

# Trigger Strategies for SUSY at the LHC

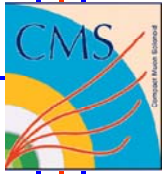
On behalf of the ATLAS and CMS collaborations:

**Antonella De Santo**

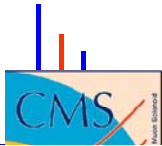
(Royal Holloway, University of London)

SUSY07, Karlsruhe, Germany

# Outline



- Trigger challenges at the LHC
- CMS and ATLAS Triggers
  - ATLAS HLT
- Trigger strategy for early SUSY searches
  - Jet/Etmiss/Lepton triggers
- Conclusions



# LHC Challenges

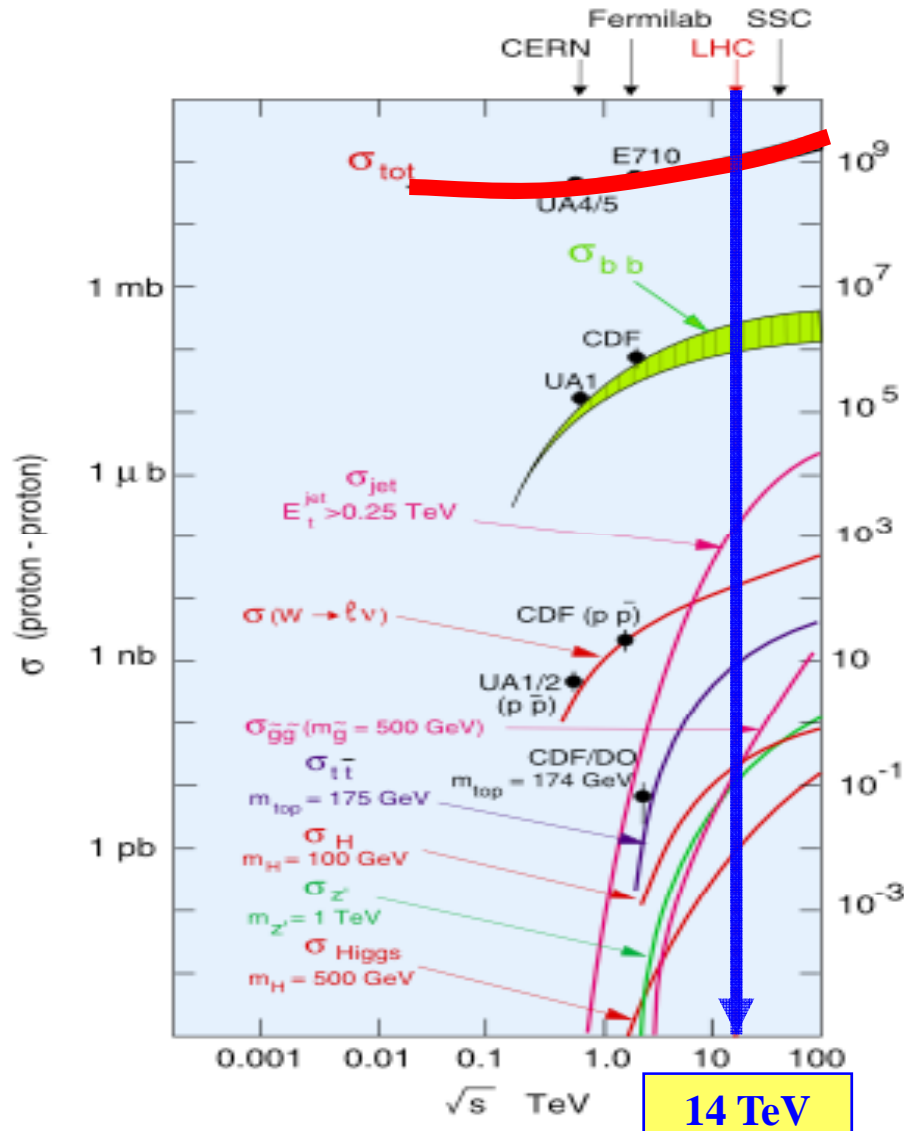
$$\sigma_{pp}^{tot} \sim 110 \text{ mb} \quad (\sigma_{pp}^{inel} \sim 70 \text{ mb})$$

Minimum Bias (MB) = inelastic pp interactions

Design  
luminosity:

"High"  $L = 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$   
("Low"  $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$ )

MB rate:  $O(10^9 \text{ Hz}) !!$



Events / sec for  $\mathcal{L} = 10^{34} \text{ cm}^{-2} \text{ sec}^{-1}$

Process	$\sigma$ (nb)	#evts [10 fb <sup>-1</sup> ]	Rates (Hz) [ "high" L ]
$b\bar{b}$	500 $\mu\text{b}$	$5 \times 10^{12}$	$5 \times 10^6$
$W \rightarrow e\nu$	15 nb	$\sim 10^8$	150
$Z \rightarrow ee$	1.5 nb	$\sim 10^7$	15
$t\bar{t}$	800 pb	$\sim 10^7$	10
$\tilde{g}\tilde{g}$ (1 TeV)	$\sim 1 \text{ pb}$	$\sim 10^4$	$10^{-2}$
$H(200 \text{ GeV}) \rightarrow 4\ell$	$\sim 10 \text{ fb}$	$\sim 10^2$	$10^{-4}$

