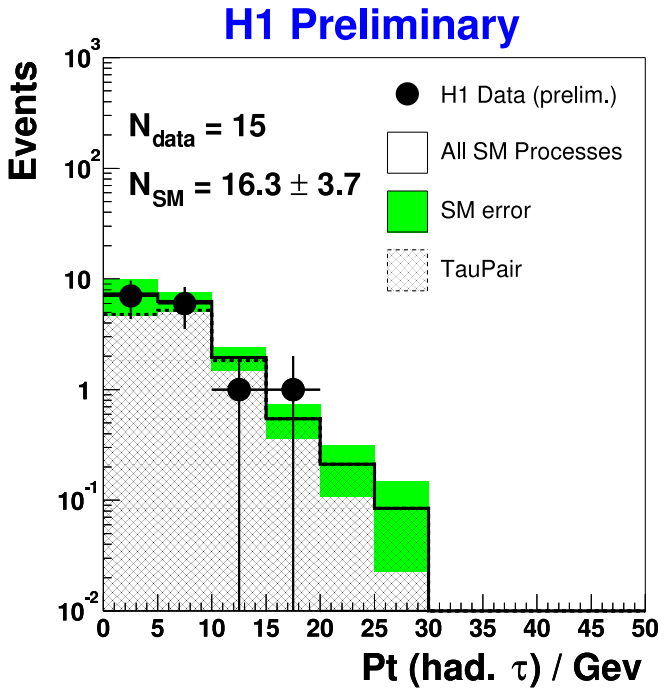
Selection Strategy

- 1st τ–lepton decaying leptonically
- 2nd τ–lepton decaying hadronically

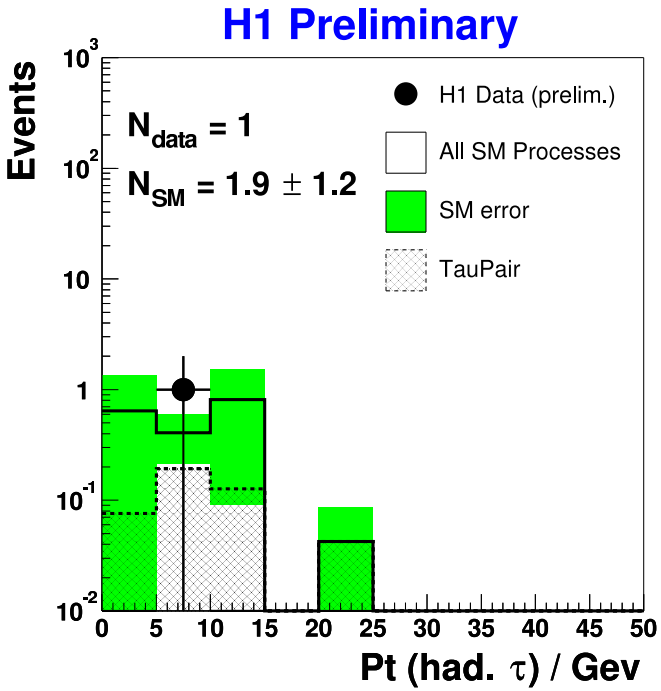
  Using Low-P_T τ–Finder
- Elastic Production



