Searches for Supersymmetry in ATLAS

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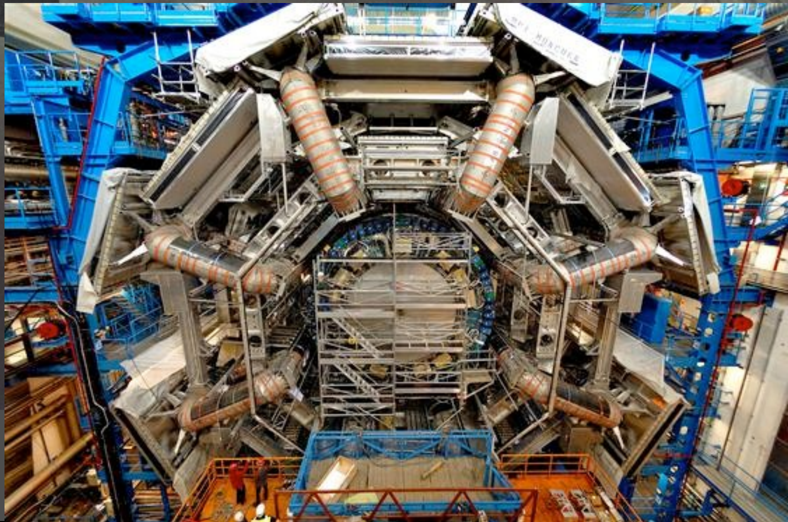


MOTIVATION

see Yann Mambrini's talk
for more details

Boson-fermion unification appears “sexy” to some, but this is a matter of taste*. There are indisputable facts, however:

SUSY provides remedies for large number of fundamental problems of to-date physics (hierarchy problem, m_{Higgs} fine tuning, running of coupling const., connection to the String Theory, DM candidate), being at the same time highly predictive (at least in its minimal incarnation).

The most relevant aspect in the context of this conference is admittedly the existence of the DM candidate thanks to the R-parity conservation. This itself puts constraints on models and parameter space itself. The LSP must be:

- weakly interacting,
- neutral.

The ONLY problem there is with SUSY is that it must be a broken symmetry and nobody has ever seen any direct evidence for superpartners ☹

The Supersymmetry breaking mechanism has implications on the low-E scale physics:

- mSUGRA appears among the most popular scenarios for Supersymmetry breaking with lightest neutralino LSP (in the great majority of parameter space). => hope for direct WIMP detection ☺
- GMSB is also an interesting alternative with gravitino LSP and lightest neutralino or a sfermion (usually stau) NLSP. => no sensitivity to WIMP's ☹
- Other scenarios as split SUSY (R-hadrons), AMSB, NUHM are also considered in ATLAS but will not be covered here.

*as in life

Preamble

Results shown here obtained if the framework of the final assessment of ATLAS physics potential and reported in the CERN-OPEN-2008-020 are normalised to $1fb^{-1}$ at the CM energy of 14 TeV.

Results assume conservative uncertainties on the SM backgrounds (20% for top and electroweak, 50% for QCD).

Scaling with luminosity is difficult due to importance of data-driven background estimation which will also depend on statistics – ongoing effort.

Generic SUSY signatures at a hadron collider

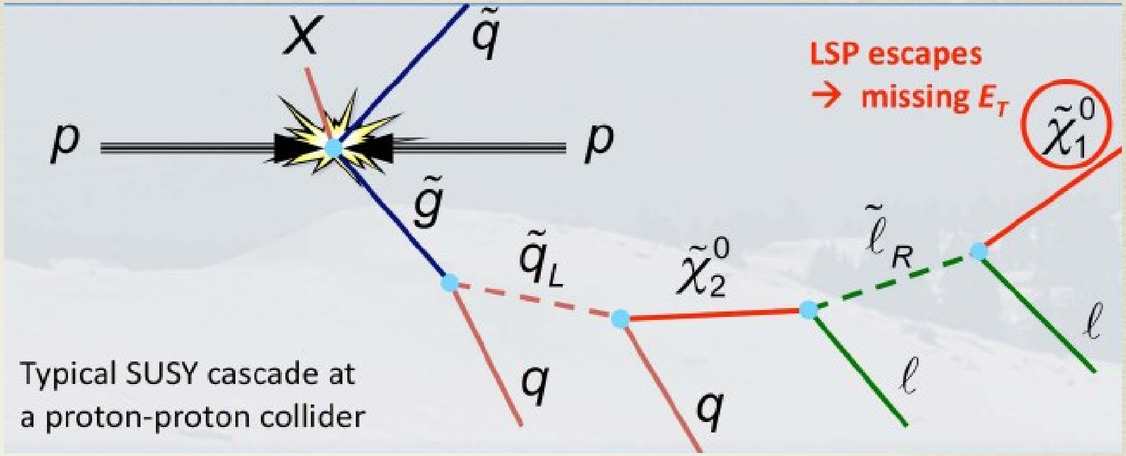
R-parity conserving SUSY:

➢ pair-produced

➢ two LSP's in the final state

➢ if WIMP-like must be neutral and weakly interacting => escapes detection!

N.B. not unique to SUSY (UED, Little Higgs, …)



Typical SUSY cascade at a proton-proton collider

Inherent difficulty:

❑ No direct mass resonance sparticles

❑ Preferably strongly produced => final states complicated (multi-jet + leptons + $\not{E}_T$)

❑ This implies large MC uncertainties on the backgrounds (mostly ttbar, W&Z+jets, QCD)

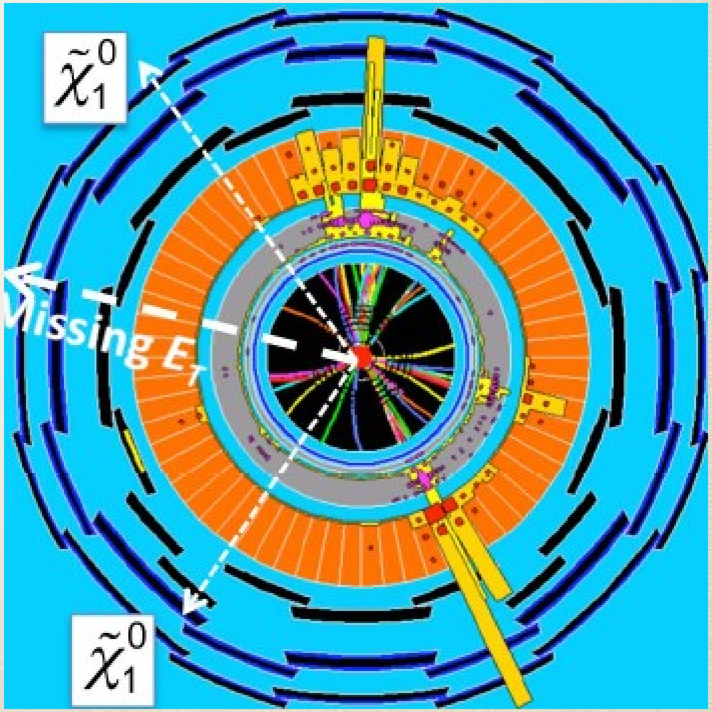
❑ Data-driven methods necessary!

Rescue from:

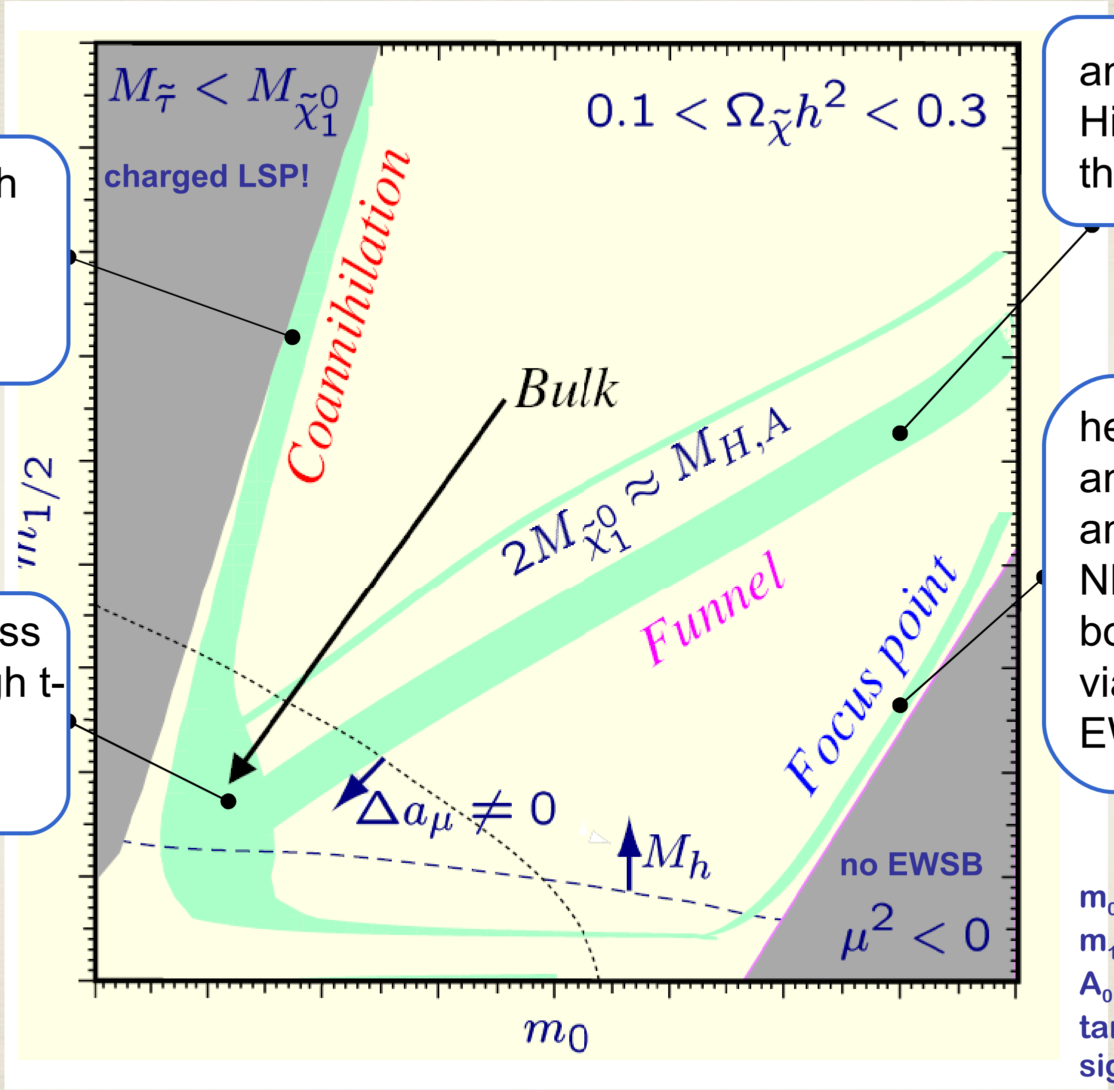
✓ Large $\not{E}_T$ due to two escaping LSP's

✓ High transverse energy (M_{eff}) in the event

✓ Isolated leptons



mSUGRA parameter space - a qualitative view



co-annihilation with nearly degenerate lightest sfermion (usually stau)

moderate LSP mass annihilation through t-channel sfermion exchange

annihilation through Higgs resonance in the s-channel

heavy sfermions. annihilation and co-annihilation with NLSP chargino in both s & t channels via large coupling to EW bosons

