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Lepton Identification and Trigger Decision at Atlas Experiment

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Outline

◊ Introduction
◊ Leptons (e/mu/tau)
  – Leptonic signatures at LHC
  – Reconstruction/Identification
  – In-situ calibration using early data
◊ Trigger
  – Trigger system overview
  – Menus at low luminosity run
◊ Summary

Leptons

Introduction

- ◊ Leptons:
  - – Leptonic signatures are clean.
    - • Easy to trigger and select.
    - • Suppression of physics (QCD) and non-physics backgrounds.
    - • Excellent for calibration and alignment of the detector.
  - – Thus primary channels of LHC discoveries are leptonic.

- ◊ We summarize;
  - – lepton reconstruction, identification and predicted performances at the ATLAS detector,

  and also give our perspectives of;
  - – In-situ calibration using early data and expected performances
  - – They are sufficient for early discoveries??

Leptonic signatures

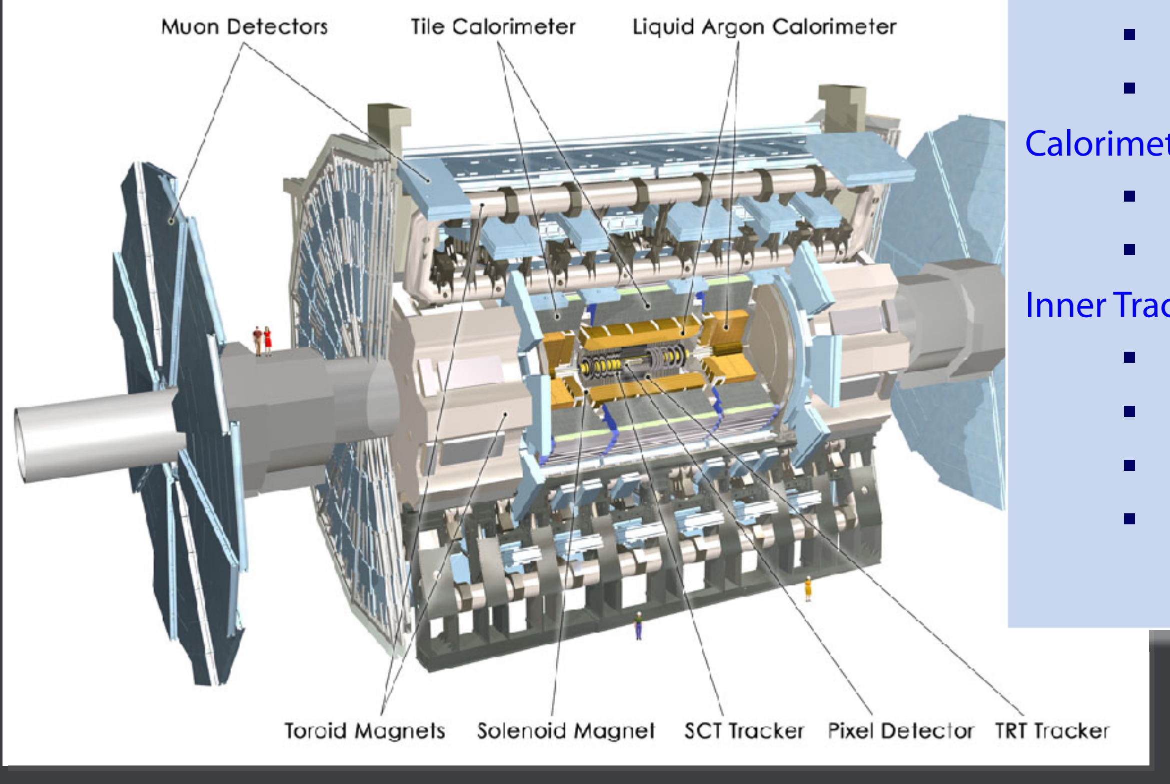
Physics shopping list w/ leptonic signatures

- *Standard Model Higgs*
  - $H \to ZZ \to llll$
  - $H \to WW \to l\nu l\nu$
  - $qqH \to qq\tau\tau$ (one or both $\tau \to l\nu\nu$)
- *MSSM Higgs*
  - $gg \to bbH(A), H(A) \to \tau\tau,\mu\mu$
- *Doubly Charged Higgs*
  - $H^{\pm\pm} \to W^{\pm}W^{\pm} \to l^{\pm}\nu l^{\pm}\nu$
- *Massive Vector Bosons (KK, Gravitons, etc.)*
  - $Z',G \to ll$
  - $Z',G \to WW \to l\nu l\nu$
  - $W' \to l\nu$ or WZ
- *SUSY*
  - $\tilde{g} \to q\tilde{q}_L$

    $\tilde{q}_L \to q\tilde{\chi}_2^0 \to ql\tilde{l}_R \to qll\tilde{\chi}_1^0$

- *GMSB* ($\tilde{\chi}_1^0 \to \tilde{G}\gamma, \tilde{l}_R \to \tilde{G}l$)
  - $\tilde{\chi}_2^0 \to l\tilde{l}_R \to ll\tilde{\chi}_1^0 \to ll\tilde{G}\gamma$
- *Right-Handed W*
  - $W_R \to l + N \to l + ljj$
- *Excited & Heavy Leptons*
  - $pp \to ll' \to llZ \to l + ljj$ (resonances)
  - $gg \to Z,Z' \to LL \to lZ + lZ \to ljj + ljj$
- *Etc.*
  - SM precision measurements, e.g.