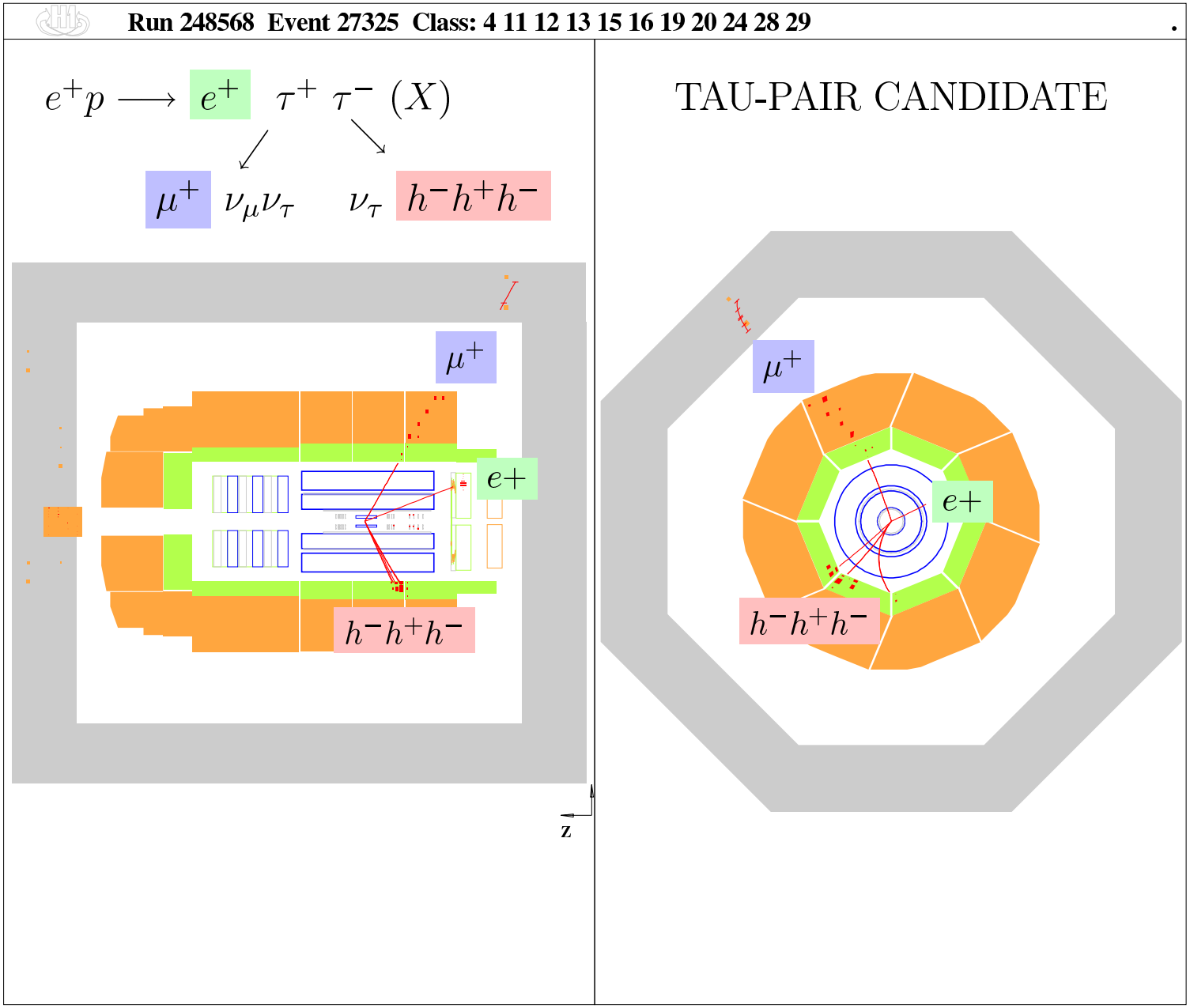
Odd Charge Sample:



Even Charge Sample:

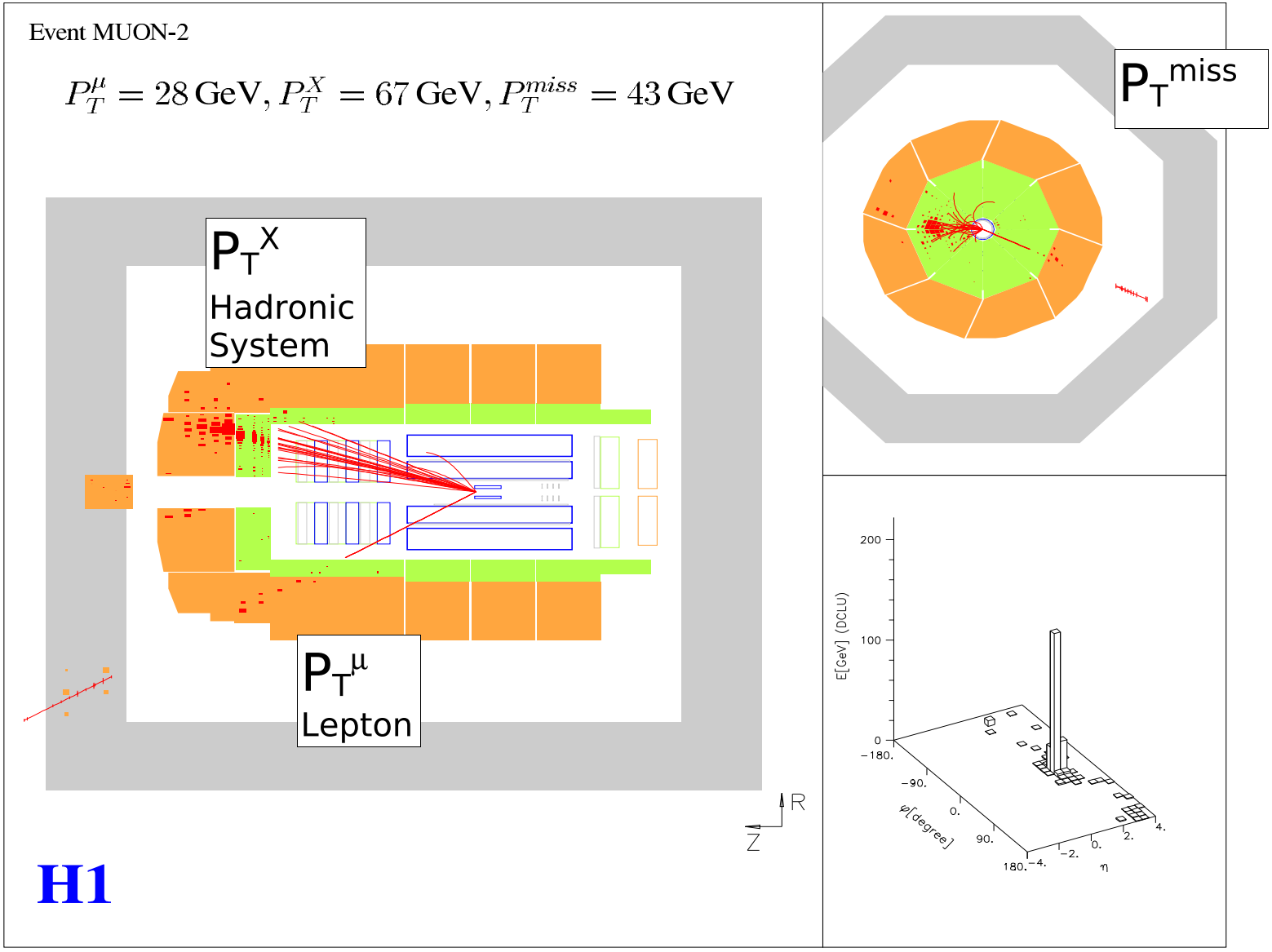


τ-Pair Event Example



Reminder: Topology of Isolated Lepton Events

$$e^+p \to \mu^+X$$



Signal Processes for Isolated τ–Leptons at HERA

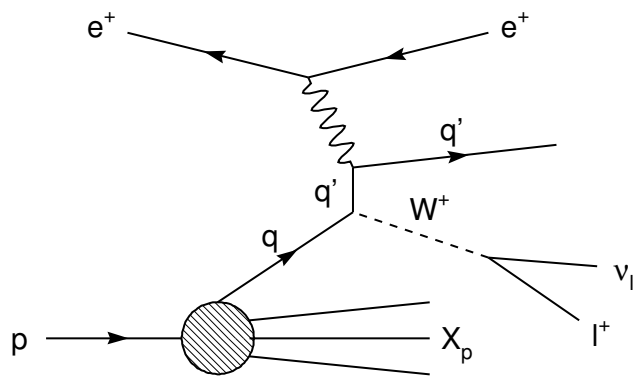
Standard Model *W*-Production

$ep \rightarrow W\,X$

$W \rightarrow \tau\,\nu_\tau$

$\tau \rightarrow$ hadrons ν_τ

(typically low/medium P_T^τ)



P_T^X *q*-Jet / *p*-Rest

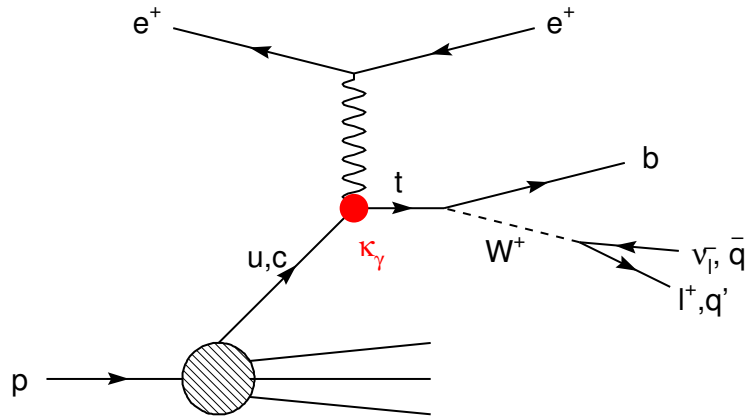
P_t^{miss} Neutrino

P_T Lepton

Also: From BSM-Land many possibilities...