"Needle in haystack"



# Minimum Bias and Pile-up



- At nominal high (low) luminosity, on average  $\sim 23$  (2.3) **minimum bias events** superimposed on any rare discovery signal
  - 25 ns bunch crossing
  - only 2835/3564 "full" bunches
  - Minimum Bias rate  $\sim 7 \times 10^8$  ( $7 \times 10^7$ ) Hz
- And  $\sim 1000$  (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 ought to be **very fast and extremely selective**:
  - 40 MHz input  $\rightarrow O(100 \text{ Hz})$  "on tape" (the right 100 events/s !!)
  - selection at the  $< 10^{-4}/10^9 = 10^{-13}$  level, with virtually zero dead-time !

I.

# The Detectors

(see other ATLAS+CMS talks for more details)

**CMS**

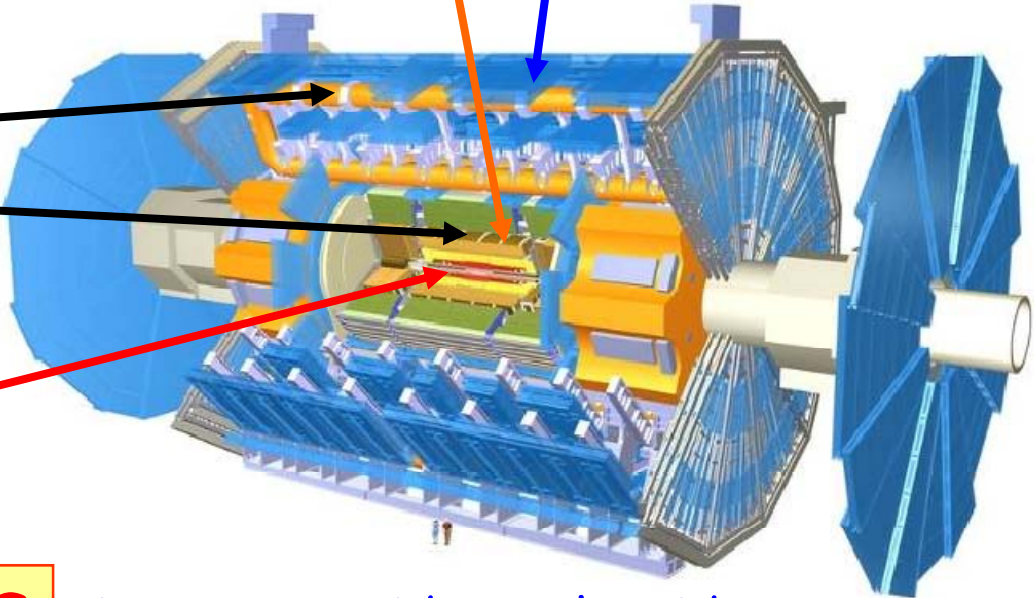
Solenoid with Fe flux return

Muon System

Calorimetry

Magnet system

Tracking

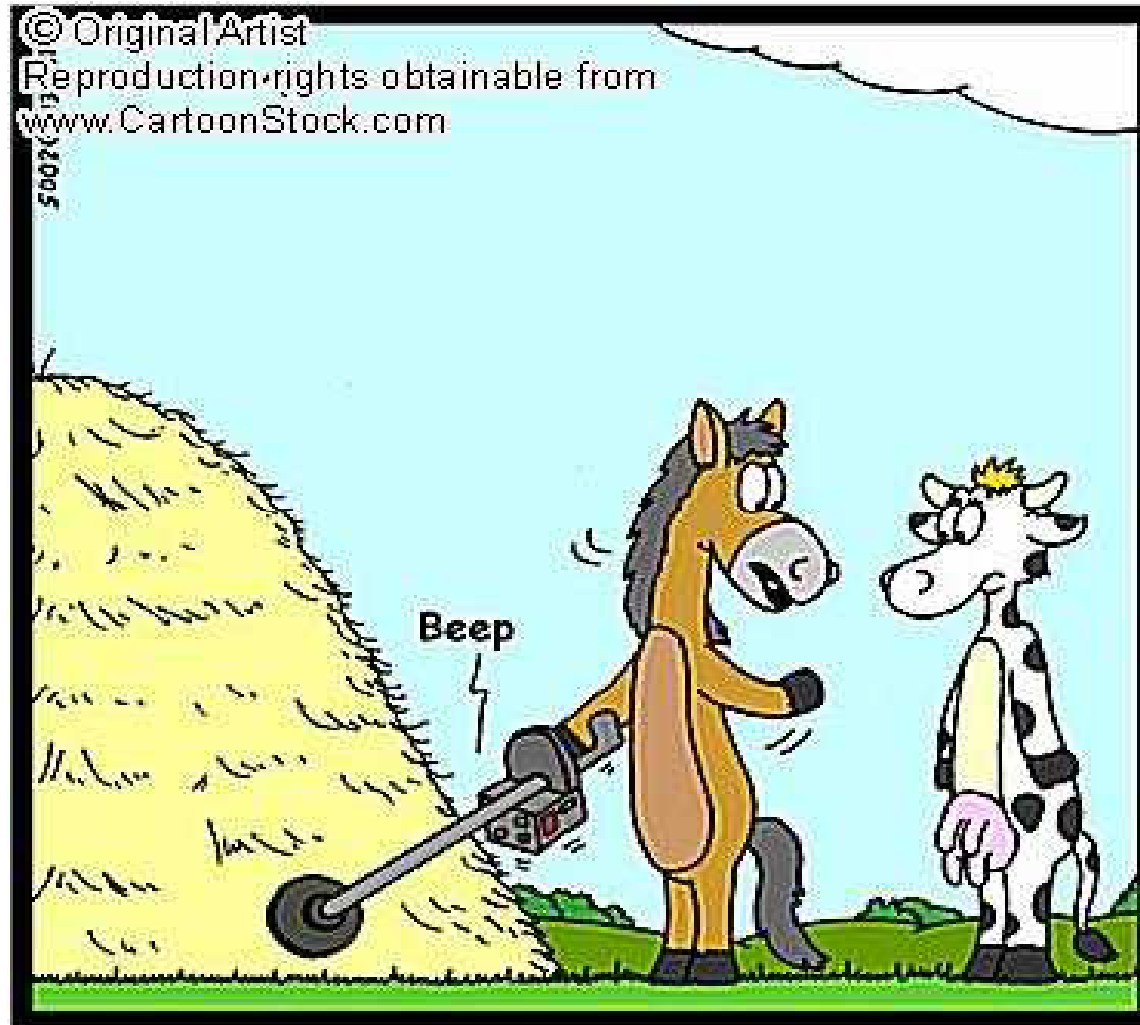


**ATLAS**

Air-core toroids + solenoid

Royal Holloway  
University of London

# The Needle in the Haystack...

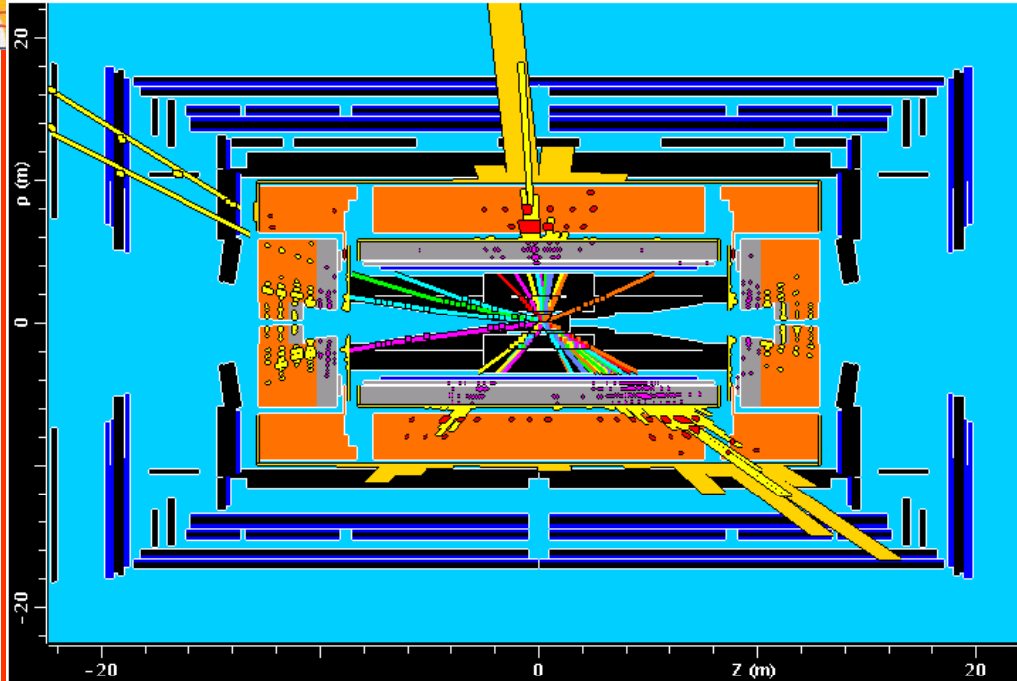


You were right: There's a needle in this haystack...