Detector Overview



ATLAS (A Toiroidal Lhc ApparatuS)

"Small" 2T Solenoid for Tracking

3 Large Toroids for Muon Spectroscopy

- *High BL^2 for Standalone Measurements*

Muon Spectrometer

- *Precision: MDT, CSC*
- *Trigger: RPC, TGC*
- *Excellent acceptance at poles*

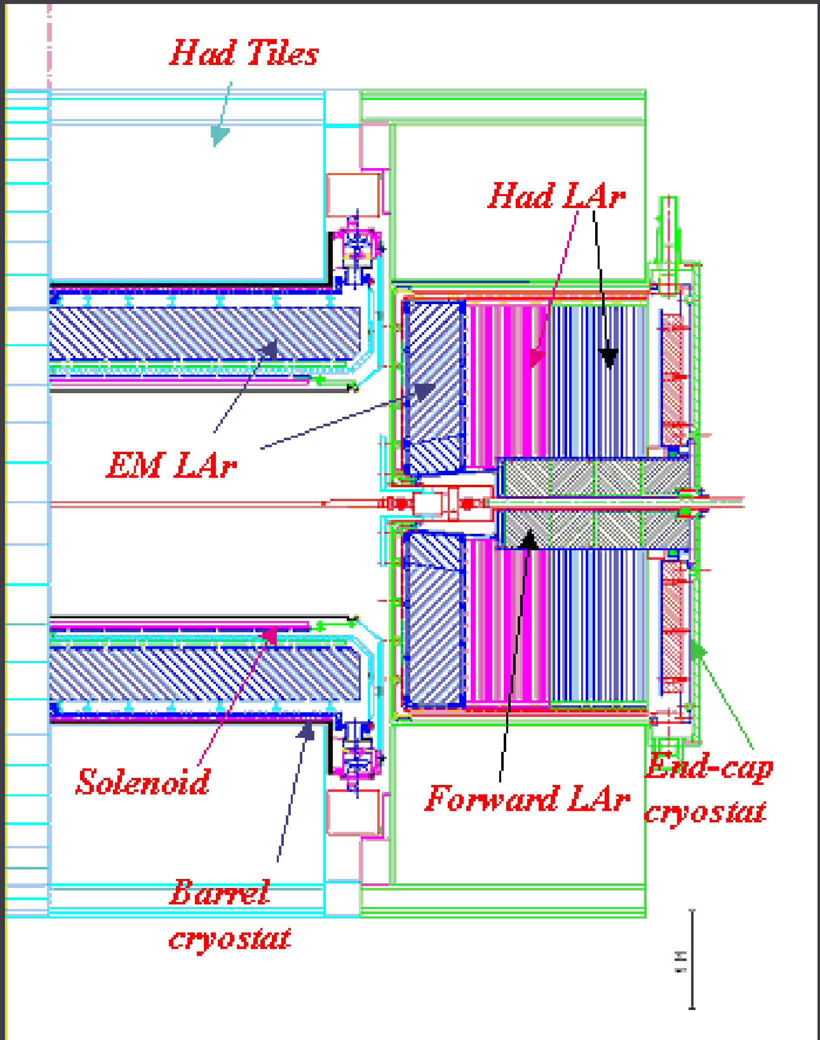
Calorimetry

- *Lateral & Longitudinal Segmentation*
- *FCAL only 4.9m from IP*

Inner Tracking (Pixel, SCT, TRT)

- *Pixels: 50μm (r-ϕ) x 400μm (z)*
- *$\Delta p/p$ (1 GeV)= 0.013,0.02 ($\eta \approx$0,2.5)*
- *$\Delta p/p$ (100 GeV) = 0.038,0.11*
- *TRT for e/π identification*

ATLAS calorimetry



Calorimeter Parameters	
Outer Dimensions (r / z)	2.25m / ±6.65m (ECAL) 4.25m / ±6.10m (HCAL)
Coverage (η)	±3.2 (ECAL, HCAL) ±4.9 (FCAL)
ECAL Technology	Presampler Pb / LAr (Liquid Argon) Accordion (190,000)
HCAL Technology	Fe / Scintillator (10,000) Cu / LAr (HEC) Cu / W / LAr (FCAL)
Samplings	1 + 3 + 3 (Barrel) (1) + 3 + 4 (Endcap) 3 + 3 (Forward)
Material	24 X_0 - 26 X_0 (ECAL) 11 λ (HCAL)
Resolution (η / ϕ)	0.025 / 0.025 mrad (ECAL) 0.100 / 0.100 mrad (HCAL)

Basic detector performance

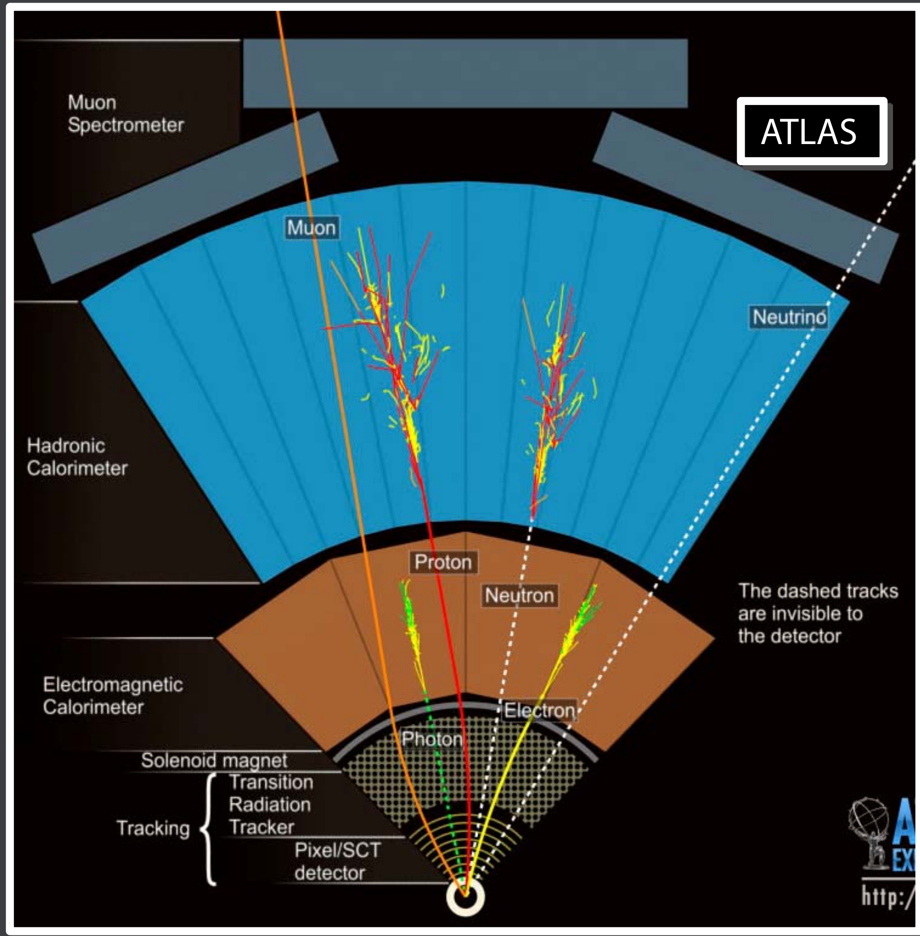
Tracking		
	$\eta \approx 0$	$\eta \approx 2.5$
$\delta p/p$ at $p_T = 1$ GeV	1.3%	2.0%
$\delta p/p$ at $p_T = 100$ GeV	3.8%	11.0%
ε(pions) at $p_T = 1$ GeV	84.0%	
ε(electrons) at $p_T = 5$ GeV	90.0%	