Template Process
for High–P_T Isolated τ–leptons:

Single *top*-Production



P_T^X *b*-Jet

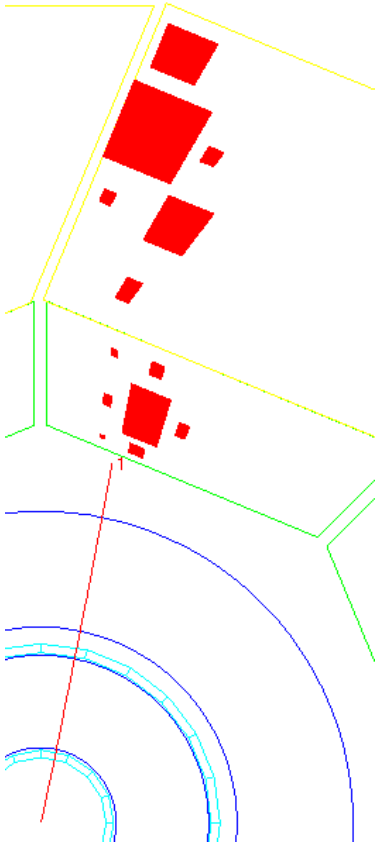
P_t^{miss} Neutrino

P_T Lepton

Signature of τ-Leptons

Hadronic Decays:

- Narrow jet with “hadr.” + “em.” component
- Low particle multiplicity
- 1 or 3 charged tracks (“prong”)



MC Example:
“1-prong” hadronic decay

Leptonic decay modes

$\tau \to e\,\nu$	~17%
$\tau \to \mu\,\nu$	~18%

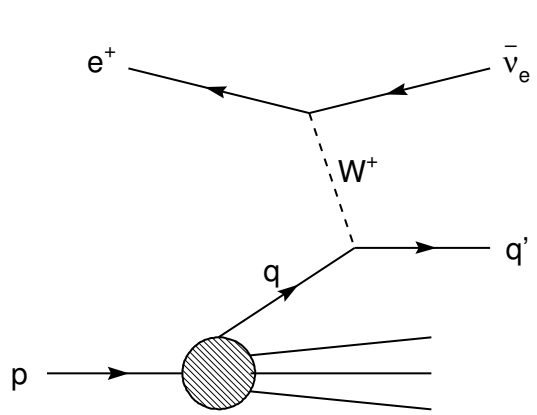
Hadronic decay modes “1-prong”

$\tau \to \pi^{\pm}\,\nu$	**~11%**
$\tau \to \rho^{\pm}\,\nu \to \pi^{\pm}\ \pi^{0}\,\nu$	**~25%**
$\tau \to \pi^{\pm}\ \pi^{0}\,\pi^{0}\,\nu$	**~9%**

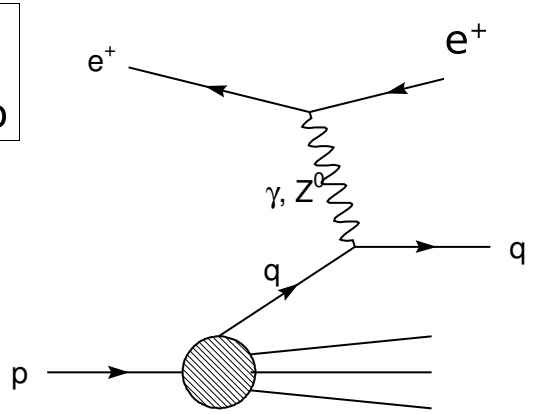
Hadronic decay modes “3-prong”