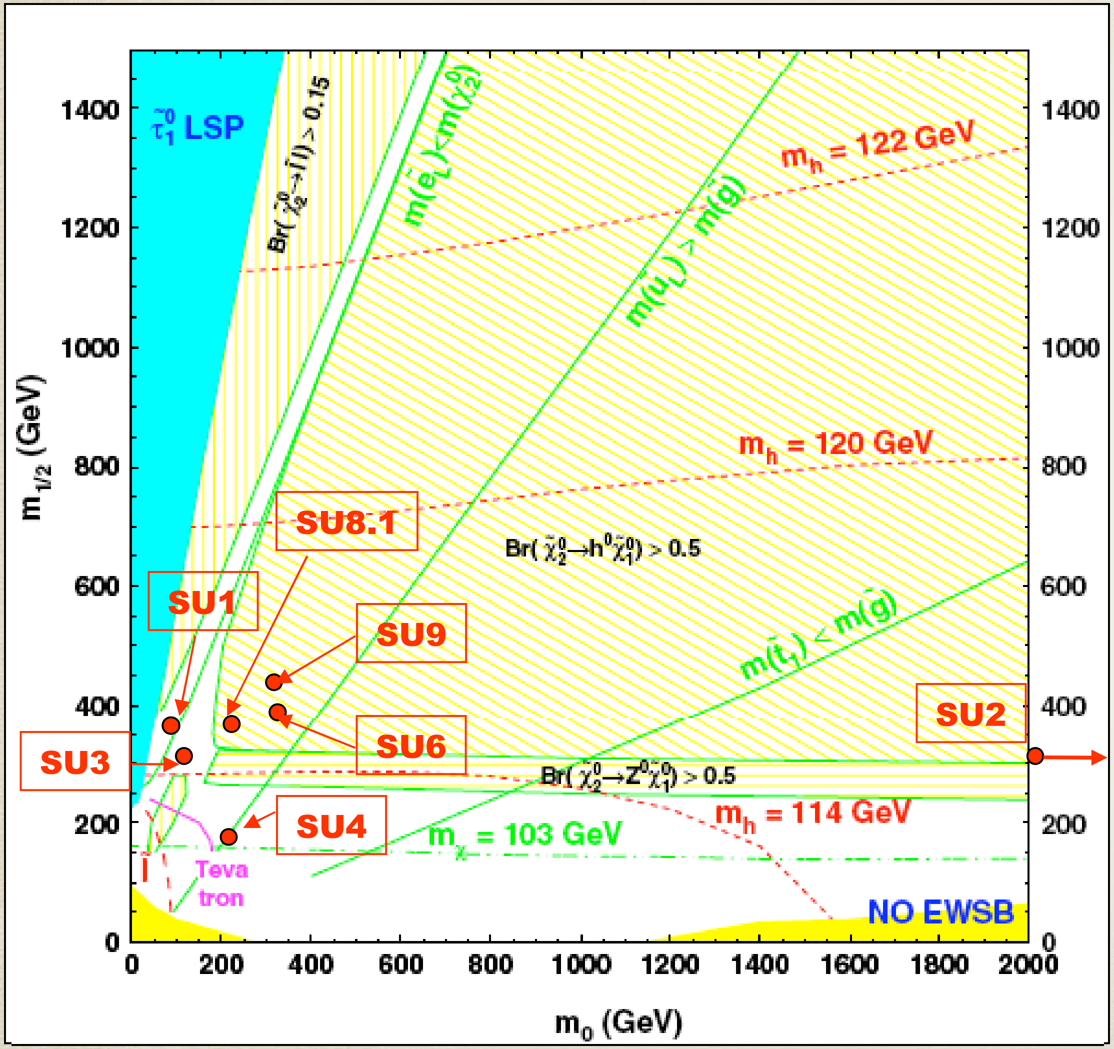
m_0 - sfermion mass
$m_{1/2}$ - gaugino mass
A_0 - trilinear coupling
tanβ - ratio of Higgs VEV's
sign(μ) - set by EWSB

Now DM density is better known. The allowed phase-space is shrinking (hep-ph/0303043)

$$0.094 \leq \Omega_{\tilde{\chi}} h^2 \leq 0.129$$

ATLAS choice of mSUGRA benchmark points

Exclusion regions for $A_0 = 0$, $\mu > 0$, $\tan\beta = 10$



	M_0 [GeV]	$M_{1/2}$[GeV]	A_0 [GeV]	$\tan\beta$	$\arg\mu$	$\sigma_{\rm LO}$ [pb]
SU1	70	350	0	10	+	8.15
SU2	3550	300	0	10	+	5.17
SU3	100	300	-300	6	+	20.85
SU4	200	160	-400	10	+	294.46
SU6	320	375	0	50	+	4.47
SU8.1	210	360	0	40	+	6.48

Particle	SU1	SU2	SU3	SU4	SU6	SU8.1	SU9
$\tilde{d}_L$	764.90	3564.13	636.27	419.84	870.79	801.16	956.07
$\tilde{u}_L$	760.42	3563.24	631.51	412.25	866.84	797.09	952.47
$\tilde{b}_1$	697.90	2924.80	575.23	358.49	716.83	690.31	868.06
$\tilde{t}_1$	572.96	2131.11	424.12	206.04	641.61	603.65	725.03
$\tilde{d}_R$	733.53	3576.13	610.69	406.22	840.21	771.91	920.83
$\tilde{u}_R$	735.41	3574.18	611.81	404.92	842.16	773.69	923.49
$\tilde{b}_2$	722.87	3500.55	610.73	399.18	779.42	743.09	910.76
$\tilde{t}_2$	749.46	2935.36	650.50	445.00	797.99	766.21	911.20
$\tilde{e}_L$	255.13	3547.50	230.45	231.94	411.89	325.44	417.21
$\tilde{\nu}_e$	238.31	3546.32	216.96	217.92	401.89	315.29	407.91
$\tilde{\tau}_1$	146.50	3519.62	149.99	200.50	181.31	151.90	320.22
$\tilde{\nu}_\tau$	237.56	3532.27	216.29	215.53	358.26	296.98	401.08
$\tilde{e}_R$	154.06	3547.46	155.45	212.88	351.10	253.35	340.86
$\tilde{\tau}_2$	256.98	3533.69	232.17	236.04	392.58	331.34	416.43
$\tilde{g}$	832.33	856.59	717.46	413.37	894.70	856.45	999.30
$\tilde{\chi}_1^0$	136.98	103.35	117.91	59.84	149.57	142.45	173.31
$\tilde{\chi}_2^0$	263.64	160.37	218.60	113.48	287.97	273.95	325.39
$\tilde{\chi}_3^0$	466.44	179.76	463.99	308.94	477.23	463.55	520.62
$\tilde{\chi}_4^0$	483.30	294.90	480.59	327.76	492.23	479.01	536.89
$\tilde{\chi}_1^+$	262.06	149.42	218.33	113.22	288.29	274.30	326.00
$\tilde{\chi}_2^+$	483.62	286.81	480.16	326.59	492.42	479.22	536.81
h^0	115.81	119.01	114.83	113.98	116.85	116.69	114.45
H^0	515.99	3529.74	512.86	370.47	388.92	430.49	632.77
A^0	512.39	3506.62	511.53	368.18	386.47	427.74	628.60
H^+	521.90	3530.61	518.15	378.90	401.15	440.23	638.88
t	175.00	175.00	175.00	175.00	175.00	175.00	175.00

The Large Hadron Collider (LHC)

- pp collision cm : 14 TeV (x7 Tevatron)
  - 25 ns bunch spacing
  - 1.1 10^{11} proton/bunch
- Design lumi: 10^{34}cm^{-2}s^{-1} (10 nb^{-1}s^{-1})
- Physics/year ≈ 100 days

  100 fb^{-1} /year; ≈20 int./x-ing (≥2012?)
- Low lumi: ≈10^{33}cm^{-2}s^{-1} (1 nb^{-1}s^{-1})

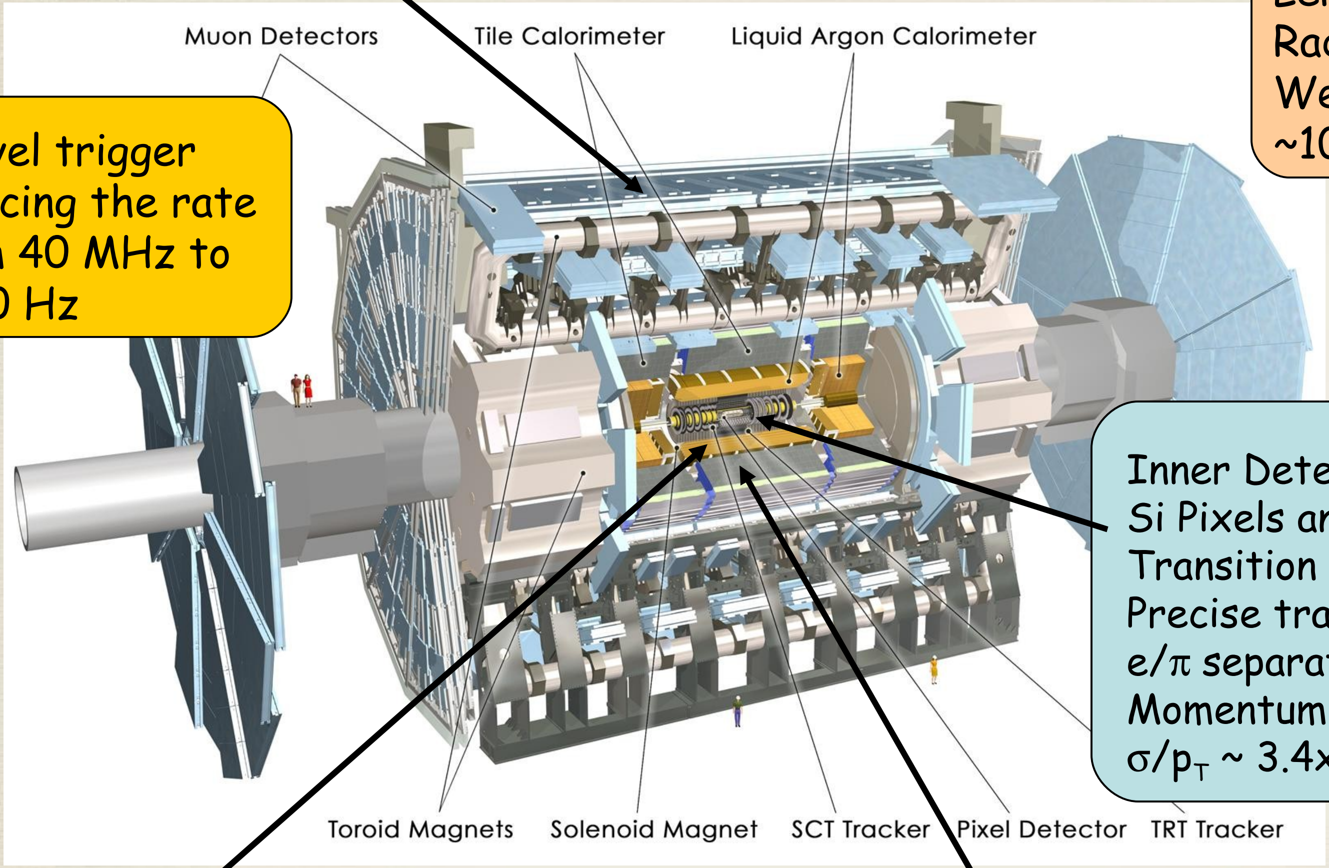
  10 fb^{-1} /year ; ≈2 int./x-ing (≥2011)
- Initial lumi:<10^{32}cm^{-2}s^{-1} (0.1 nb^{-1}s^{-1}) (2010)

  <<1 fb^{-1} /year (at reduced energy!)

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based chambers
Muon trigger and measurement with momentum resolution < 10% up to E_μ ~ TeV

3-level trigger reducing the rate from 40 MHz to ~200 Hz

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~10^8 electronic channels

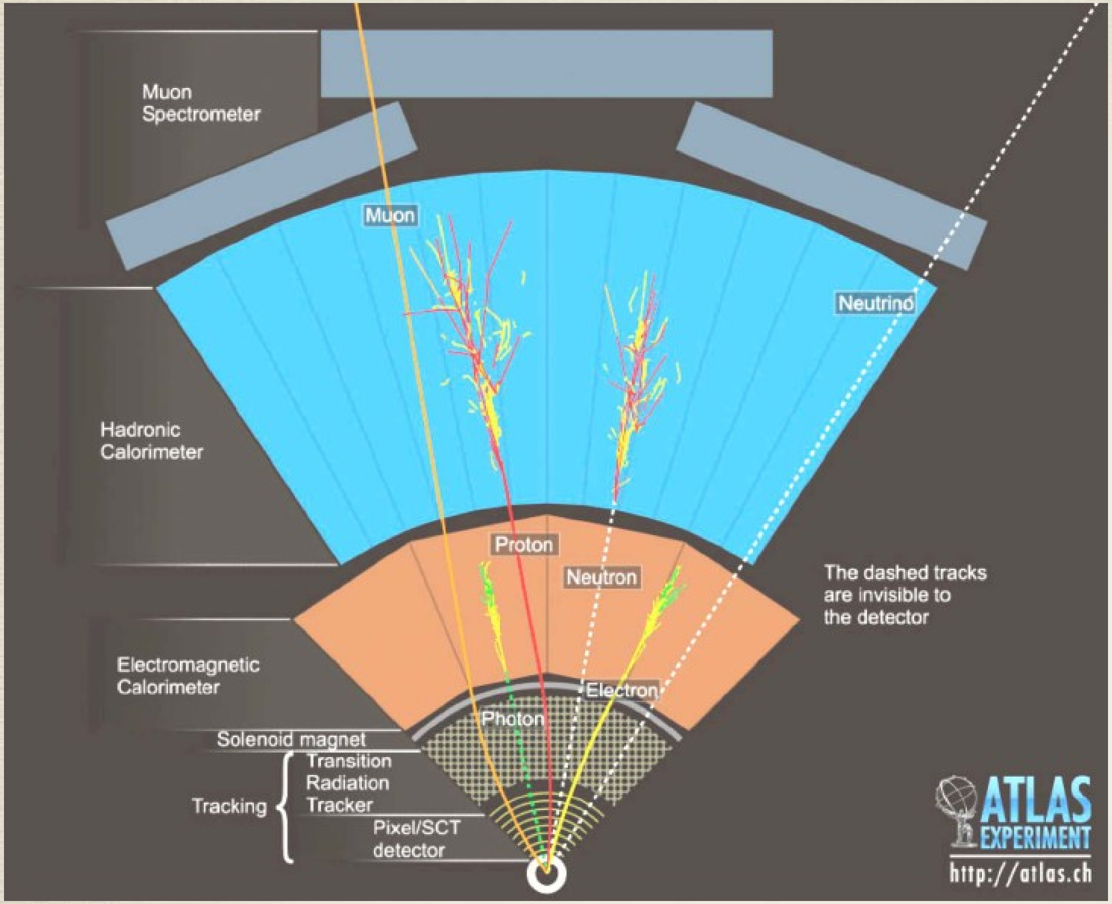


Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels and strips (SCT) +
Transition Radiation straws
Precise tracking and vertexing,
e/π separation (TRT).
Momentum resolution:
$\sigma/p_T \sim 3.4\text{x}10^{-4}\ p_T(\text{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: ~ 1% at 100 GeV, 0.5% at 1 TeV