Calorimeter	
ECAL $\delta E/E$ (100 GeV Photons)	1 - 1.5%
ECAL $\delta E/E$ (50 GeV Electrons)	1.3 - 2.3%
ECAL+HCAL Stochastic Term	$55\% / \sqrt{E}$
ECAL+HCAL Constant Term	2.3%

Muon Spectrometer				
	Standalone		Combined	
	$\eta \approx 0$	$\eta \approx 2$	$\eta \approx 0$	$\eta \approx 2$
$\delta p/p$ at $p = 10$ GeV	3.9%	6.4%	1.4%	2.4%
$\delta p/p$ at $p = 100$ GeV	3.1%	3.1%	2.6%	2.1%
$\delta p/p$ at $p = 1000$ GeV	10.5%	4.6%	10.4%	4.4%

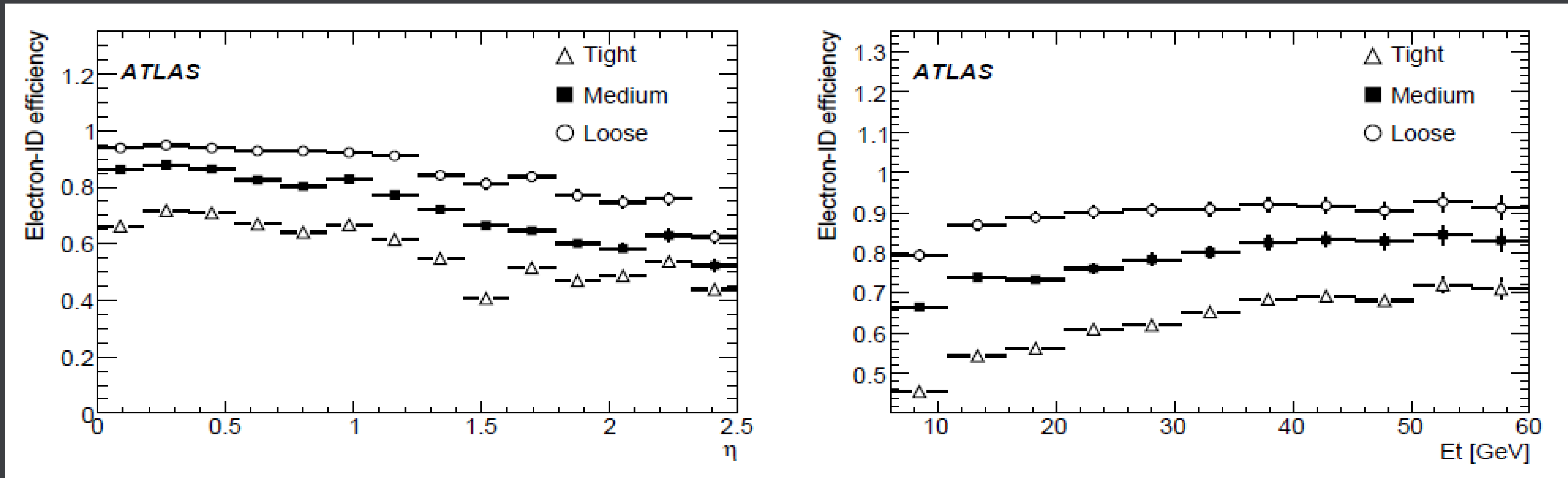
Electron: reconstruction

1. Build clusters from ECAL cells
2. Correct for geometry effects
3. Correct for cell saturation
4. Match clusters to tracks
5. Correction for bremsstrahlung
6. Require isolation
7. (kinematic cuts for analysis)



Electron: performance

◊ Predicted performances from MC simulation

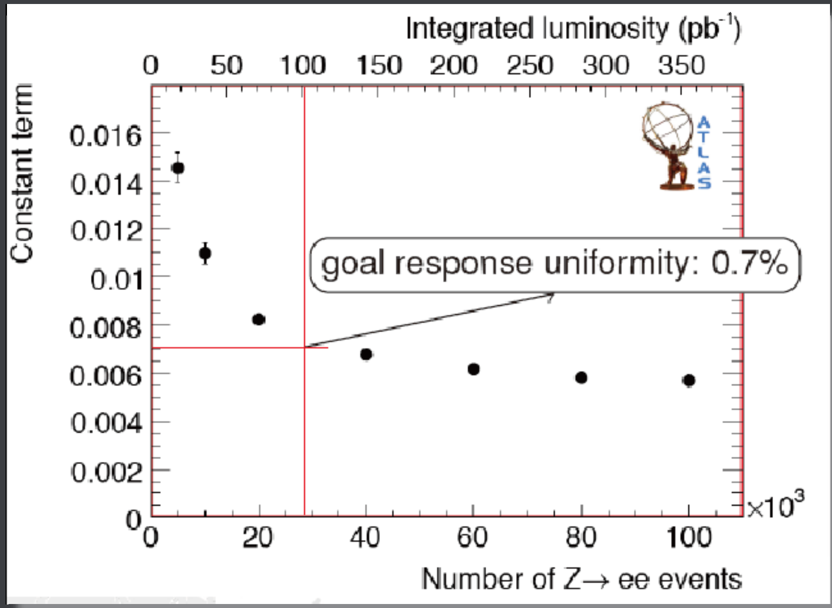


The drop in efficiency is visible at:

- gap region between the barrel and endcap calorimeters
- low pt, mainly due to the loss of discrimination power of the shower shape cuts.