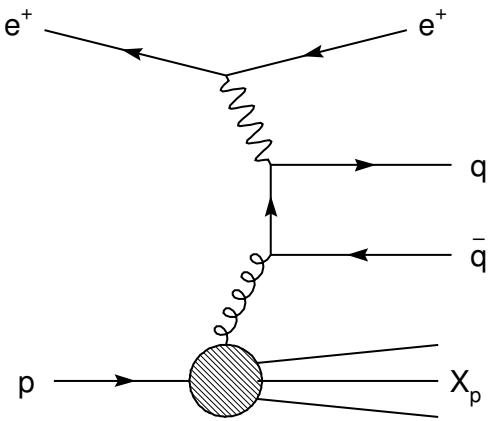
$\tau \to \pi^{\pm}\,\pi^{\pm}\,\pi^{\pm}\,\nu$	~10%
$\tau \to \pi^{\pm}\,\pi^{\pm}\,\pi^{\pm}\,\pi^{0}\,\nu$	~4%

Standard Model Background Processes



P_t^{miss} Neutrino





Charged Current

Neutral Current

Photoproduction

Enter Phase-Space because of ...

- **Missing P_T**: Real (CC) or due to Fluctuation (NC, γP)
- **Hadronic Jets**: Possibly Misidentified as τ–Jet
- **Leptons**: Possibly Misidentified as τ–Jet

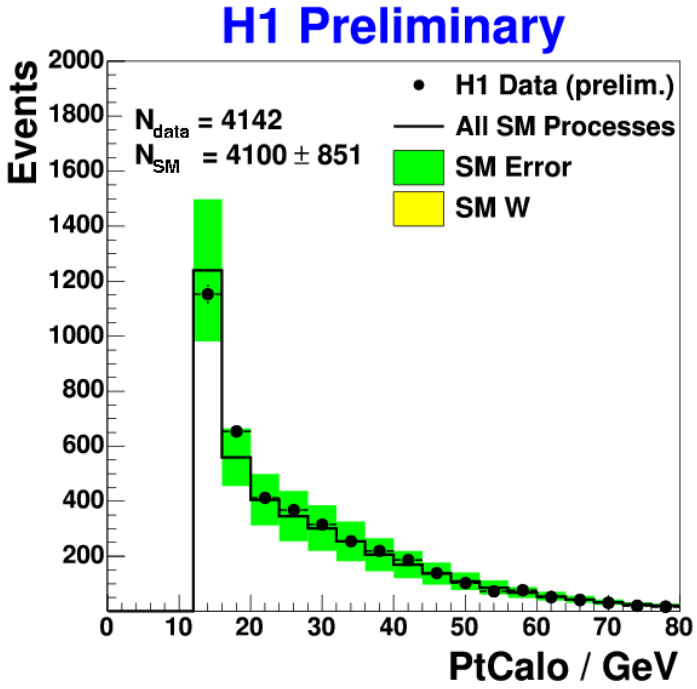
Data Sample Selection for Isolated τ–Lepton Search

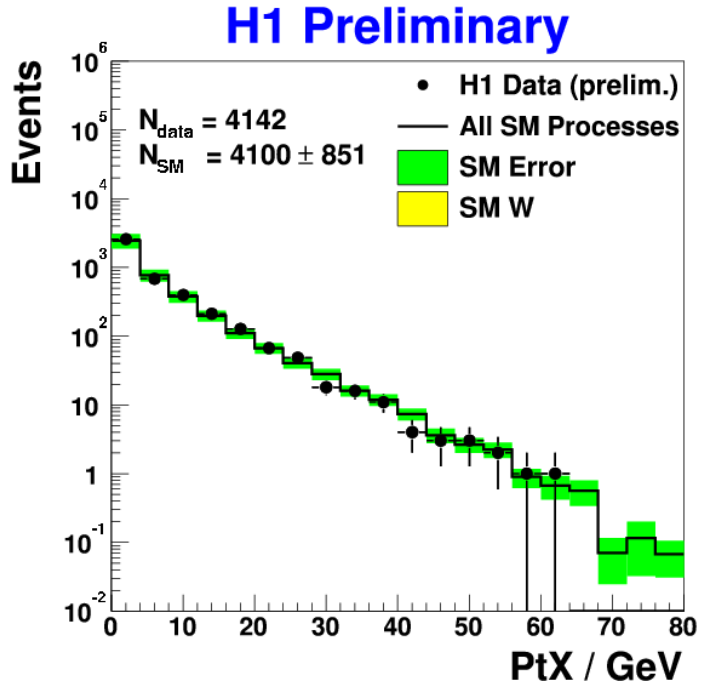
1996-2000 HERA-I Data (108 pb^{-1})