HAD calorimetry ($|\eta|<5$): segmentation, hermeticity
Tilecal Fe/scintillator (central), Cu/W-LAr (fwd)
Trigger and measurement of jets and missing E_T
E-resolution: $\sigma/E \sim 50\%/\sqrt{E} \oplus 0.03$

Measurements from the ATLAS spectrometer



- Precise tracking:
  - charged particles
  - primary and secondary vertices
- Electromagnetic calorimeter:
  - Electron identification
  - Photon identification
- Hadronic energy:
  - Jets
  - Missing E_T ($\not{E}_T$)
- Muon spectrometer
- ATLAS is a 4Π hermetic detector
- Longitudinal boost unknown. Only momentum balance in the transverse plane possible

Definition of some variables relevant to the discussed analyses

$$M_{\mathrm{eff}} \equiv \sum_{i=1}^{4} p_T^{\mathrm{jet},i} + \sum_{i=1} p_T^{\mathrm{lep},i} + E_{\mathrm{T}}^{\mathrm{miss}} \qquad S_T \equiv \frac{2\lambda_2}{(\lambda_1+\lambda_2)} \quad S_{ij} = \Sigma_k \, p_{ki} p^{kj}$$

$$M_T^2(\mathbf{p}_T^{\alpha}, \mathbf{p}_T^{\mathrm{miss}}, m_\alpha, m_\chi) \equiv m_\alpha^2 + m_\chi^2 + 2\left(E_T^\alpha E_T^{\mathrm{miss}} - \mathbf{p}_T^\alpha \cdot \mathbf{p}_T^{\mathrm{miss}}\right)$$

mSUGRA – generic searches in ATLAS:

- ✓ 4 jets + 0 leptons
- ✓ 4 jets + 1 lepton
- ✓ 2 (or 3) jets + 0 leptons
- ✓ 2 (or 3) jets + 1 lepton
- o 4 jets + 2 leptons (OS or SS)
- o 3 leptons + jet
- ✓ 3 leptons + $\not{E}_T$
- o 4 jets + τ
- o 4 jets + ≥2 b-tagged

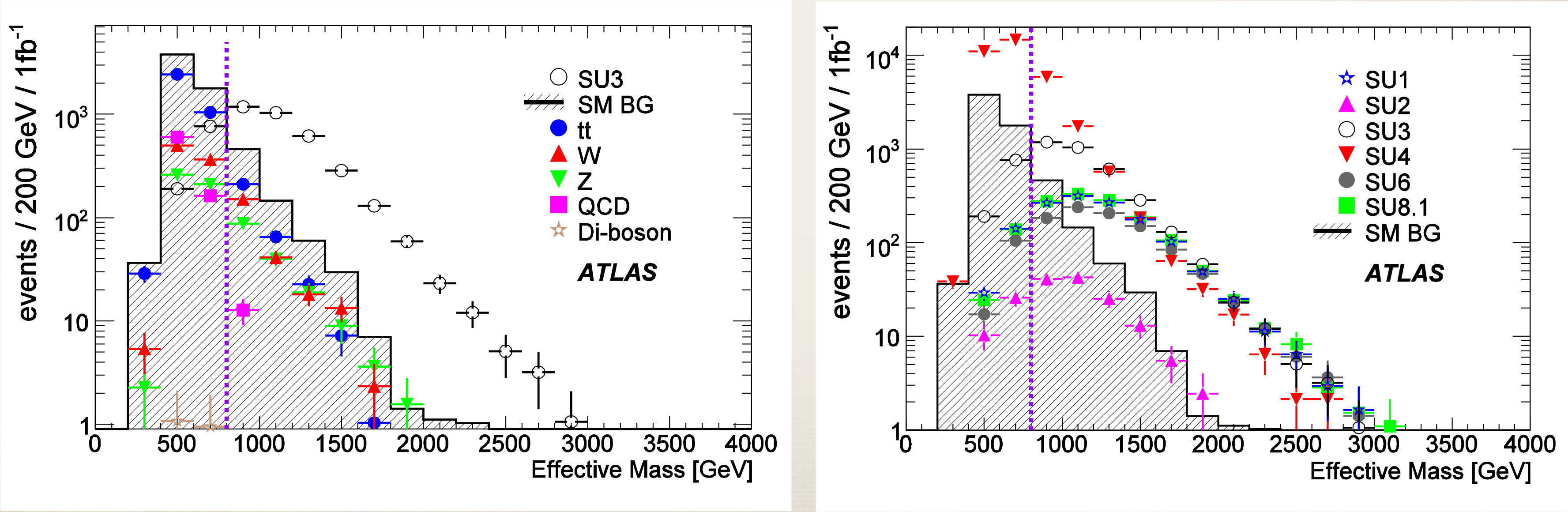
} Enhanced at tanβ>>1

The search strategy is largely motivated by the cosmological constraints on the DM relic density. Nevertheless, the final sensitivity scan is generic and takes into account only the direct exclusion limits from LEP and Tevatron. DM constraints merely a hint rather than constraint to generic SUSY searches!

mSUGRA: inclusive 0-lepton mode

- ☐ This channel has the highest statistics but suffers from remaining QCD background
- ☐ Cuts on sphericity & colinearity of $\not{E}_T$ with a jet reduce QCD contribution.
- ☐ ttbar background remains dominant after all cuts.
- ☐ Only SU2 (focus point) cannot be assessed in this channel. Need leptonic signatures!

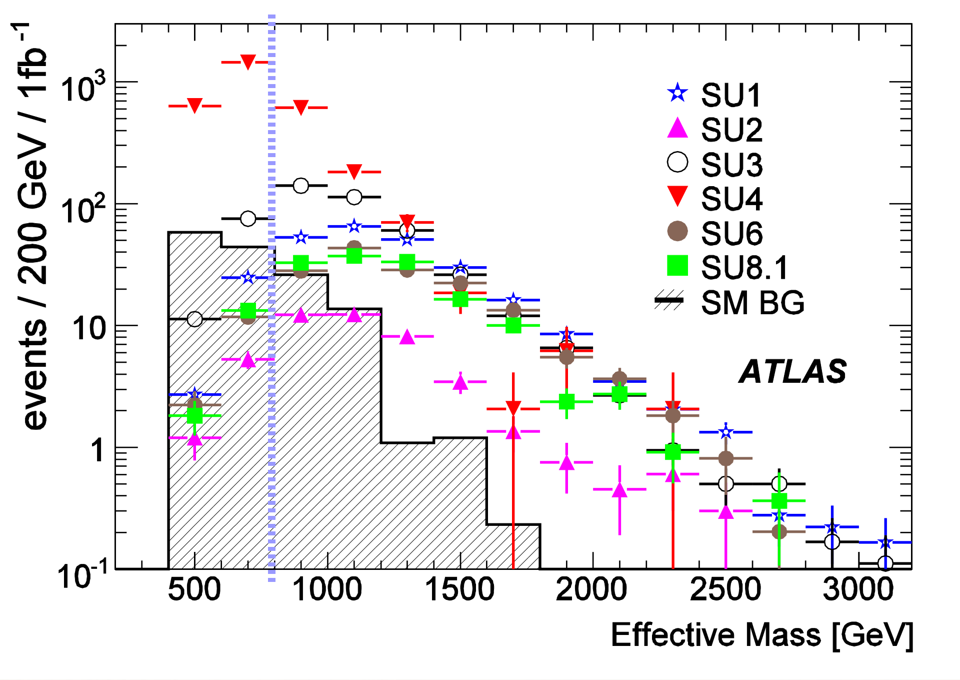
$\geq$4 jets p_T>50GeV
$\geq$1 jet p_T>100GeV
$\not{E}_T$>100GeV
$\not{E}_T$>0.2M_{eff}
S_T>0.2
$\Delta\phi(\text{jet}_{1,2,3}-\not{E}_T)$>0.2
veto events with e,μ
M_{eff}>800GeV
trigger: J70_xE70



mSUGRA: inclusive 1-lepton mode

- ❑ QCD background efficiently suppressed by the isolated lepton requirement.
- ❑ ttbar background dominates by far after all cuts.
- ❑ Similar significance to the 0-lepton mode.
- ❑ SU2 (focus point) more accessible.

1 isolated lepton p_T>20GeV
no other leptons (p_T>10GeV)
≥4 jets p_T>50GeV
≥1 jet p_T>100GeV
$\not{E}_T$>100GeV
$\not{E}_T$>0.2M_{eff}
S_T>0.2
$\Delta\phi(jet_{1,2,3}-\not{E}_T)$>0.2
M_T>100GeV
M_{eff}>800GeV
trigger: J70_xE70



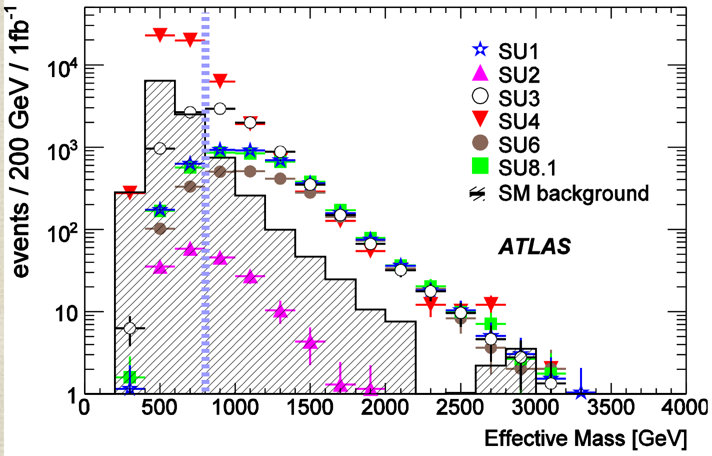
mSUGRA: lower jet multiplicity option

- Supersymmetry generically includes lower jet multiplicity final states, e.g.:

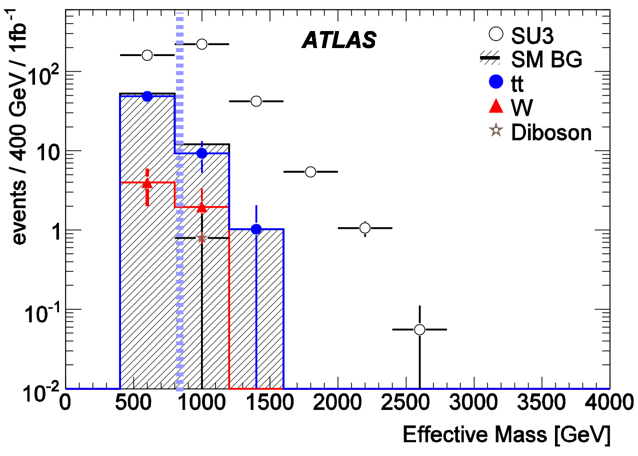
$$\tilde{q}_L + \tilde{q}_R \rightarrow \tilde{\chi}_1^{\pm} q' + \tilde{\chi}_1^0 q$$
$$\tilde{\chi}_1^{\pm} \longrightarrow \tilde{\chi}_1^0 \ell^{\pm} \nu$$

- Lower jet multiplicity may be attractive especially for the early data where understanding of topologically complicated events may be limited (systematic uncertainties in modelling of multi-parton final states) .
- Naturally higher background is compensated by harder cuts on jet energy and $\not{E}_T$.
- The approach proves efficient in both 0 and 1 lepton modes.