In-situ calibration using Z→ee (1)

- Robust analysis at early stage
  - No track info. needed
  - Key tool for commissioning of electron reconstruction and ID.
- Correct the residual non-uniformity under Z mass constraint.
  - ~30,000 events of Z→ee enough to achieve a response uniformity of 0.7%



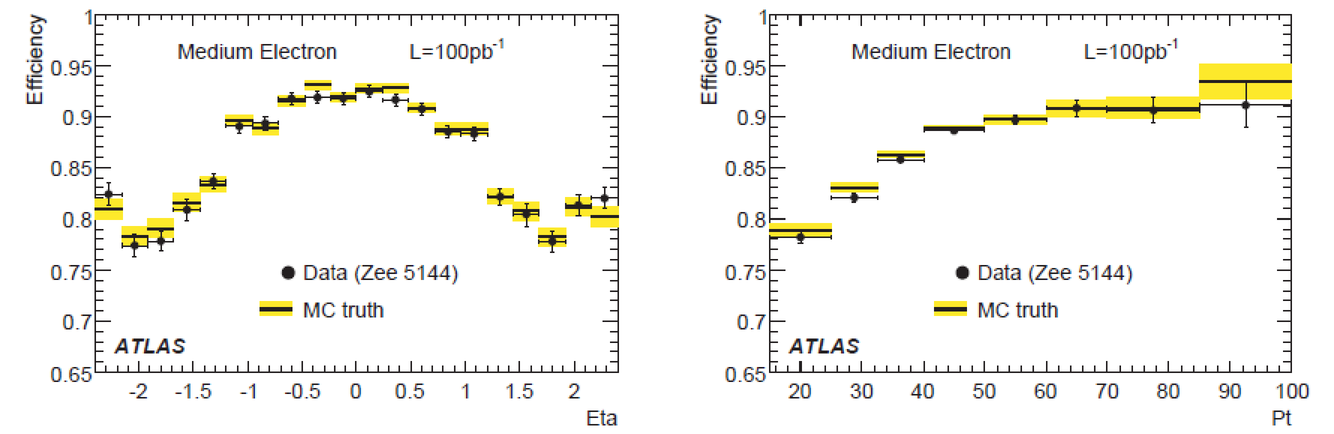
In-situ calibration using Z→ee (2)

Tag and probe method to determine efficiencies:

- "tag" electron: well identified electron on one side
- "probe" electron: track/EM cluster on the other side

Single electron trigger provides unbiased probes.
Agrees with the predicted performances.

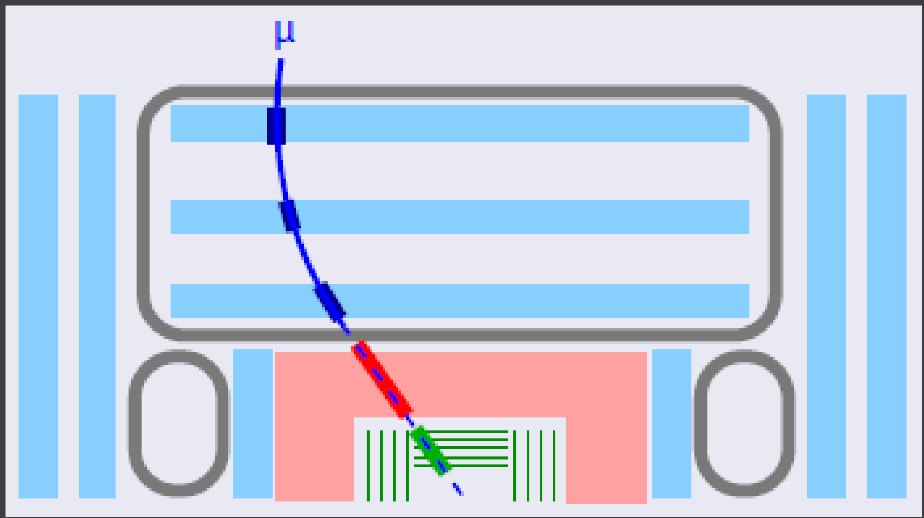
~2% accuracy with 100pb^{-1}



	15.00–25.00	25.00–40.00	40.00–70.00
0.00–0.80	83.60±2.35±3.76	89.75±0.68±0.69	92.63±0.53±0.23
0.80–1.37	75.60±2.76±6.13	87.64±0.91±0.58	90.86±0.77±0.33
1.52–1.80	71.93±4.38±4.04	76.90±1.85±1.77	83.58±1.89±0.59
1.80–2.40	78.05±2.73±4.75	79.24±1.38±1.36	82.50±1.37±0.79

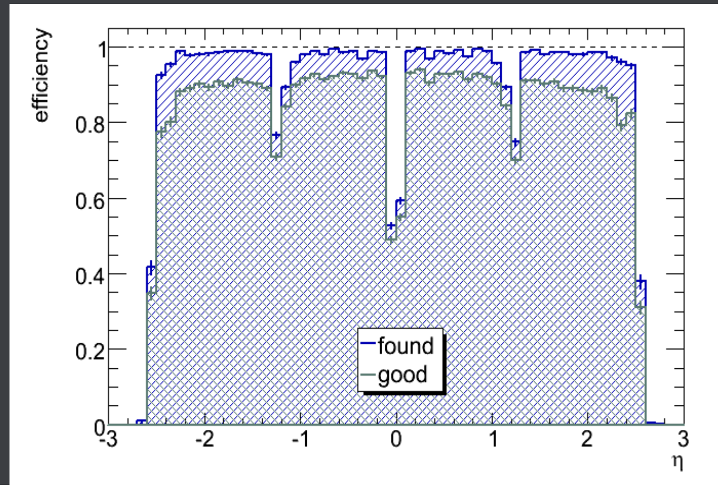
Muon: reconstruction

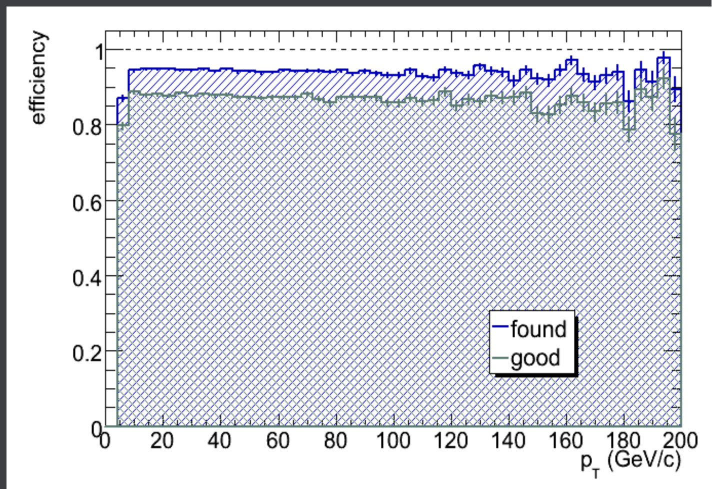
1. Build segments in muon stations
2. Build tracks from hits or segments
3. Correct for E_{loss} & multiple scattering
4. Match inner tracks (or calorimeter hits)
5. Combine statistically or re-fit