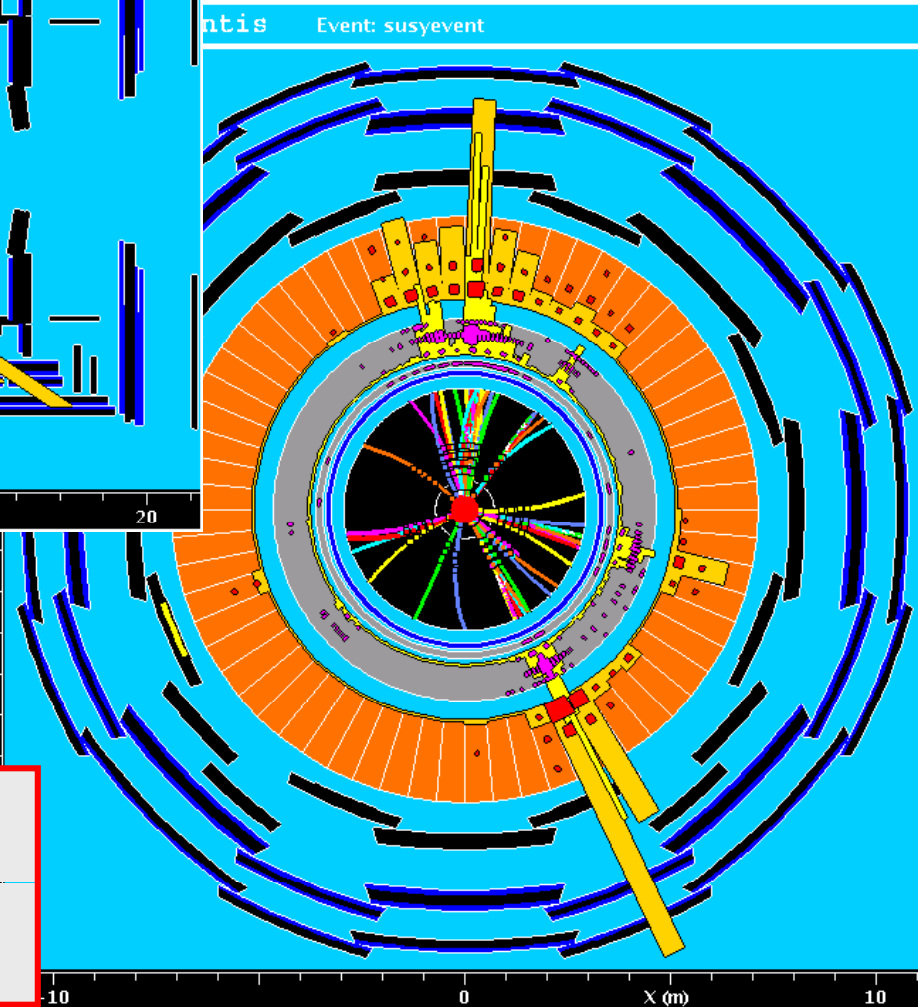
# ... a SUSY event in ATLAS...



ATLAS Atlantis Event: susyevent

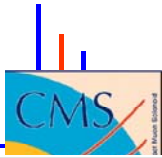


ntis Event: susyevent



Multi-jet event in Bulk Region

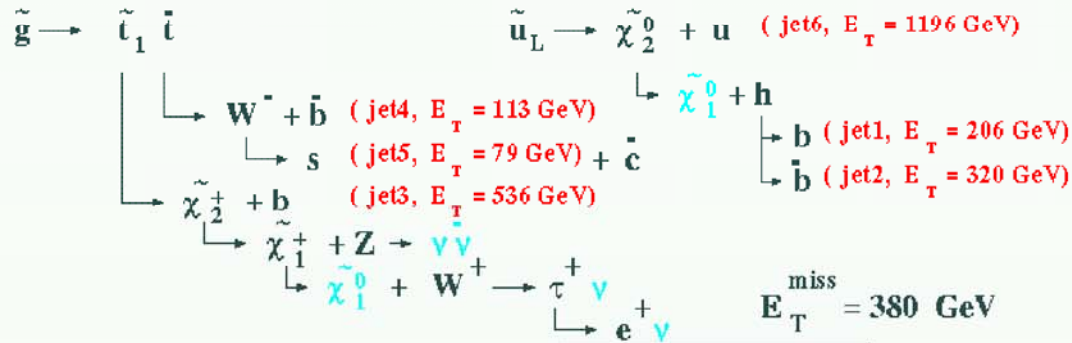
- 6 jets
- 2 high-pt muons
- Large missing  $E_T$