Selection Requirements

- Missing Transverse Momentum $P_T^{calo} > 12$ GeV
- Suppression of Standard Model Background

  $\sum (E - P_z) < 45$ GeV
- At least one Jet with $P_T^{jet} > 7$ GeV





τ–Identification

Selection of τ–Candidate Jet

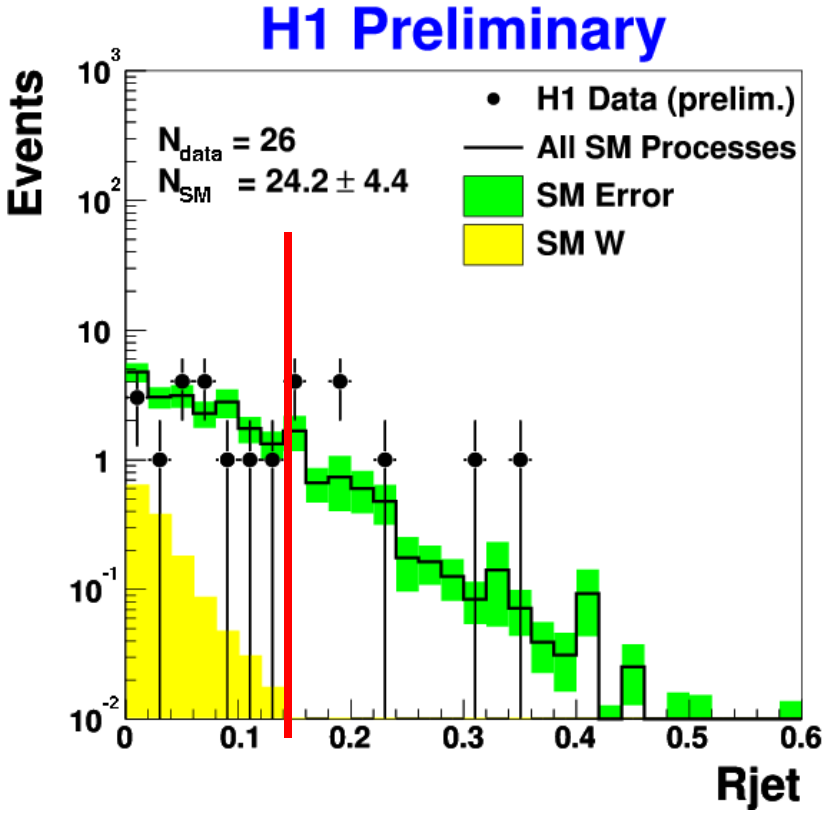
- Jet with $P_T > 7$ GeV in $20° < \theta < 120°$
- No *e*, μ in Jet and Isolation from other Jets
- Exactly 1 Track in Jet with $P_T^{track} > 2$ GeV

QCD-Jet Suppression

- Jet Radius $R_{jet} < 0.12$

$$R_{jet} = \frac{1}{E_{jet}} \sum_i E_i \sqrt{\Delta\varphi(jet,i)^2 + \Delta\eta(jet,i)^2}$$