0-lepton



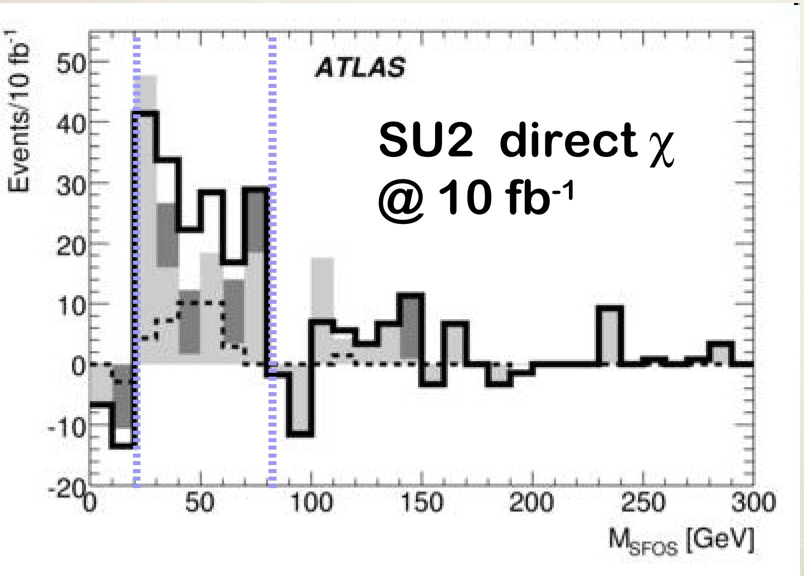
1-lepton



cut modification:
$\geq$2 jets p_T>100GeV
$\geq$1 jet p_T>150GeV
$\not{E}_T$>100GeV
$\not{E}_T$>0.3M_{eff}

mSUGRA: tri-lepton analysis (direct gaugino production)

- "Worst case scenario": very high m_0 and suppressed strong production through gluinos.
- Assessed using SU2 benchmark point with a jet veto.
- This point particularly difficult due to low mass differences, hence low p_T leptons and low $\not{E}_T$.
- Direct chargino-neutralino production with three leptons in the final state has small cross-section (32.6 fb).
- SM background low but very stringent lepton isolation cuts required to suppress ttbar and Zb. WZ is inherently irreducible. Systematics small (5%).
- Requires considerably larger $L_{int..}$(5σ discovery with ~80 fb^{-1})



pair of OSSF leptons (e or μ)
NO $81.2 < m_{OSSF} < 102.2$ GeV
≥3 leptons pT>10 GeV
$p_{T\ \mathrm{track,max}}^{\Delta R=0.2}$>2 Gev for electron
$p_{T\ \mathrm{track,max}}^{\Delta R=0.2}$>1 Gev for muon
$\not{E}_T$>30 GeV
no jet with p_T>20GeV
trigger: L2_e22i || L2_mu20

Name of the game:
Understanding SM backgrounds from real data!

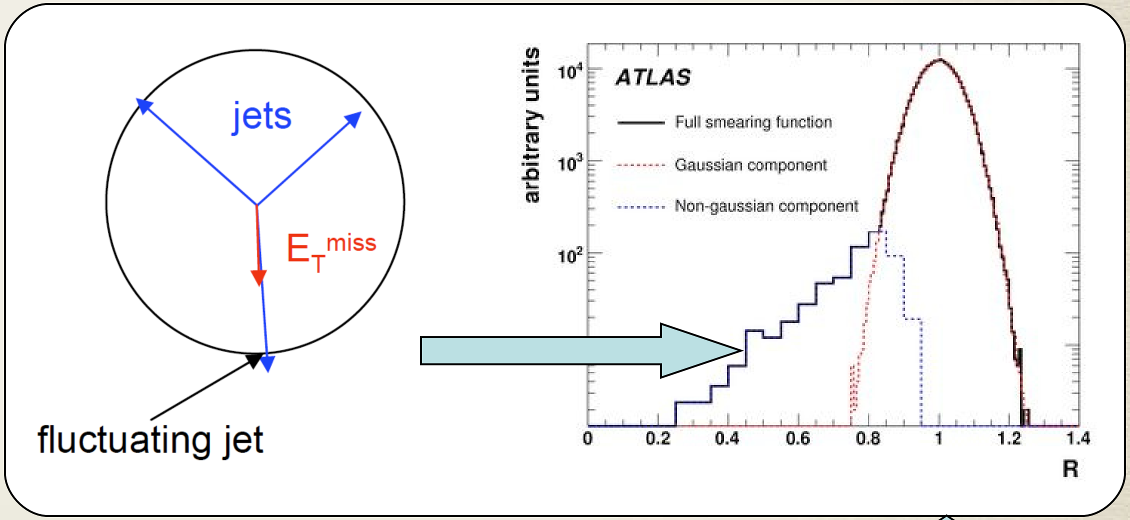
SM backgrounds must eventually be estimated from data itself.
Strategy includes:

- excellent understanding of the detector response (lepton efficiencies, JES, $\not{E}_T$...)
- understanding of the individual backgrounds using control samples

Different techniques used for different types of backgrounds and analysis modes.

Example:
jet response

The non-Gaussian tail of the resolution function obtained from the jet mismeasurements in the "mercedes" QCD events



The Gaussian part of the resolution function
from the jet-photon balance

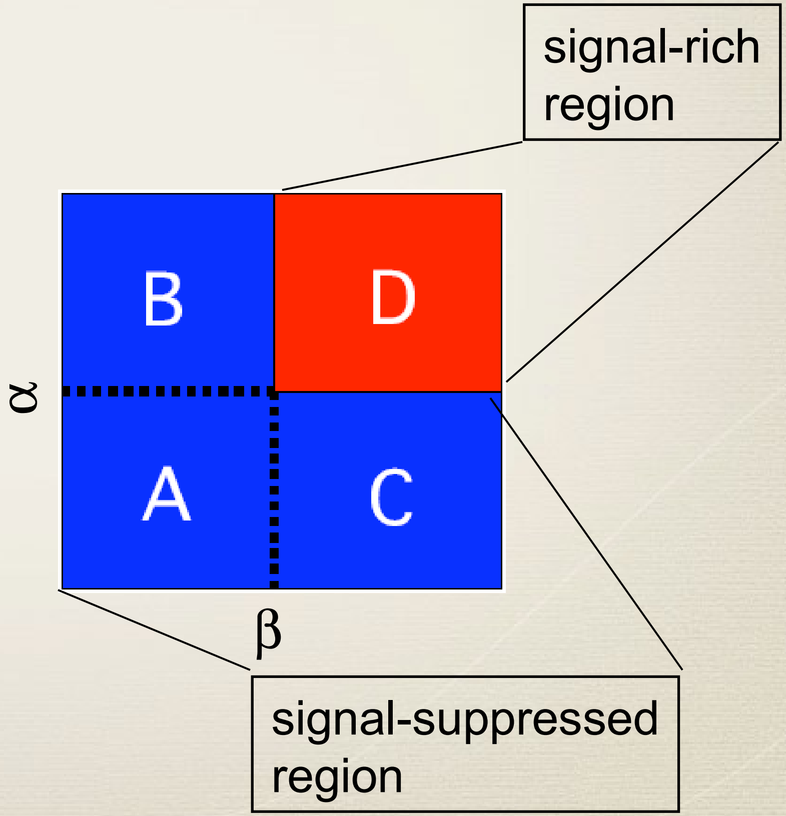
Data-driven methods – the guiding principle

- ☐ Most have a common principle which relies on identifying a control region (exclusive to the actual signal search region) which is signal suppressed but still representative for the background.
- ☐ One needs two variables (α,β) which are approximately independent:

- ➢β distribution from background events in the signal region can be estimated from data using:
  - ➢$D=Cx\underbrace{B/A}$

normalisation from data-suppressed region using an independent α variable

- ➢If there is no SUSY signal (signal region consistent with the predicted background) -> DONE
- ➢Otherwise one can iterate subtracting the observed signal from the control sample ("new M_T method")

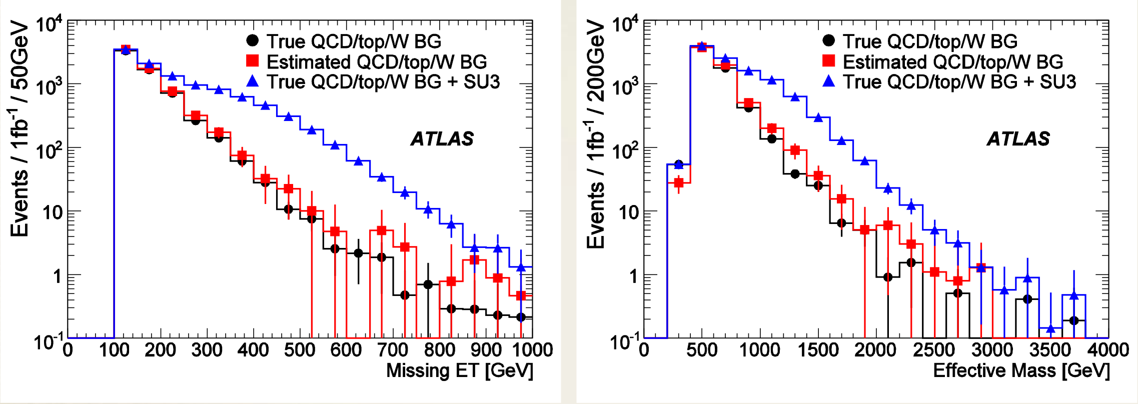


The new M_T method at work

ttbar & W+jets:
require a lepton (p_T>20GeV)
drop it and recalculate kinematics
normalise in the region:
100 GeV<$\not{E}_T$<200 GeV

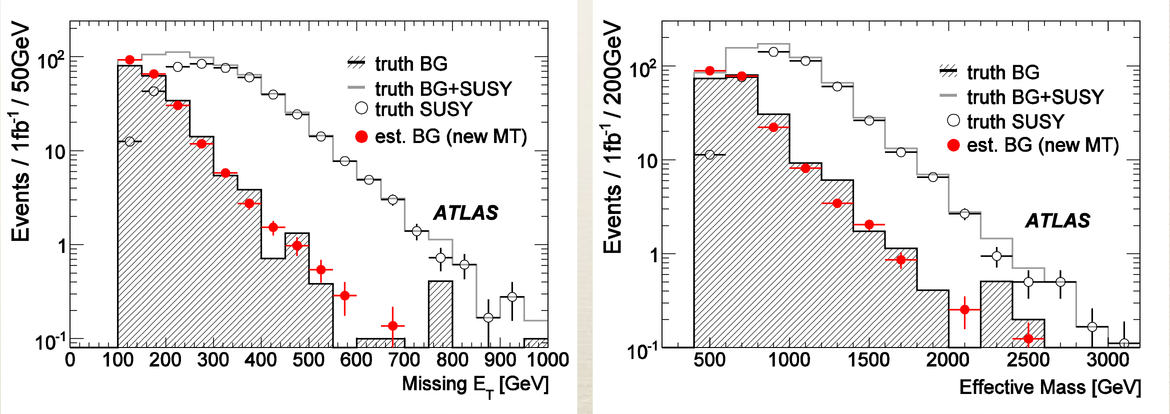
QCD:
Require $\not{E}_T$<100 GeV (light QCD)
correct for sl b,c contribution
normalise in the region:
$\Delta\phi(\text{jet-}\not{E}_T)_{min}$<0.2

QCD/top/W backgrounds in 0-lepton mode



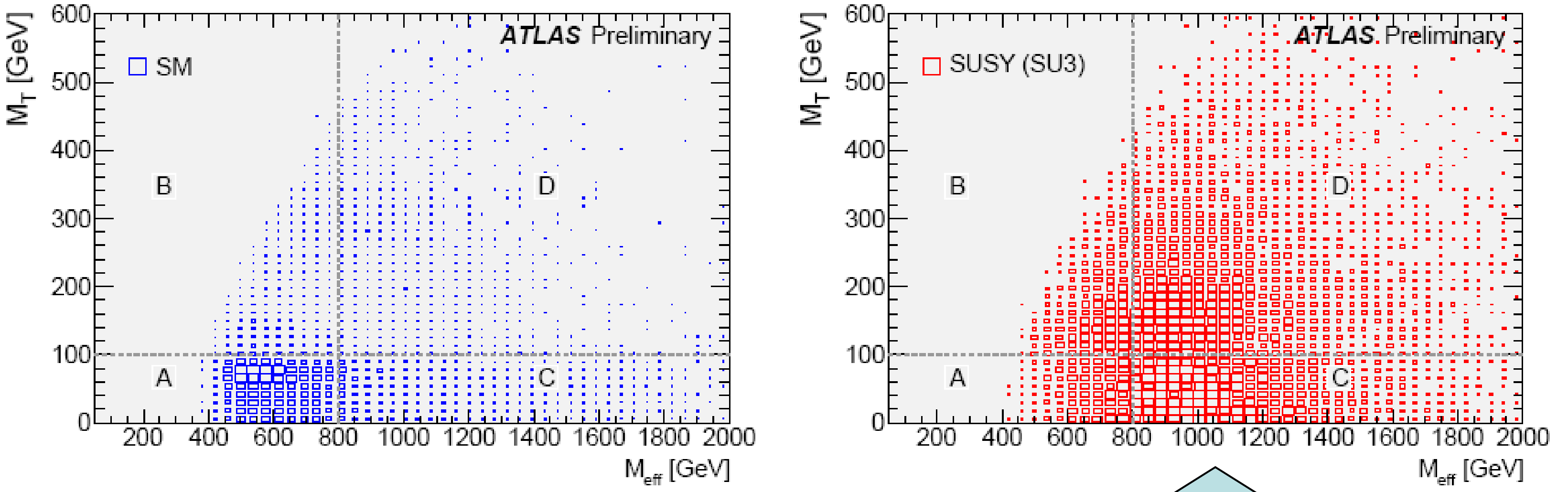
top/W backgrounds in 1-lepton mode

M_T (lepton, $\not{E}_T$)
control: M_T<100 GeV
signal: M_T>100 GeV
normalisation region:
100 GeV<$\not{E}_T$<150 GeV