# ... and one in CMS

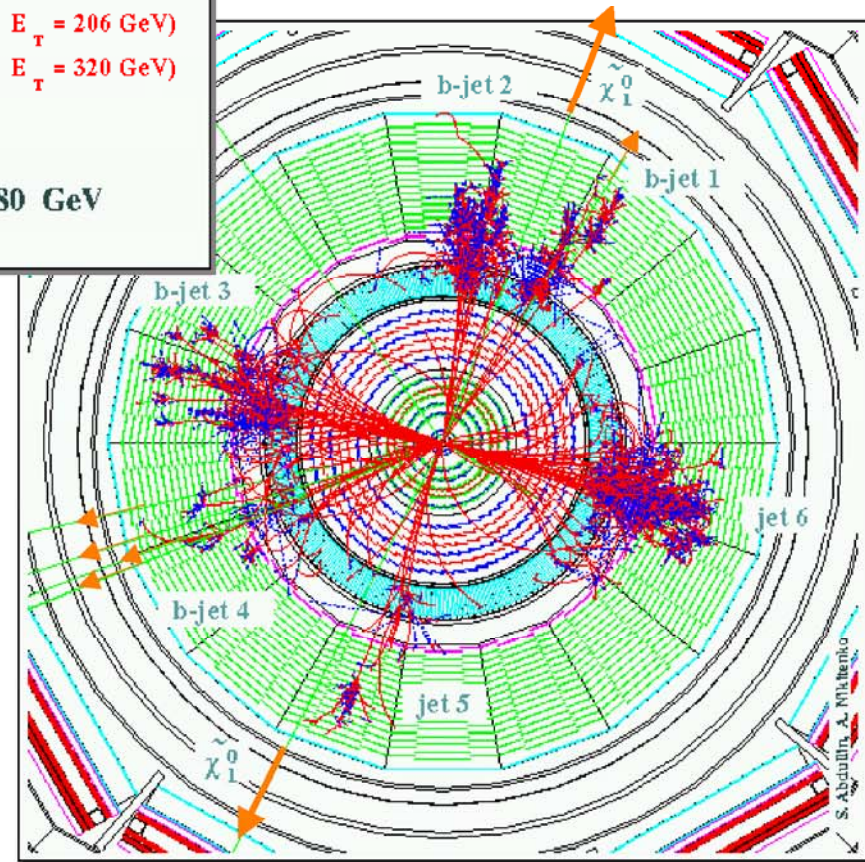


mSUGRA :  $m_0 = 1000 \text{ GeV}$ ,  $m_{1/2} = 500 \text{ GeV}$ ,  $A_0 = 0$ ,  $\tan\beta = 35$ ,  $\mu > 0$

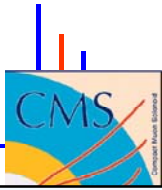


Multi-jet event  
with large  
missing  $E_T$

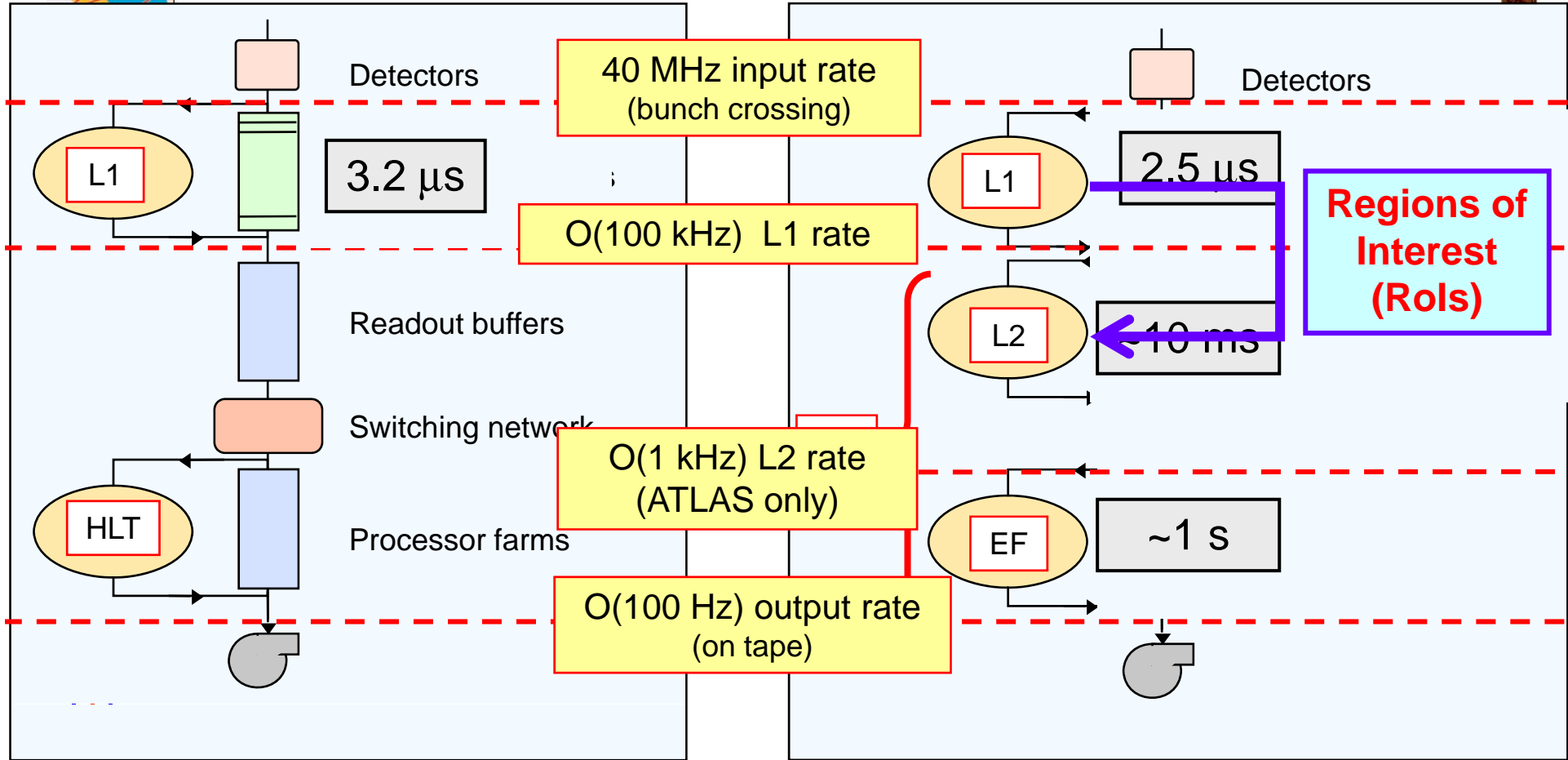
- $m_{\tilde{g}} = 1266 \text{ GeV}$
- $m_{\tilde{u}_L} = 1450 \text{ GeV}$
- $m_{\tilde{t}_1} = 1026 \text{ GeV}$
- $m_{\tilde{\chi}_2^0} = 410 \text{ GeV}$
- $m_{\tilde{\chi}_1^0} = 214 \text{ GeV}$
- $m_h = 119 \text{ GeV}$