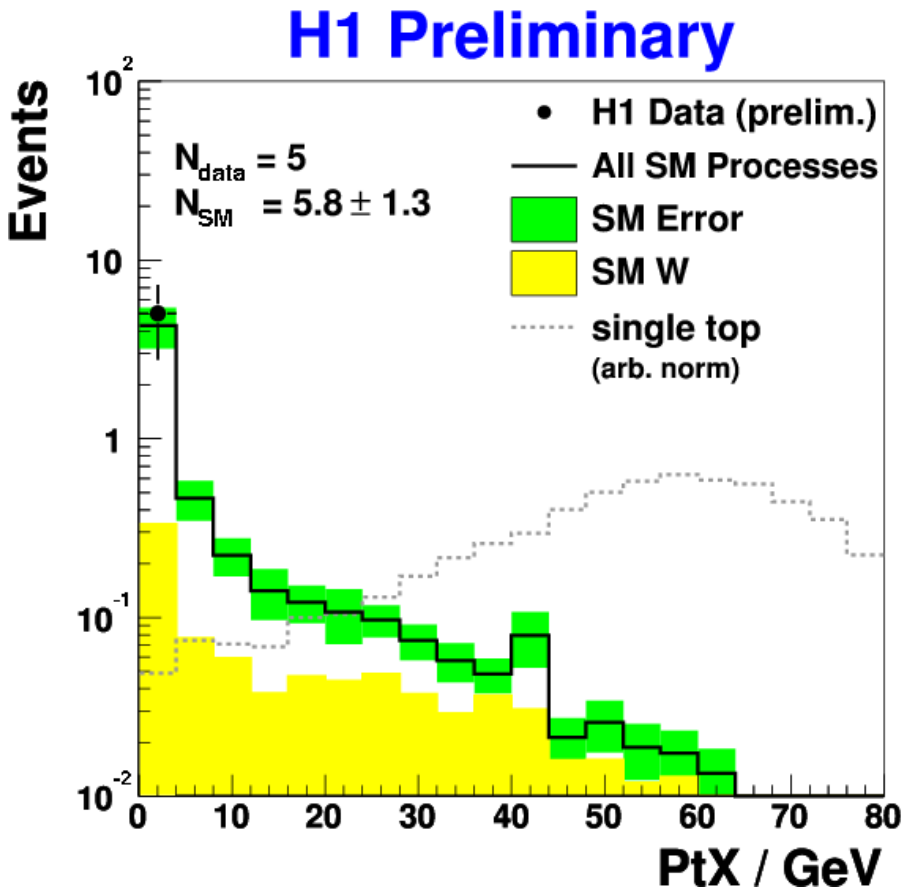
(where *i* runs over all particles in jet)



Final Sample and Results

Final Cuts

- Acoplanarity: $\Delta\varphi(\tau\text{–Jet, X}) < 170°$
- $P_T^{calo} > 20$ GeV
- $P_T^{track} > 5$ GeV



RESULTS

- **5 events / 5.8 ± 1.3 expected**
- **No events in high P_T^X region**

Summary Tables of Isolated τ-Lepton Analyses at HERA-I

H1 Preliminary

1996-2000 $e^{\pm}p$ 108 pb^{-1}	Data observed	All SM Processes expected	SM W expected	Single top Eff. * BR
All P_T^X	**5**	**5.81** ± 1.36	**0.87**	**0.52** %
P_T^X > 25 GeV	**0**	**0.53** ± 0.10	**0.26**	**0.49** %
P_T^X > 40 GeV	**0**	**0.22** ± 0.05	**0.12**	**0.42** %

ZEUS Results

1994-2000 $e^{\pm}p$ 130 pb^{-1}	Data observed	All SM Processes expected	SM W expected	Single top Eff. * BR (%)
All P_T^X	**3**	**0.40** ± 0.12	**0.19**	**0.27** %
P_T^X > 25 GeV	**2**	**0.20** ± 0.05	**0.09**	**0.27** %
P_T^X > 40 GeV	**1**	**0.07** ± 0.02	**0.05**	**0.25** %

Summary Tables of all Isolated Lepton Searches at HERA-I

1994-2000 *ep* 118 pb^{-1}	Electron observed / expected	Muon observed / expected	**Tau** (108 pb^{-1}) **observed / expected**
Full Sample	**11 / 11.54**	**8 / 2.94**	**5 / 5.81**
$P_T X > 25$ GeV	**5 / 1.76**	**6 / 1.68**	**0 / 0.53**
$P_T X > 40$ GeV	**3 / 0.66**	**3 / 0.64**	**0 / 0.22**

1994-2000 *ep* 130 pb^{-1}	Electron observed / expected	Muon observed / expected	Tau observed / expected
Full Sample	**24 / 20.6**	**12 / 11.9**	**3 / 0.40**
$P_T X > 25$ GeV	**2 / 2.9**	**5 / 2.75**	**2 / 0.20**
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Summary & Outlook

SUMMARY

- Low-P_T τ-Pairs in Elastic Events have been observed.
- A Search for High-P_T Isolated τ-Leptons has been done in H1:

  5 events observed with **5.8** expected.
  0 events observed with **0.53** expected at $P_T^X > 25$ GeV.

OUTLOOK

- Continue Searches for τ–Leptons at HERA-II
- Help solve Mystery of Isolated Leptons

Expecting lots of τ–Leptons in 1 fb^{-1} !