The “tiles method” - yet another way

- Variables in the SM backgrounds may exhibit correlations
- SM shapes (fractions) must be known (eg from MC)



$$\bar{N}_A = f_A^{SM}\bar{N}^{SM} + f_A^S\bar{N}^S, \qquad \bar{N}_B = f_B^{SM}\bar{N}^{SM} + f_B^S\bar{N}^S,$$

$$\bar{N}_C = f_C^{SM}\bar{N}^{SM} + f_C^S\bar{N}^S, \qquad \bar{N}_D = f_D^{SM}\bar{N}^{SM} + f_D^S\bar{N}^S,$$

$f_A^{SM}, \ldots, f_D^{SM}$ Taken from MC

$$f_A^S = (1 - f_{M_{\text{eff}}}^S)(1 - f_{M_T}^S), \qquad f_B^S = (1 - f_{M_{\text{eff}}}^S) f_{M_T}^S,$$

$$f_C^S = f_{M_{\text{eff}}}^S (1 - f_{M_T}^S), \qquad f_D^S = f_{M_{\text{eff}}}^S f_{M_T}^S,$$

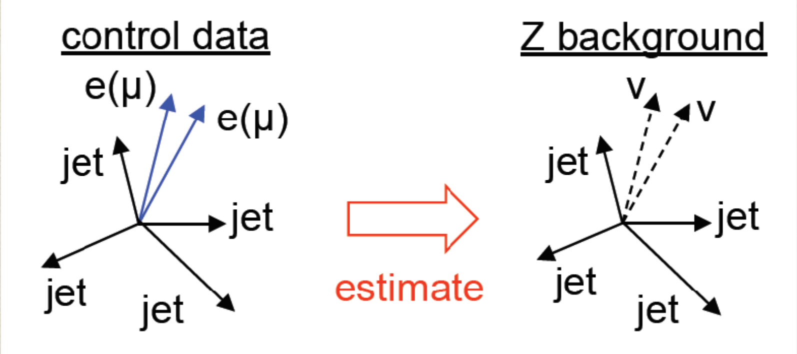
The two variables need to be independent in the signal!

The system is solvable without iterations!

ATL-PHYS-PUB-2009-077

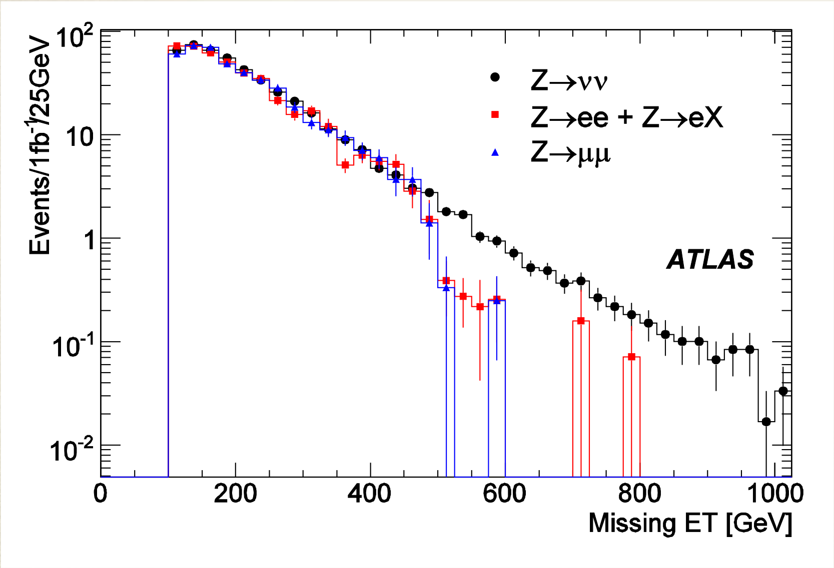
Z->νν + jets an important background to 0-lepton

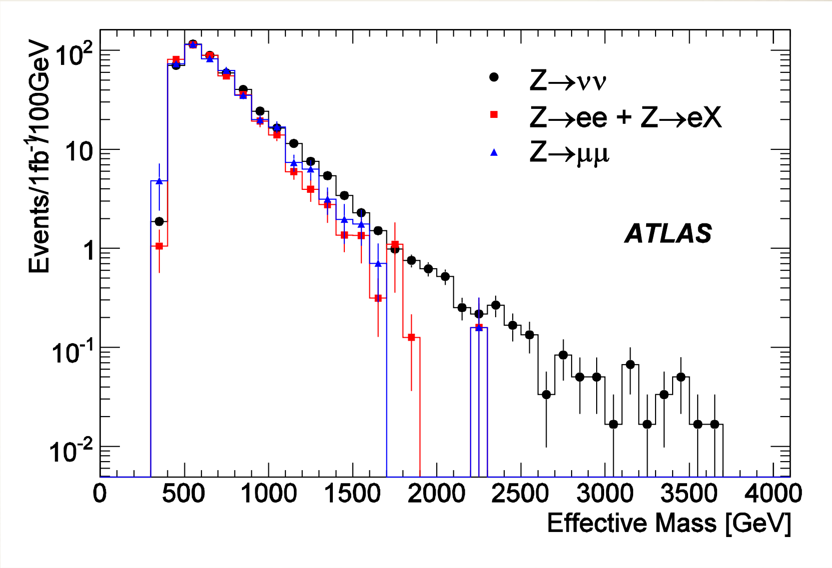
- Replace method relies on the measured Z->l^+l^-



Standard 0-lepton selection
+ Z->l^+l^-
with $p_T(l^+l^-)$ substitution for $\not{E}_T$

acceptance (η, p_T), efficiency, and Br corrections must be applied!

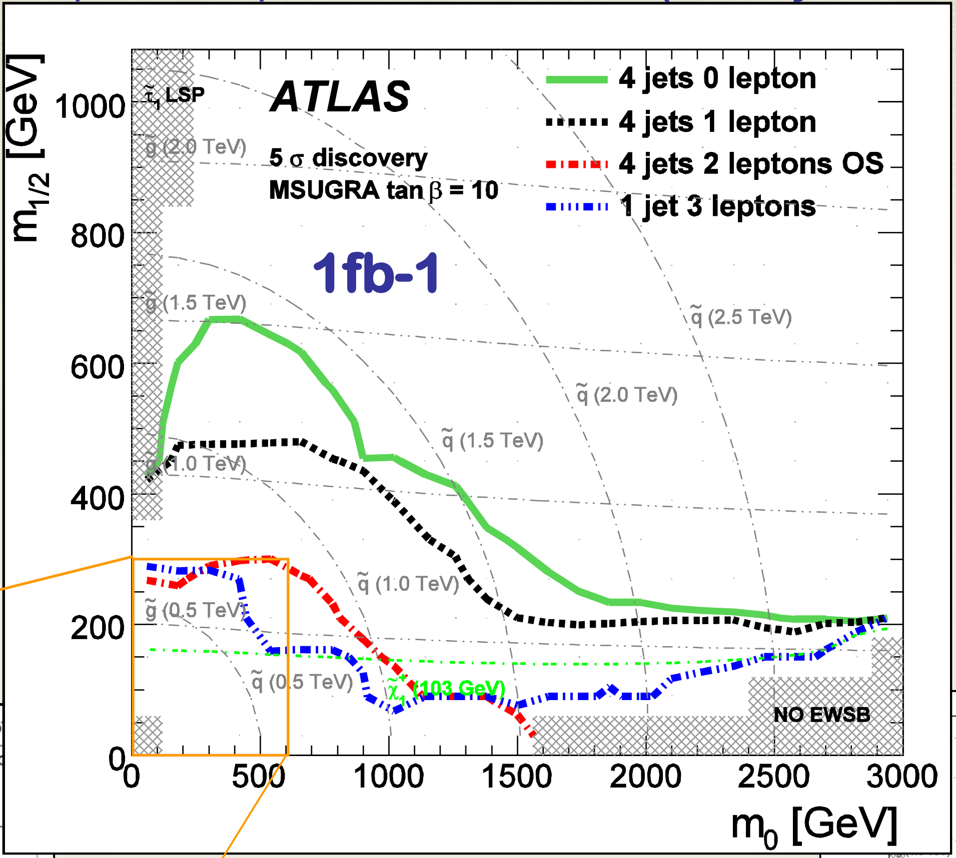


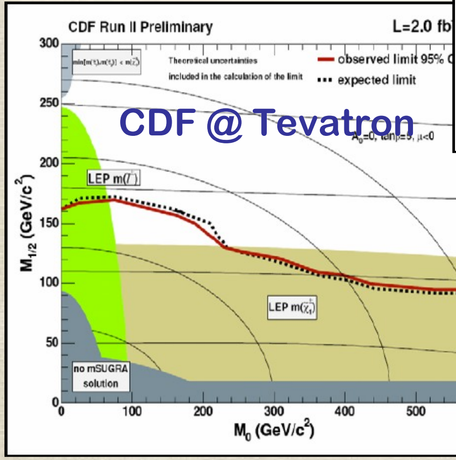


mSUGRA discovery reach with ATLAS @ $1fb^{-1}$

$A_0 = 0$, $\mu > 0$, $\tan\beta = 10$, 5σ contours (incl. systematics)

Spectacular improvement over current limits even with moderate statistics



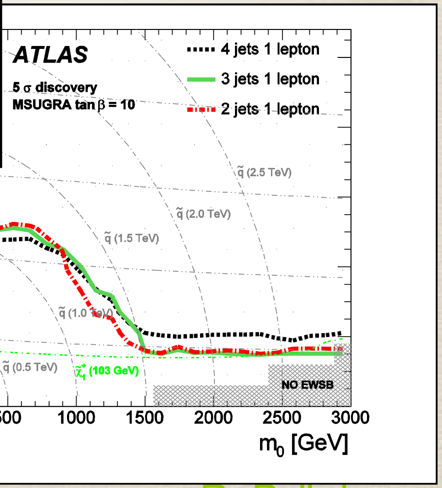


Assumed uncertainties:

- **QCD: 50%**
- **tt, V+j: 20%**

(conservative)

Lower jet multiplicity analyses consistently give similar discovery reach

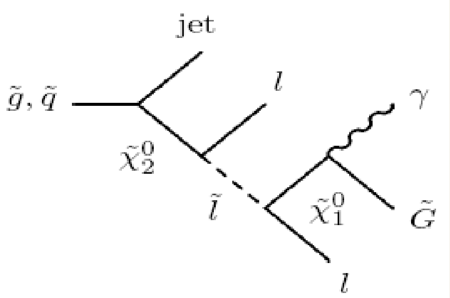


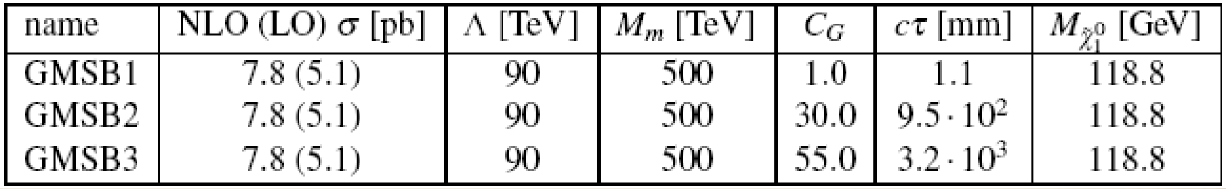
mSUGRA is merely a convenient framework for assessing the discovery potential for R-conserving SUSY with χ^0_1 as LSP.

Other SUSY breaking scenarios lead to different EW-scale phenomenology.

Will shortly discuss GMSB:

- with gravitino LSP and χ^0_1 NLSP

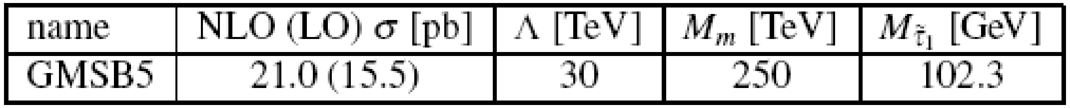




name	NLO (LO) σ [pb]	Λ [TeV]	M_m [TeV]	C_G	$c\tau$ [mm]	$M_{\tilde{\chi}_1^0}$ [GeV]
GMSB1	7.8 (5.1)	90	500	1.0	1.1	118.8
GMSB2	7.8 (5.1)	90	500	30.0	$9.5 \cdot 10^2$	118.8
GMSB3	7.8 (5.1)	90	500	55.0	$3.2 \cdot 10^3$	118.8

$\chi_1^0 \to \gamma + \tilde{G}$ lifetime

- with gravitino LSP and meta-stable slepton NLSP

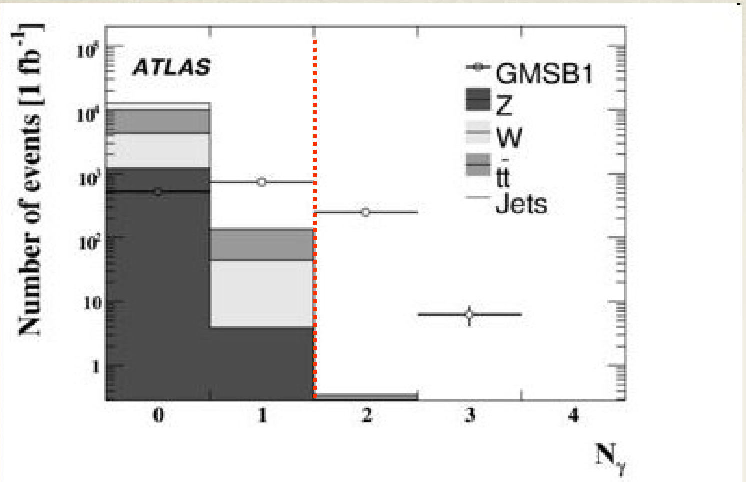


name	NLO (LO) σ [pb]	Λ [TeV]	M_m [TeV]	$M_{\tilde{\tau}_1}$ [GeV]
GMSB5	21.0 (15.5)	30	250	102.3

Others (not covered here):

- o Split SUSY (stable R-hadrons)
- o NUHM
- o AMSM

GMSB – with gravitino LSP and χ^0_1 NLSP
Exploit the hard photon emission!