# CMS and ATLAS Triggers - A Schematic Overview



**CMS - 2 levels**

**ATLAS - 3 levels (L2 + EF = HLT)**

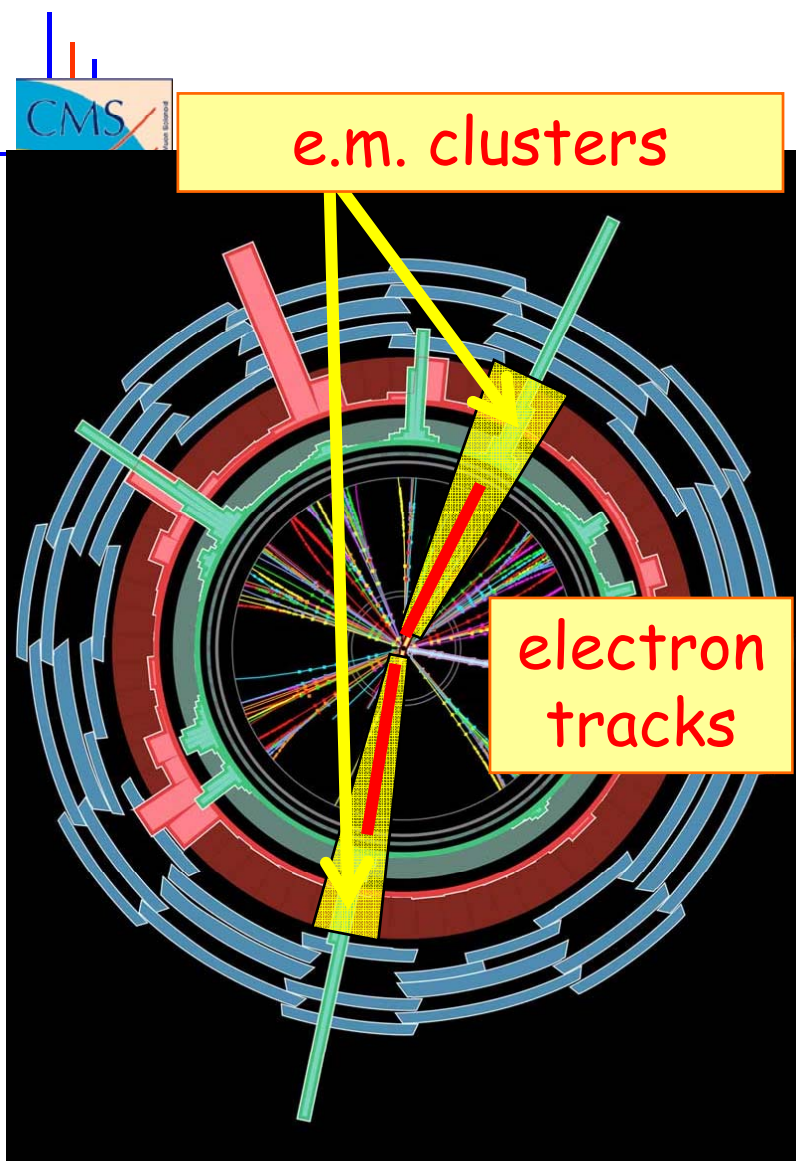
**L1: Hardware based (calo+μ's)**  
**HLT: Software based**

(HLT = High-Level Trigger)

Event size  
1-2 MBytes



# ATLAS HLT



- "Seeded" and "stepwise"
  - early rejection of uninteresting events, with minimum amount of processing
  - maximum flexibility
- RoIs "seed" trigger reconstruction chain
  - L2 gets access only to a fraction (<10%) of the event (with full granularity)
  - EF seeded by L2 ("offline" reco)
- Minimizes CPU and bandwidth
  - but adds complexity
- Care must be paid to
  - avoid biases
  - account for the "unexpected"

(see talk in "Alternatives" session for details on CMS HLT – T. Bose)



# Early Physics - Inclusive SUSY Searches



- Early SUSY searches will concentrate on inclusive signatures
  - multi-jets
  - large missing  $E_T$  ( $E_{Tmiss}$ )
  - leptons ( $\geq 0$ , e or  $\mu$ )
  - also other signatures (not discussed here): see other ATLAS+CMS talks
    - GMSB SUSY (non-pointing  $\gamma$ 's, etc), RPV SUSY (small  $E_{Tmiss}$ , extra jets/leptons), R-hadrons (highly ionizing  $\mu$ -like particles, etc)
    - also taus, b-jets
- Keep trigger selection criteria as simple as possible
  - to minimize biases and systematic effects
- Experience shows that  $E_{Tmiss}$  trigger takes time to get established
  - moreover  $E_{Tmiss}$  often crucial to define control/signal regions
    - de-emphasize  $E_{Tmiss}$  trigger in early days - instrumental effects
    - also loosen lepton selection - good to study systematics "offline"