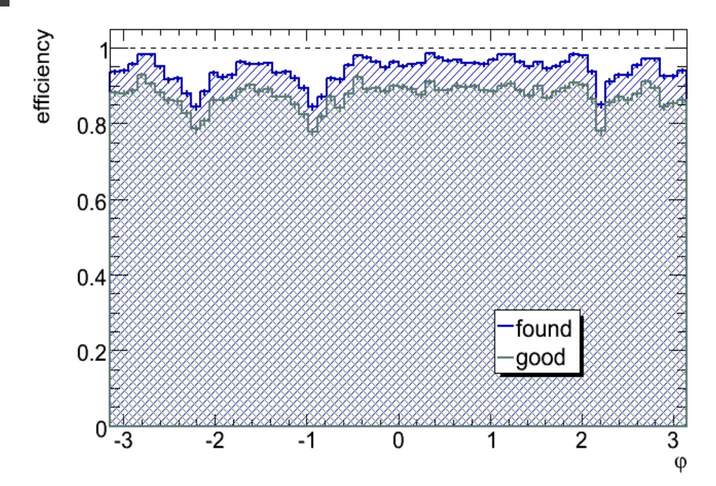


Muon: performance

- ◊ Predicted performance from ttbar MC.
- ◊ Efficiency is fairly flat for pt between 10 and 100 GeV/c.
- ◊ Efficiency loss at eta=0.0, 1.2 due to the poor detector coverage.

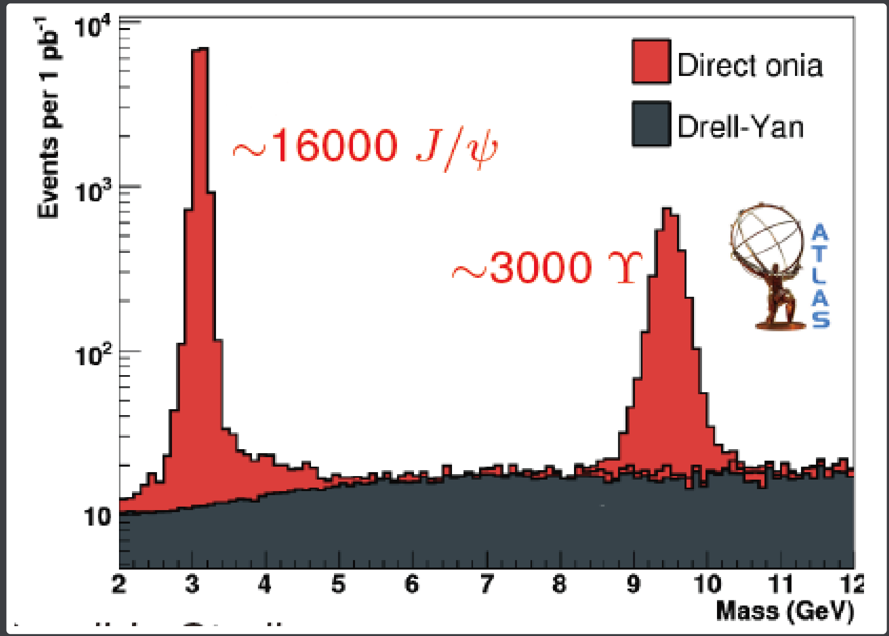






First peaks of di-muon resonances

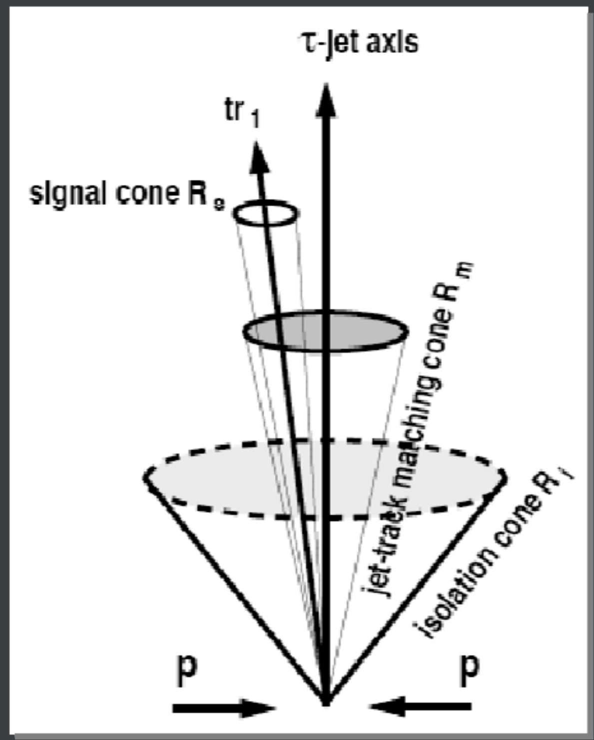
- Statistics for $1pb^{-1}$ (@10^{31})
  - Assuming 30% accelerator + detector efficiency
- Possible studies are
  - First sanity check
  - ID(tracker) alignment
    - <100micron
  - Low pt muon scale



- Z→mumu for $100pb^{-1}$
  - Detector efficiencies
  - Scales for higher-pt muons

Tau: reconstruction

1. Search for localized energy deposits in calorimeters
2. Require hadronic energy
3. Match with 1 or 3 tracks in cone
4. Remove photon conversion tracks
5. Require isolation in calorimeters
6. Require small jet mass



Hadronic tau decay (tau jet)

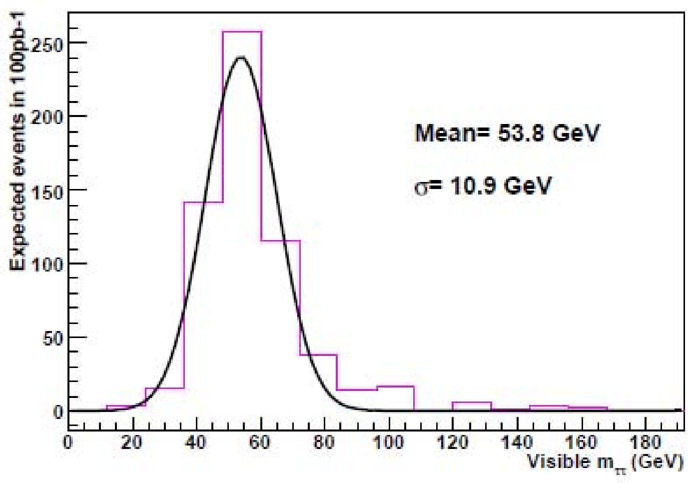
- 1prong (49.5%):
  $\tau \to \nu_\tau + \pi^{+/-} + n(\pi^o)$
- 3prong (15.2%):
- $\tau \to \nu_\tau + 3\pi^{+/-} + n(\pi^o)$