$\geq$ 2 isolated photons p_T>20GeV

$\geq$4 jets p_T>50GeV

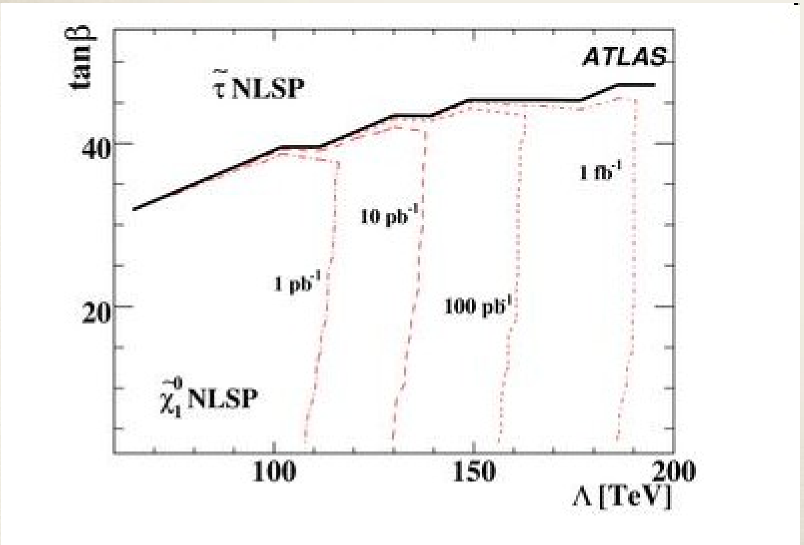
$\geq$1 jet p_T>100GeV

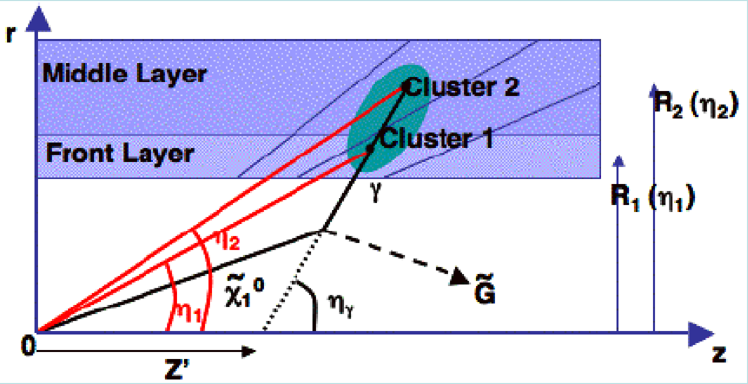
$\not{E}_T$>100GeV

$\not{E}_T$>0.2M_{eff}

trigger: g55 || 2g17i

Discovery reach:





If χ^0_1 lifetime long enough photons will appear as "non-pointing"

Lifetime measurement possible from:

- Z' reconstruction
- Calorimeter timing

GMSB – with gravitino LSP and slepton NLSP
Exploit the low velocity of the heavy meta-stable particle!

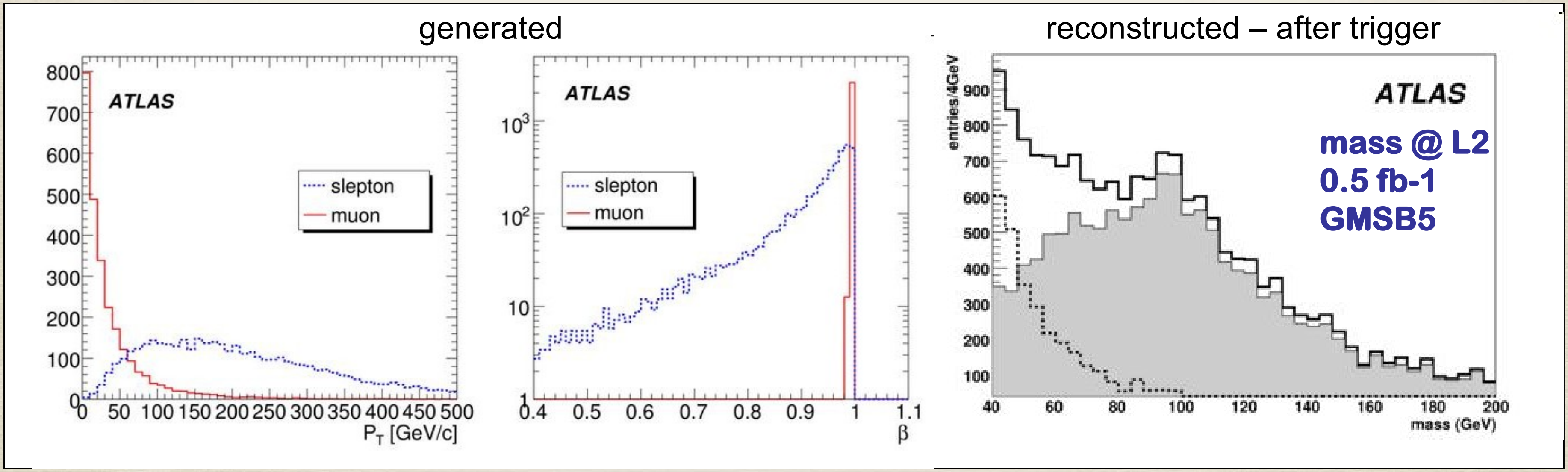
Signature: penetrating tracks with high p_T and low β

Signal in parts of detector in different bunch crossings:

Online:

- L1: require regular muon high trigger (95% efficient)
- L2: use 3ns resolution TOF information from RPC's (barrel only, ~50% eff.)
- Trigger on high mass!

pT>40 GeV, β<0.97, m>40 GeV



generated

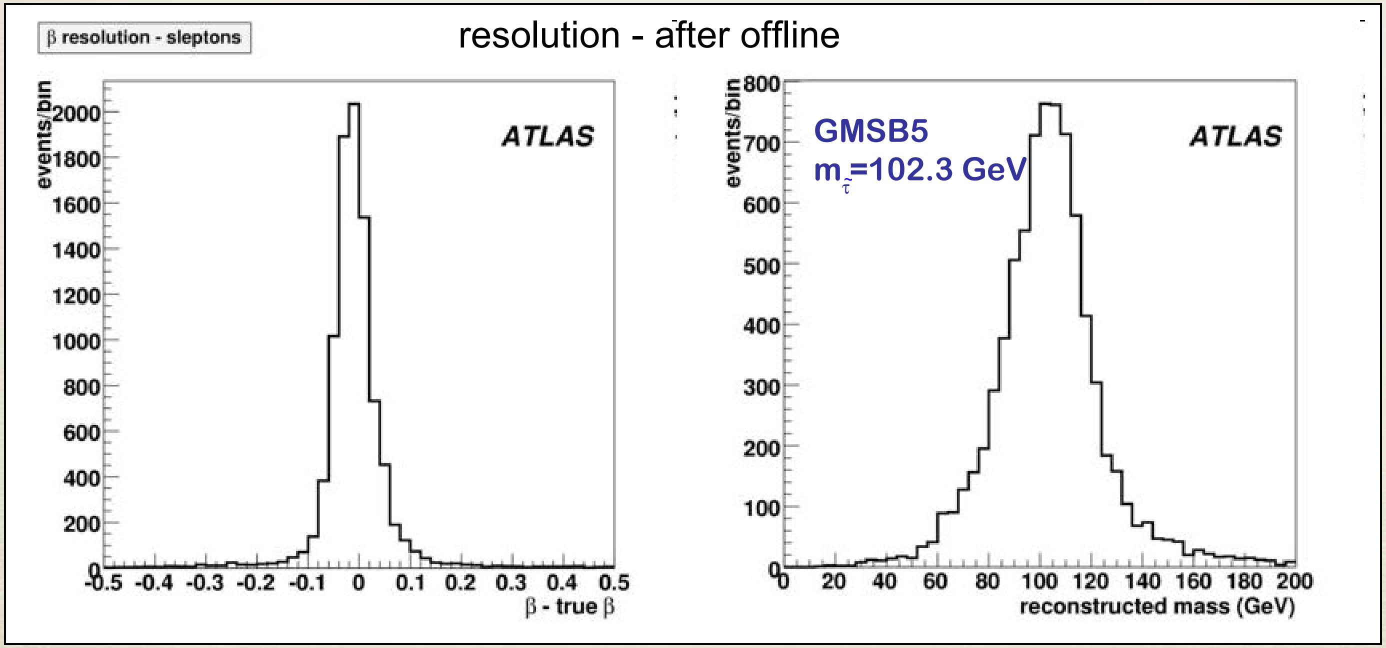
reconstructed – after trigger

GMSB – with gravitino LSP and slepton NLSP
Exploit the low velocity of the heavy meta-stable particle!

The incorrect time of arrival distorts drift time measurements in the MDT's.

Offline:

- Minimise the track reconstruction χ^2 w.r.t. tof.
- Combine this with L2 trigger to extract β.

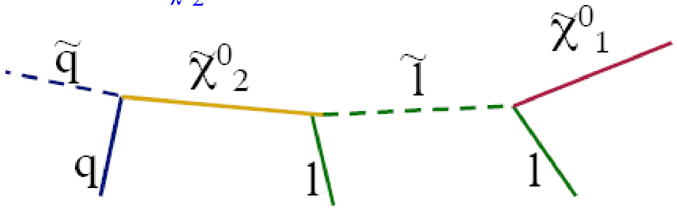


Note: similar technique applicable to R-hadron searches

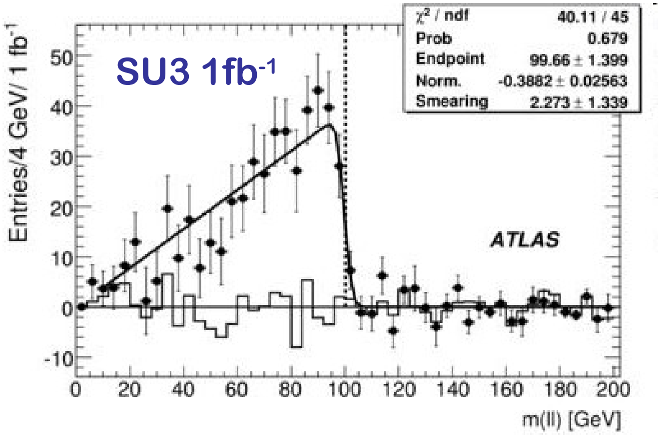
Once SUSY discovered we will try to make a better acquaintance ☺

- sparticle masses, spin, couplings, etc.