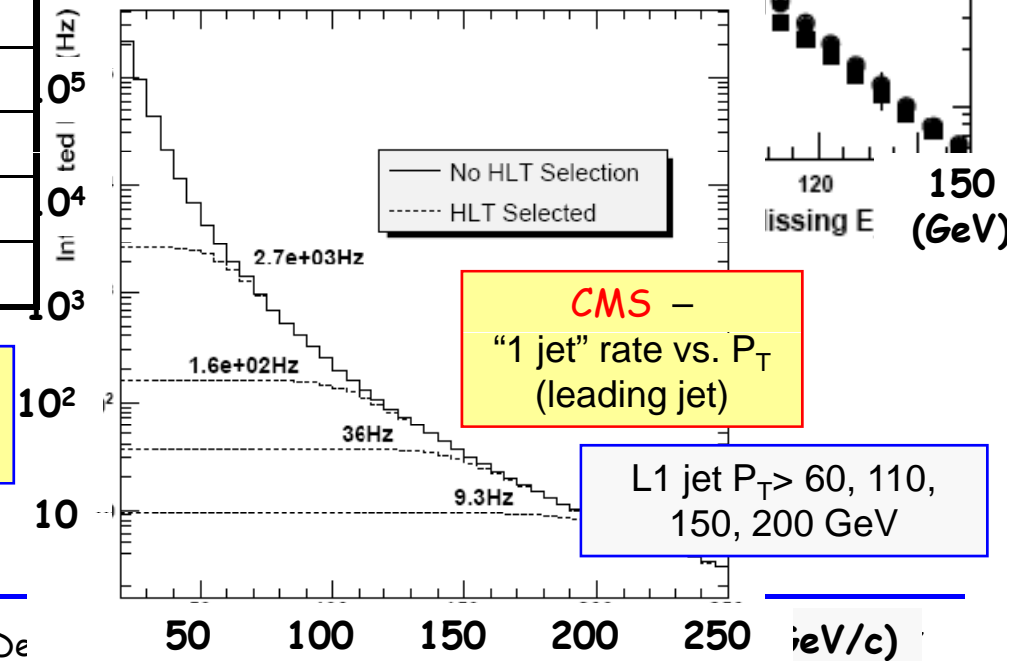
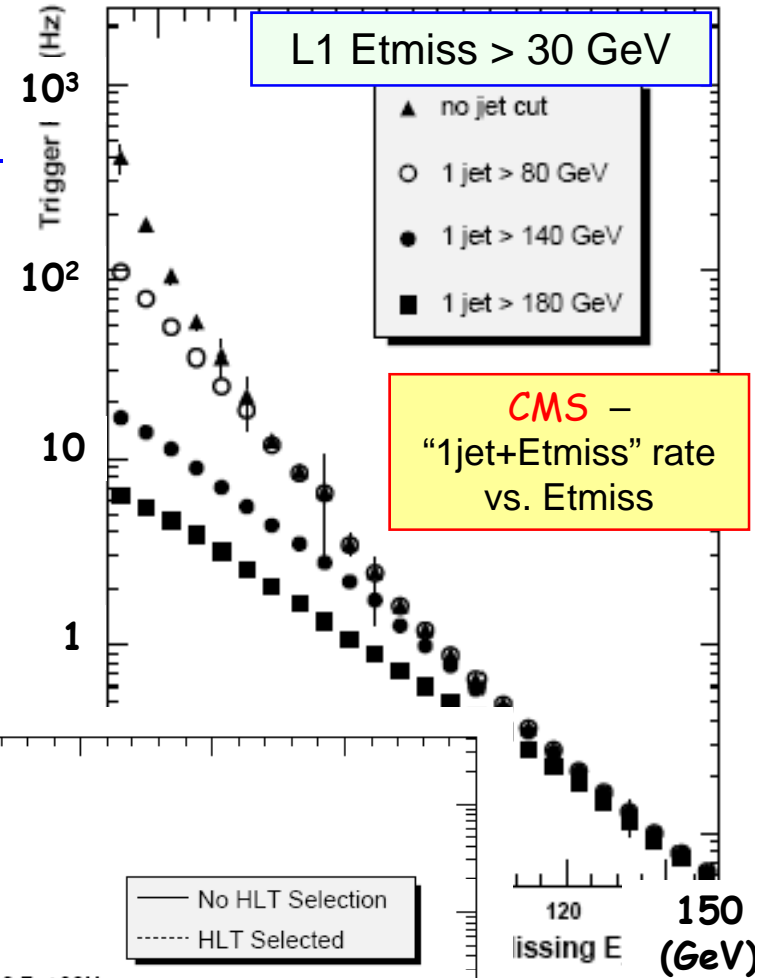
# CMS Jet/ETmiss/Lepton Triggers