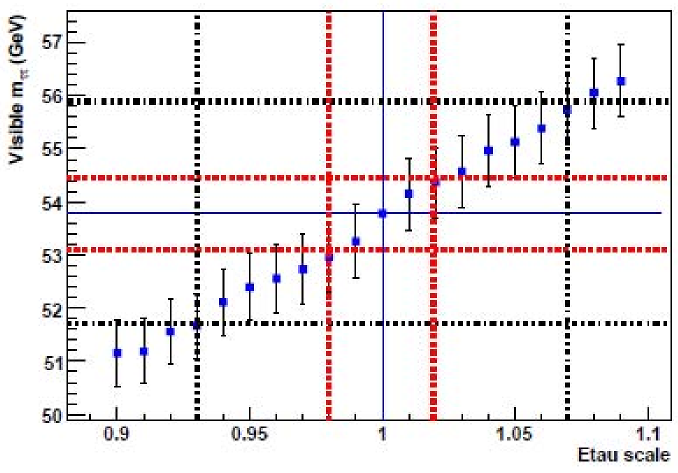
In-situ calibration of tau

◊ Z→tautau(lh)

– Visible mass of tau pairs with an integrated L of 100pb^{-1} after subtracting the SS events from the OS.

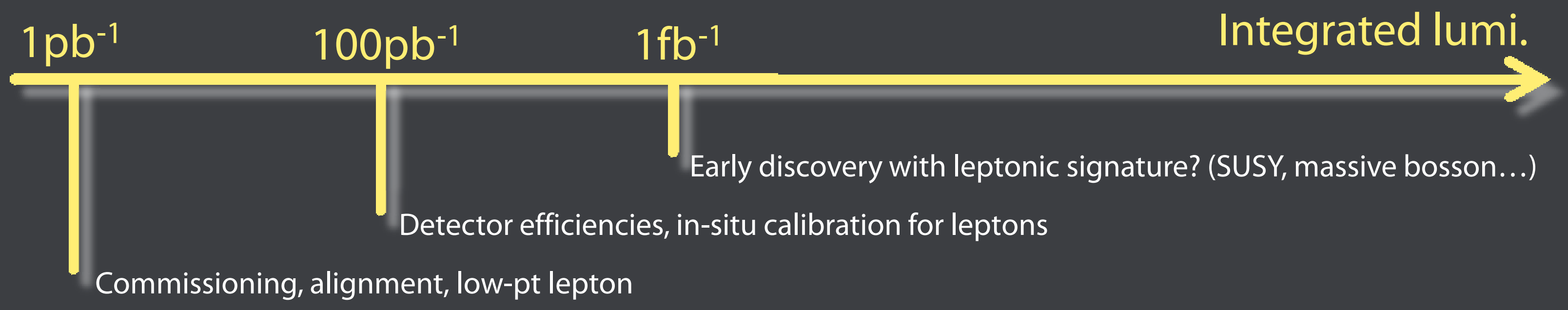
– Visible mass can be reconstructed with an error of <1%, tau scale can therefore be determined with an accuracy of a few %.





Summary of start-up and ultimate performances for leptons

	Start-up (~100pb^{-1})	ultimate
EM energy uniformity	<2%	0.7%
Electron energy scale	~2%	0.02%
ID alignment	50-100 micron	<10 micron
Muon system alignment	<200 micron	30 micron
Muon momentum scale	~1%	0.02%
Tau momentum scale	~2%	---



Cannot achieve ultimate performances, but do not need for early discoveries (<1fb^{-1})