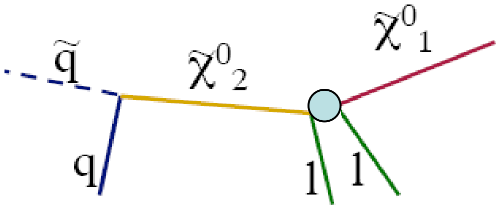
SU3: $m_{\tilde\chi_2^0} > m_{\tilde l}$



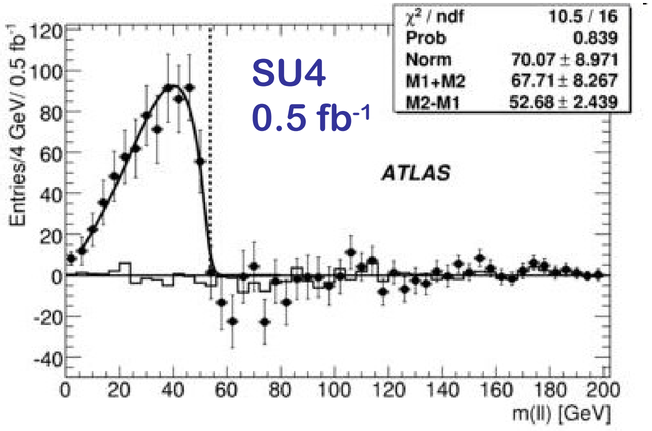
$$m_{\ell\ell}^{\rm edge} = m_{\tilde\chi_2^0}\sqrt{1-\left(\frac{m_{\tilde\ell}}{m_{\tilde\chi_2^0}}\right)^2}\sqrt{1-\left(\frac{m_{\tilde\chi_1^0}}{m_{\tilde\ell}}\right)^2}\,.$$



SU4: $m_{\tilde l} > m_{\tilde\chi_2^0}$



$$m_{\ell\ell}^{\rm edge} = m_{\tilde\chi_2^0} - m_{\tilde\chi_1^0}$$



95% of the flavour uncorrelated ttbar background!

$$N(e^+e^-)/\beta + \beta N(\mu^+\mu^-) - N(e^\pm\mu^\mp)$$

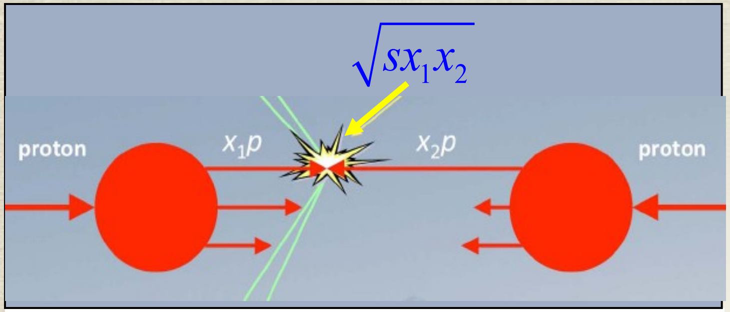
$$\chi^2 = \sum_{k=1}^{n} \frac{(m_k^{\rm max} - t_k^{\rm max}(m_{\tilde\chi_1^0}, m_{\tilde\chi_2^0}, m_{\tilde\ell_{\rm R}}, m_{\tilde q_{\rm L}}))^2}{\sigma_k^2}$$

⇒ SUSY masses ⇒ SUSY parameters &

DM density !

e.g.: hep-ph/1512204

What to expect this year? ~0.1fb^{-1} @ 7(?)TeV



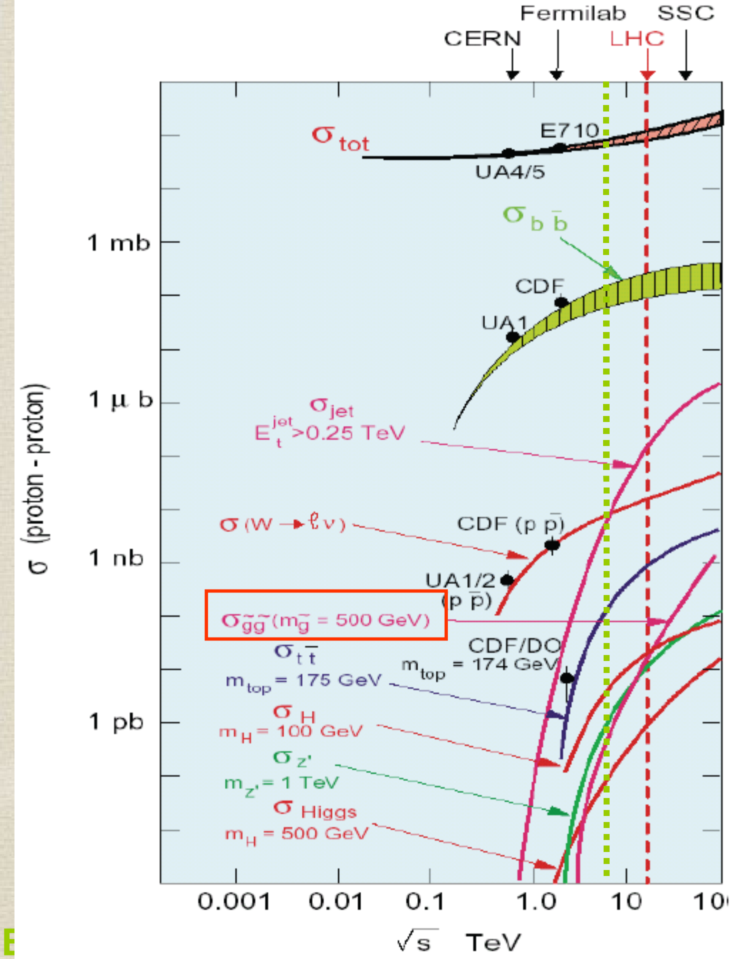
Cross-section steeply falling for heavy object production (e.g. sparticle pair)

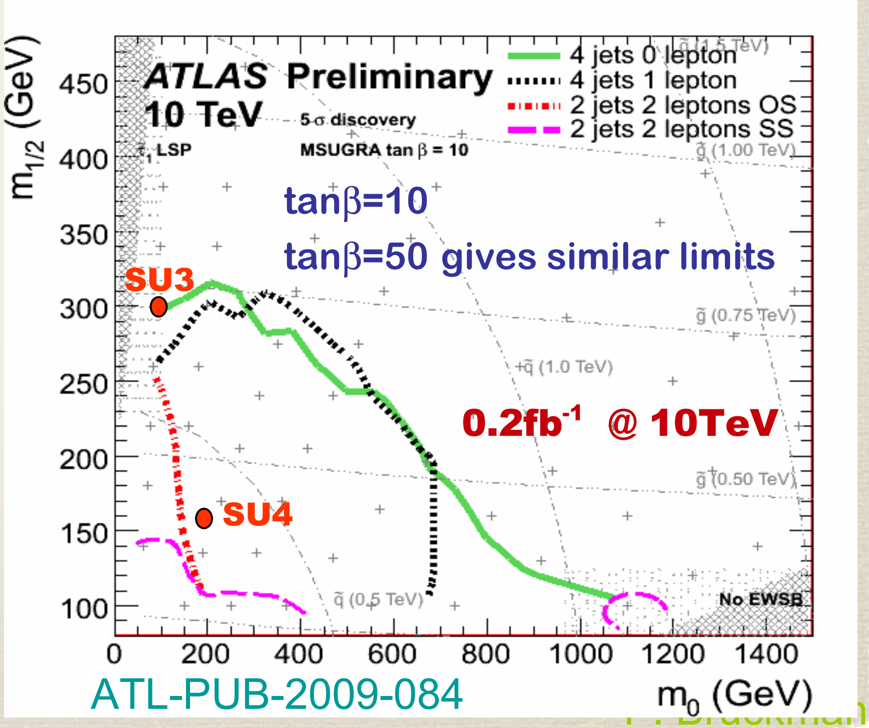
Predictions @ lower √s and lower L_{int} nontrivial:

- x-sections change rapidly
- background systematics are L_{int} dependent

If lucky we may see a glimpse of low mass SUSY (SU4-like)...

Recent update to 200fb^{-1} @ 10TeV





tanβ=10

tanβ=50 gives similar limits

0.2fb^{-1} @ 10TeV

ATL-PUB-2009-084

Changing Gears

LHC is back !!!

☺We are all very excited about it ☺

LHC milestones – from Steve Myers

Date	Day	Achieved
Nov 20	1	Each beam circulating. Key beam instrumentation working.
Nov 23	4	First collisions at 450 GeV. First ramp (reached 560 GeV).
Nov 26	7	Magnetic cycling established (reproducibility).
Nov 27	8	Energy matching.
Nov 29	10	Ramp to 1.18 TeV.
Nov 30	11	Experiment solenoids on.
Dec 04	15	Aperture measurement campaign finished. LHCb and ALICE dipoles on.
Dec 05	16	Machine protection (Injection, Beam dump, Collimators) ready for safe operation with pilots.
Dec 06	17	First collisions with STABLE BEAMS, 4 on 4 pilots at 450 GeV, rates around 1Hz. Santa!
Dec 08	19	Ramp colliding bunches to 1.18 TeV
Dec 11	22	Collisions with STABLE BEAMS, 4 on 4 at 450 GeV, > 10^{10} per bunch, rates around 10Hz.
Dec 13	24	Ramp 2 bunches per beam to 1.18 TeV. Collisions for 90mins.
Dec 14	25	Collisions with STABLE BEAMS, 16 on 16 at 450 GeV, > 10^{10} per bunch, rates around 50Hz.
Dec 16	27	Ramp 4 on 4 to 1.18 TeV. Squeeze to 7 m.

☺ 20-23 November in ATLAS ☺

Friday, November 20:

~ 20:30h: beam-1 threading → 6 beam splashes to ATLAS

~ 22:30h: beam-2 threading → 7 beam splashes to ATLAS

Saturday, 21 November:

~ 1h: beam-2 splashes to ATLAS → 27 events (side C)

~ 4h: beam-1 splashes to ATLAS → 26 events (side A)

Sunday, 22 November:

~ 6h: 15 splash events to test beam abort by BCM → successful

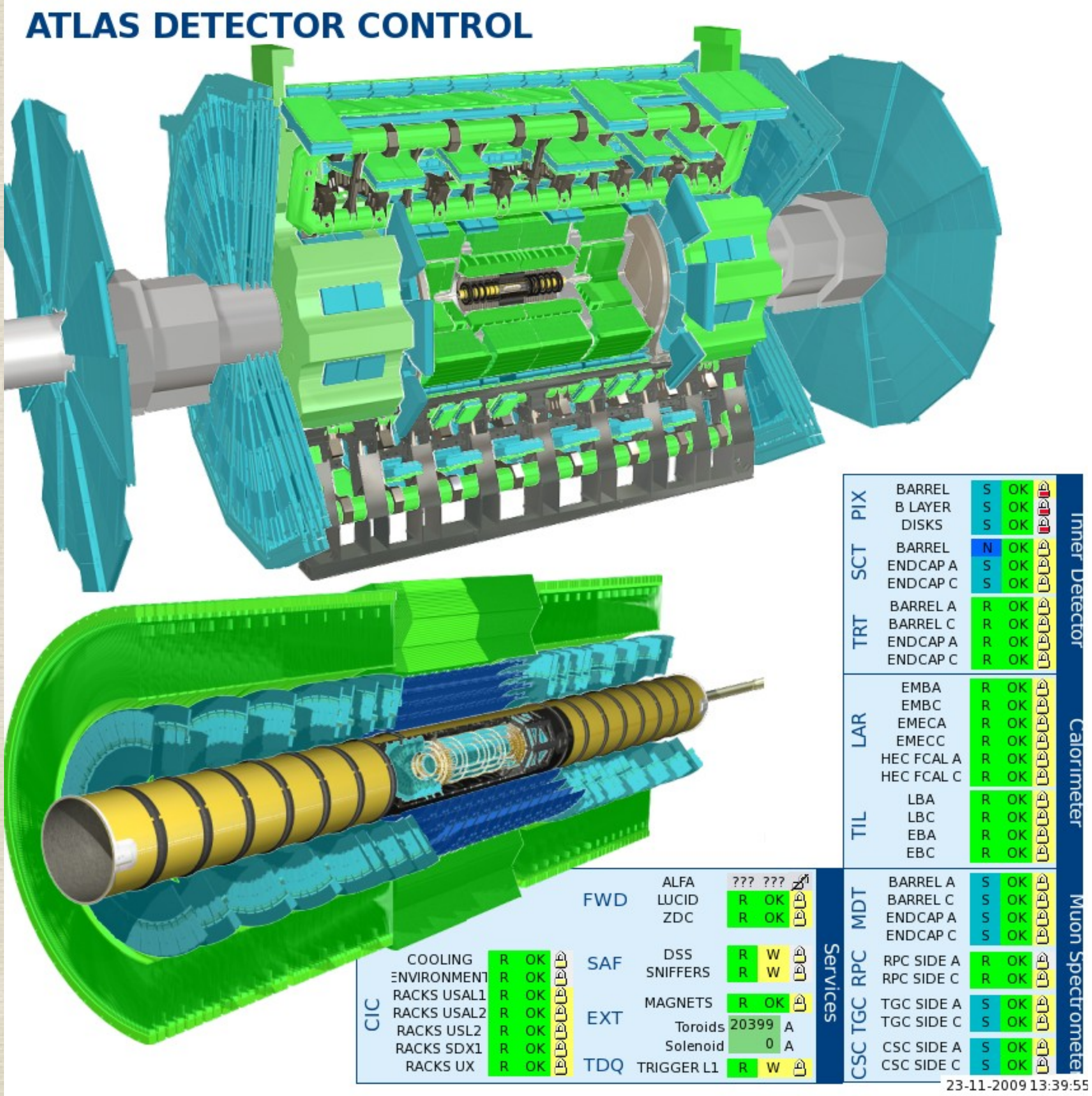
Monday 23 November:

~ 6:30: last series of splashes to ATLAS→ 25 events (side C)

~ 13:30: two beams injected for collisions at IP1 and IP5

~ **14:22: first ATLAS collision event seen !!!**

Detector fully operational



ATLAS DETECTOR CONTROL

PIX	BARREL	S	OK
	B LAYER	S	OK
	DISKS	S	OK
SCT	BARREL	N	OK
	ENDCAP A	S	OK
	ENDCAP C	S	OK
TRT	BARREL A	R	OK
	BARREL C	R	OK
	ENDCAP A	R	OK
	ENDCAP C	R	OK
LAR	EMBA	R	OK
	EMBC	R	OK
	EMECA	R	OK
	EMECC	R	OK
	HEC FCAL A	R	OK
	HEC FCAL C	R	OK
TIL	LBA	R	OK
	LBC	R	OK
	EBA	R	OK
	EBC	R	OK
MDT	BARREL A	S	OK
	BARREL C	S	OK
	ENDCAP A	S	OK
	ENDCAP C	S	OK
RPC	RPC SIDE A	R	OK
	RPC SIDE C	R	OK
TGC	TGC SIDE A	S	OK
	TGC SIDE C	S	OK
CSC	CSC SIDE A	S	OK
	CSC SIDE C	S	OK