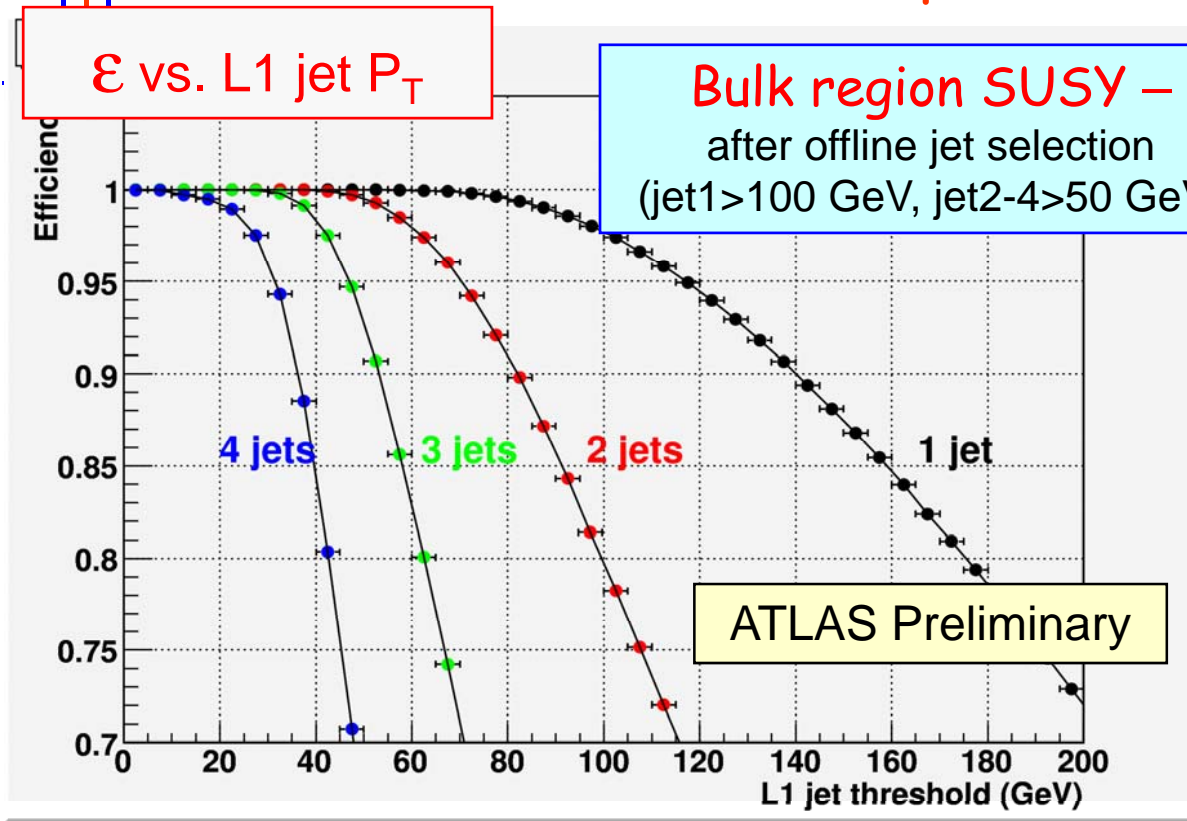
HLT Path	Thresh'd(s) (GeV)	HLT Rate (Hz)
1 jet	200	9.3
2 jets	150	10.6
3 jets	85	7.5
4 jets	60	3.9
Etmiss	65	4.9
1 jet + Etmiss	(180,60)	2.2
2 jets + Etmiss	(125,60)	1.0
3 jets + Etmiss	(60,60)	0.6
4 jets + Etmiss	(35,60)	1.2
e+jet	(12,40)	11.6
$\mu$ +jet	(7,40)	6.3

CMS HLT rates @  $L=10^{32} \text{ cm}^{-2} \text{ s}^{-1}$   
(total HLT output  $\sim 150 \text{ Hz}$ )

CMS HLT –  
CERN/LHCC 2007-021



# ATLAS Jet/Lepton/Etmiss Triggers



Possible strategy for lepton triggers for SUSY - optimize lepton selection on multi-lepton final states (e.g. at Focus Point)

Assumed initial luminosity  
 $L = 10^{31} \text{ cm}^{-2} \text{ s}^{-1}$

**Example rates – ATLAS Preliminary :**

**Total jet menus (L1) :**  
~ 25 Hz  
(including prescales)

**“1 jet” (L1) ~ 10 Hz**  
( $p_T > 100 \text{ GeV}$ )

**“e+Etmiss” (HLT) ~ 10 Hz**  
( $p_T(e, \text{Etmiss}) > 20, 15 \text{ GeV}$ )

# Conclusions



- LHC environment a **challenge**, also for the trigger
  - need very sophisticated system to do the job
- SUSY events "easy" to trigger on in principle...
  - rich phenomenology : jets, Emiss, leptons, ...
- ... but need to **keep selection simple**
  - to avoid systematic effects
- Trigger menus for early physics shown to be efficient enough, while keeping rates at manageable level
  - on Monte Carlo events, at least...
- **Can't wait to put system to test !!**