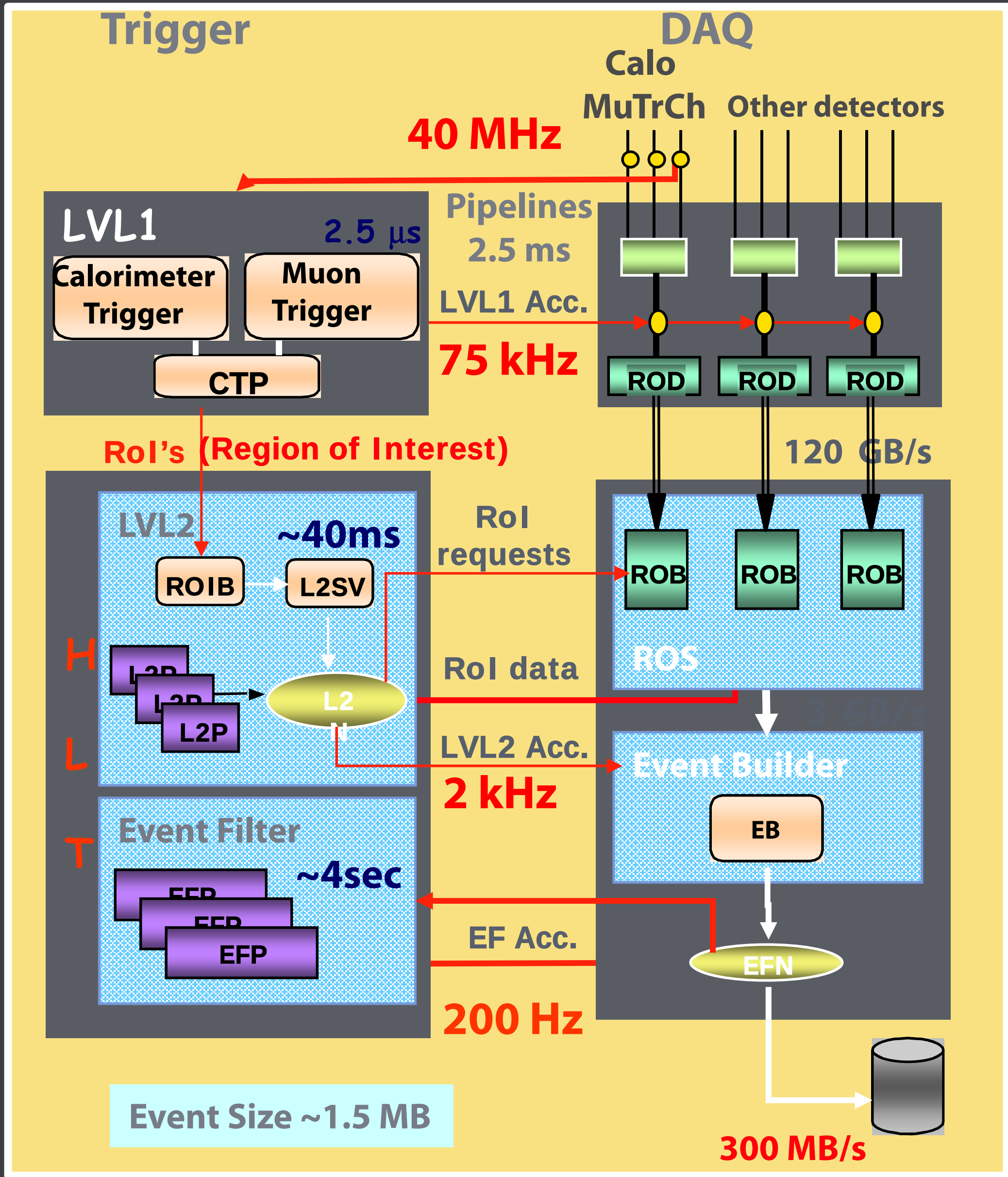
Trigger

Trigger: introduction

- At nominal high (low) luminosity, on average ~23 (2.3) minimum bias events superimposed on any rare discovery signal
  - 25 ns bunch crossing
  - Minimum bias rate ~$7x10^8$ ($7x10^7$) Hz
- ~1000 (100) low-pt tracks per event !
- Moreover, due to finite detector response time, out-of-time pile-up from different bunch crossings
  - need "time stamp" to distinguish events
- Trigger system should be very fast and extremely selective:
  - 40 MHz input and O(100 Hz) "on tape" (100 events/s)
  - selection at the $<10^{-4}/10^9 = 10^{-13}$ level, with virtually zero dead-time !

Trigger System Overview

- Level 1:
  - Hardware based : Calo + Muon
  - Latency 2.5 µs
  - Output rate ~37kHz(75k)
- Level 2: ~500 farm nodes
  - "Regions of Interest" (RoI) to guide reconstruction
  - Custom algorithms
  - Average execution time ~40 ms
  - Output rate up to ~1kHz (2k)
- Event Builder: ~100 farm nodes
- Event Filter (EF):~1600 farm nodes
  - Seeded by level 2
  - Access to full built event
  - Offline algorithms
  - Average execution time ~4 s
  - Output rate up to ~200 Hz



Trigger menu at start-up ($L \sim 10^{31} cm^{-2}s^{-1}$)

Unprescaled items (rate in Hz)

e10_tight	21.9±1.49	e20_g20	<0.1	tau60	10.7±1.04
e12	19.3±1.4	e10_mu6	0.51±0.23	tau20i_xe30	4.89±0.71
g20	6.62±0.82	e10_xe30	0.71±0.27	tau20i_e10	1.22±0.35
2e5	6.72±0.83	e20_xe15	2.24±0.48	tau20i_mu6	2.85±0.54
2g10	<0.1	g20_xe15	2.44±0.5	2tau25i	2.65±0.52
		mu15_xe15	2.65±0.52		
mu10	18.7±1.38			tau20i_j70	7.13±0.85
2mu4	2.34±0.49	j70_xe30	9.87±1	tau25i_b35	9.98±1.01
		2j42_xe30	6.41±0.81	tau20i_2j70	0.81±0.29
J120 (L1 only)	8.65±0.94	4j23_e15i	0.1±0.1	tau20i_3j23	0.92±0.31
4J23 (L1 only)	6.92±0.84	4j23_mu15	0.1±0.1		
FJ120 (L1 only)	0.92±0.31	mu10_j18	7.13±0.85		
JE340 (L1 only)	0.1±0.1			trk20i_calib	9±1
2FJ35 (L1 only)	1.73±0.42	Bmu4mu4	0.71±0.27		
2b23_3L1J23	2.65±0.52	MU4_Bmumu	2.14±0.47	MBTS	0 (4)
xe70 (L1 only)	0.2±0.14	mu4_DsPhiPi_FS	10.4±1.03	Random	2
te650 (L1 only)	0.31±0.18	MU4_Jpsimumu	2.04±0.46	SpacePoints	4

Trigger menu at L~10^{32}cm^{-2}s^{-1}

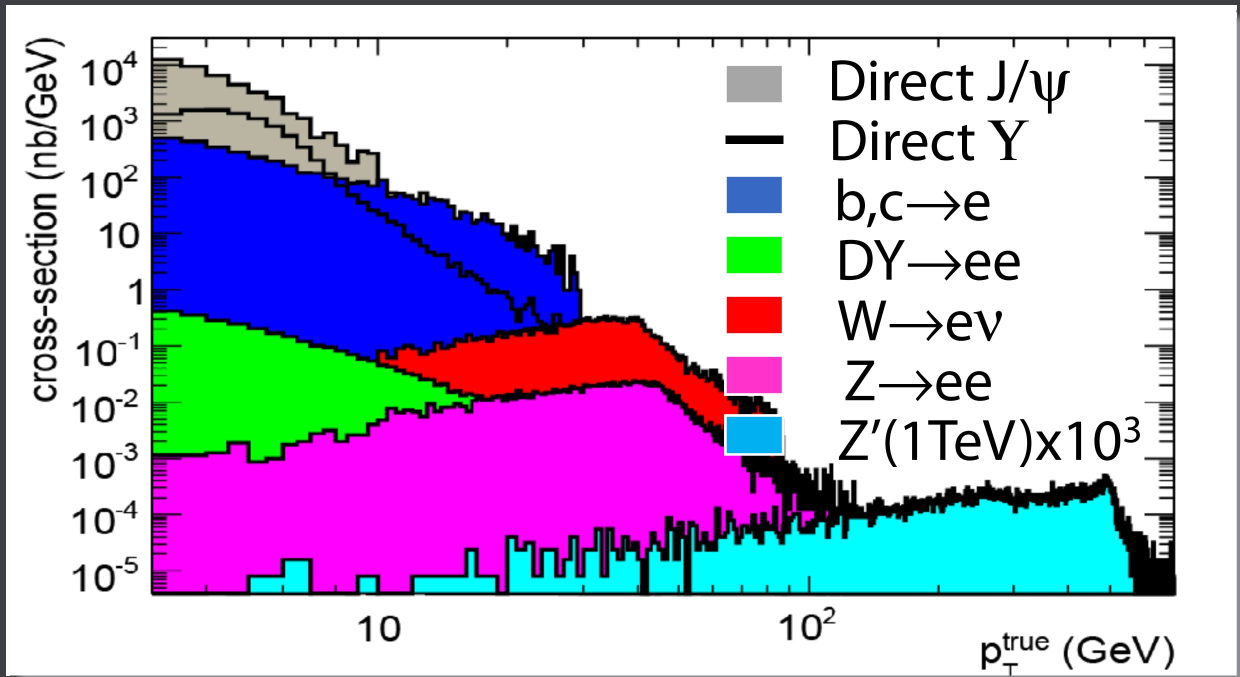
Unprescaled items (very preliminary) (rate in Hz)

e15i	54.1±7.4	e20_g20	0	0	tau100	24.5±5	
e20_tight	19.4±4.4	e10_mu6	5.1±2.3		tau35i_xe40	4.08±2	
g25_L32	19.4±4.4	e10_xe30	7.14±2.7		tau25i_e15i	1.02±1.02	
2e15	<1	e20_xe15	22.4±4.8		tau25i_mu10	10.2±3	
2g20	<1	g20_xe15	24.5±5				
		mu15_xe15	26.5±5.2				
mu20	19.4±4.4				tau20i_j120	11.2±3.4	
mu4_mu6	4.3±3.8	j70_xe30	99±10		tau25i_b35	100±10	
		2j42_xe30	64.3±8.1		tau15i_b23_j42	69.4±8.4	
J120	85.7±9.3	4j23_e15i	1.02±1		tau20i_3j23	9.18±3.0	
JE340	1.02±1	4j23_mu15	1.02±1				
2FJ70	<1	j42_xe30_e15i	1.02±1				
2b35_3L1J35	3.06±1.8	j42_xe30_mu15	4.08±2		trk20i_calib	9±1	
3b18_4L1J18	1.02±1						
xe70	2.04±1.4	Bmu4mu4	7.14±2.7		MBTS	0	(4)
te650	3.06±1.8	mu4_Bmumu	16.3±4.1		Random	2	
		mu4_Jpsimumu	16.3±4.1		SpacePoints	4	

Not yet for 10^{33}

In-situ measurement of trigger efficiency(1)

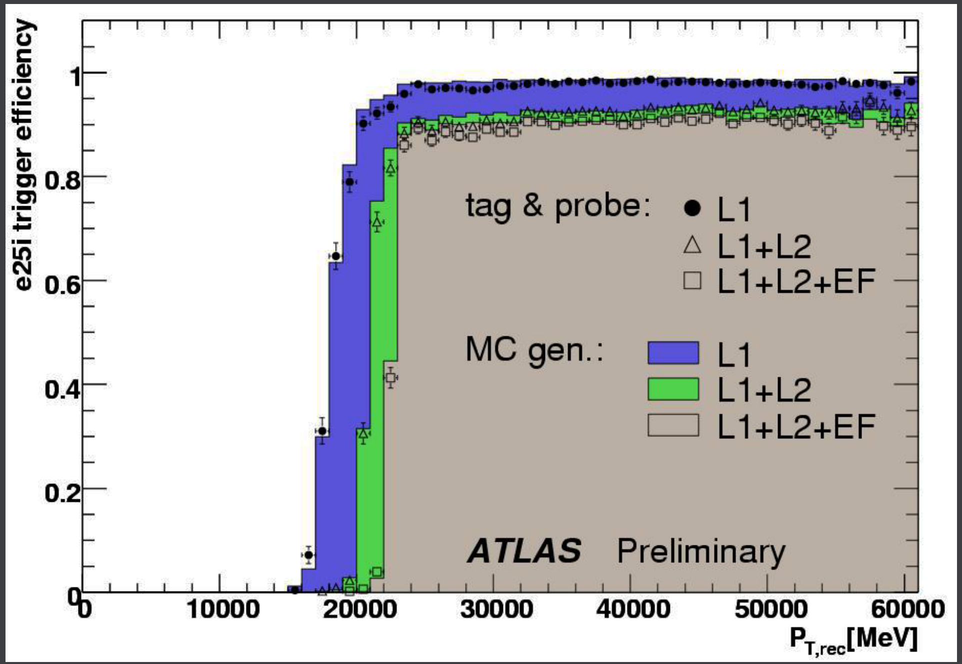
◊ At design low luminosity ($10^{33}cm^{-2}s^{-1}$), L1 rates do not allow to go below ~20GeV for the single and ~12GeV for the double electron signatures. Physics/Detector studies dominated by W and Z.



In-situ measurement of trigger efficiency(2)

Z→ee example:

- Select events accepted by single e trigger (e15, e15i, e25, e25i) →TAG
- Events with 2 electrons. Build inv. mass & keep only those with inv. mass close to Z peak.
- For this selection, check how many times the 2nd electron also triggered (2e15, 2e15i, 2e25, 2e25i) →probe



Tag and probe method still works for trigger efficiency measurements.

Triggers for inclusive SUSY searches

- Early SUSY searches will focus on inclusive signatures of:
  - Multiple jets
  - Large missing ET
  - Leptons
- To minimize biases and systematic effects, we should keep trigger selection criteria as simple as possible.
  - Due to its rich phenomenology, triggering SUSY events is easy in principle.
- We estimate Etmiss trigger takes time to get established and Etmiss is often crucial for signal selection (instrumental effects);
  - de-emphasize Etmiss trigger and loosen lepton selection are better choice in early days??

- Lepton triggers could be robust and urgent issue is
  - Strategy/method for evaluation of multi-jet/XE trigger.

Summary

- Data is coming this year and leptons play an important role for early physics at LHC.
  - Detector alignment will be performed with e/mu using very early data(~1pb^{-1}).
  - pt scales of leptons are determined with an accuracy of ~2% in the first 100pb^{-1}

  → Satisfactory performances for early discoveries.

- Trigger menu at start-up (10^{31}) is well tuned and close to final.
  - Menus for 10^{32} and10^{33} are presently under study.
- Tag and probe method works for determination of lepton trigger efficiencies.
- Also need in-situ measurements of jet/XE trigger efficiencies