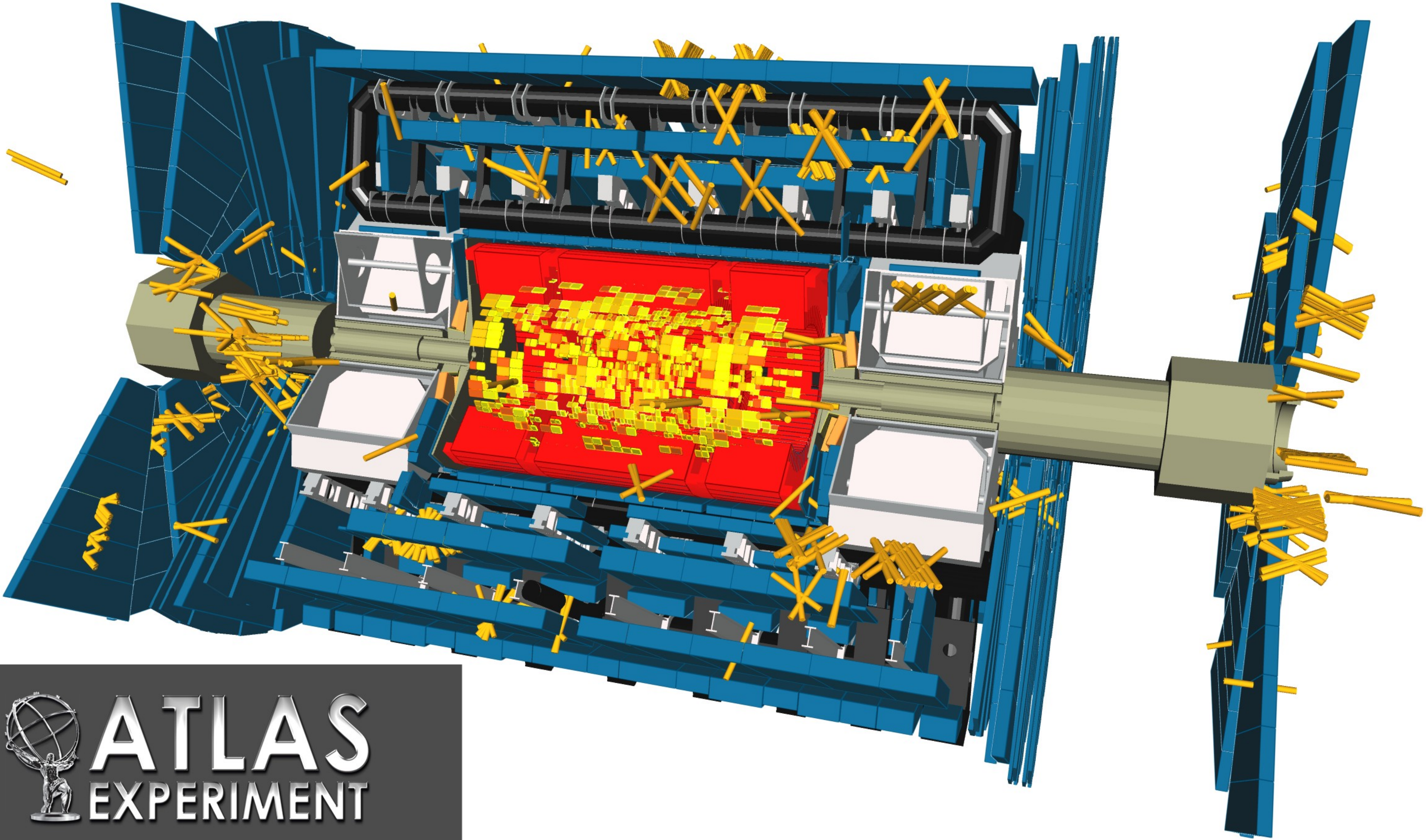
CIC	COOLING	R	OK
	ENVIRONMENT	R	OK
	RACKS USAL1	R	OK
	RACKS USAL2	R	OK
	RACKS USL2	R	OK
	RACKS SDX1	R	OK
	RACKS UX	R	OK
FWD	ALFA	???	???
	LUCID	R	OK
	ZDC	R	OK
SAF	DSS	R	W
	SNIFFERS	R	W
EXT	MAGNETS	R	OK
	Toroids	20399	A
	Solenoid	0	A
TDQ	TRIGGER L1	R	W

23-11-2009 13:39:55

Setup for beam commissioning

- Pixel off
- SCT(standard bias voltage 150 V)
  - Standby V is 20 V →~50% hit efficiency (increases with incidence angle)
  - Barrel and endcap increased to 50V for short stable beam periods during collisions
  - Barrel voltage sometimes lower than 20V for beam set up (eg. splash events)
- All other systems ON
- **No solenoid field, toroids ON**

Beam One (clockwise)



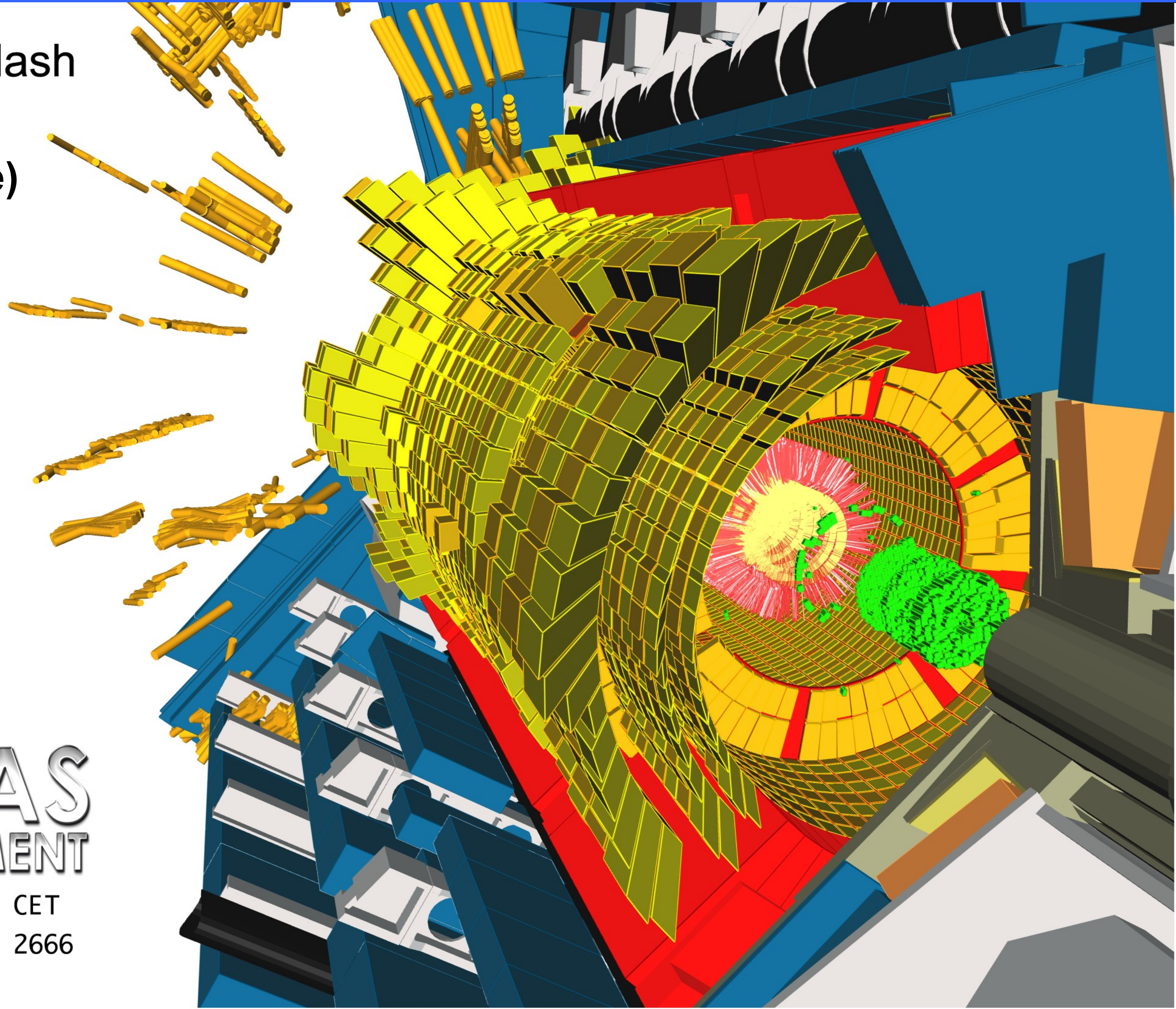
ATLAS EXPERIMENT

2009-11-20, 20:33 CET
Run 140370, Event 2154

First Splash Event 2009

1st Beam Splash from Beam-2

(anticlockwise)



ATLAS EXPERIMENT

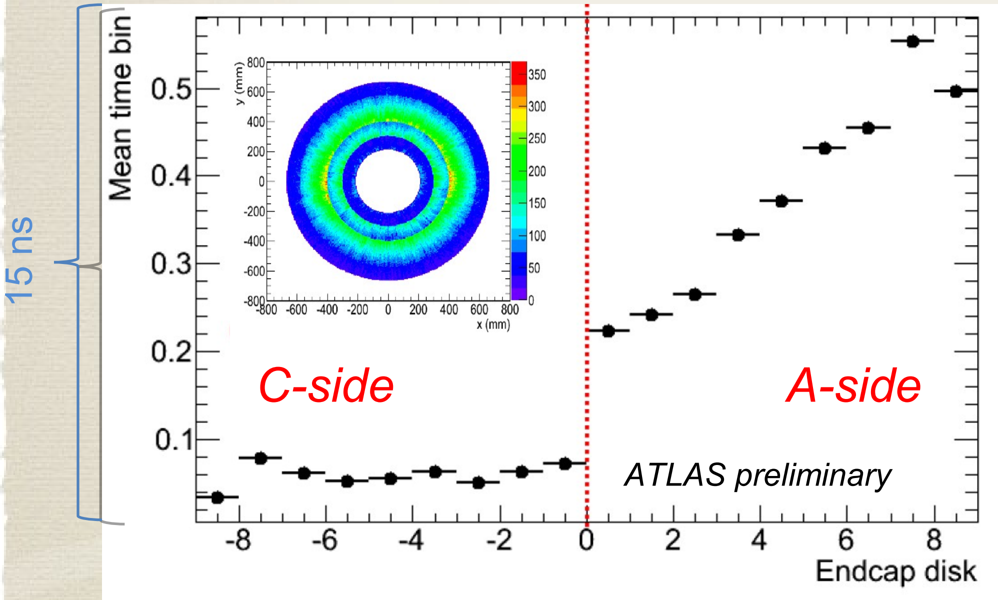
2009-11-20, 23:32 CET

Run 140370, Event 2666

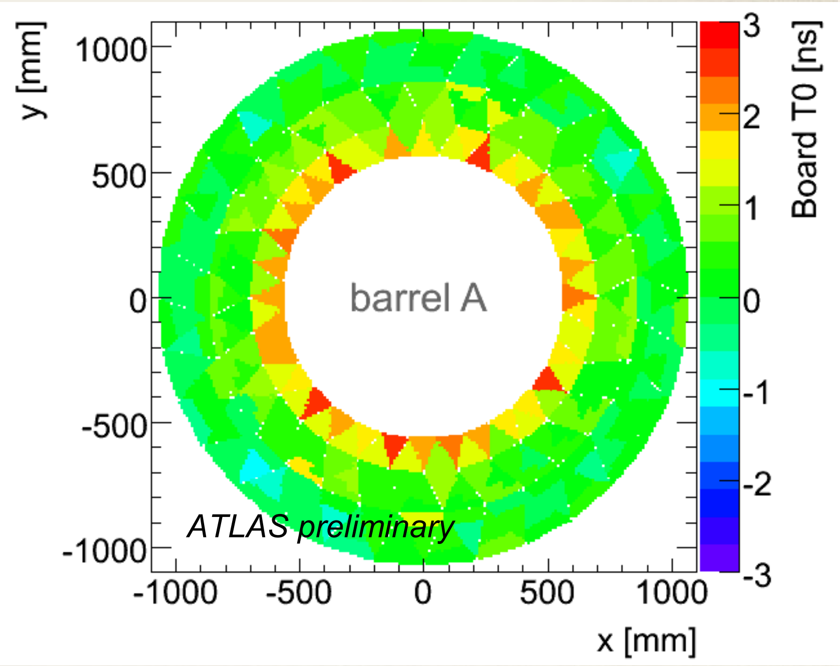
Timing studies with beam-splash events (Inner Detector)

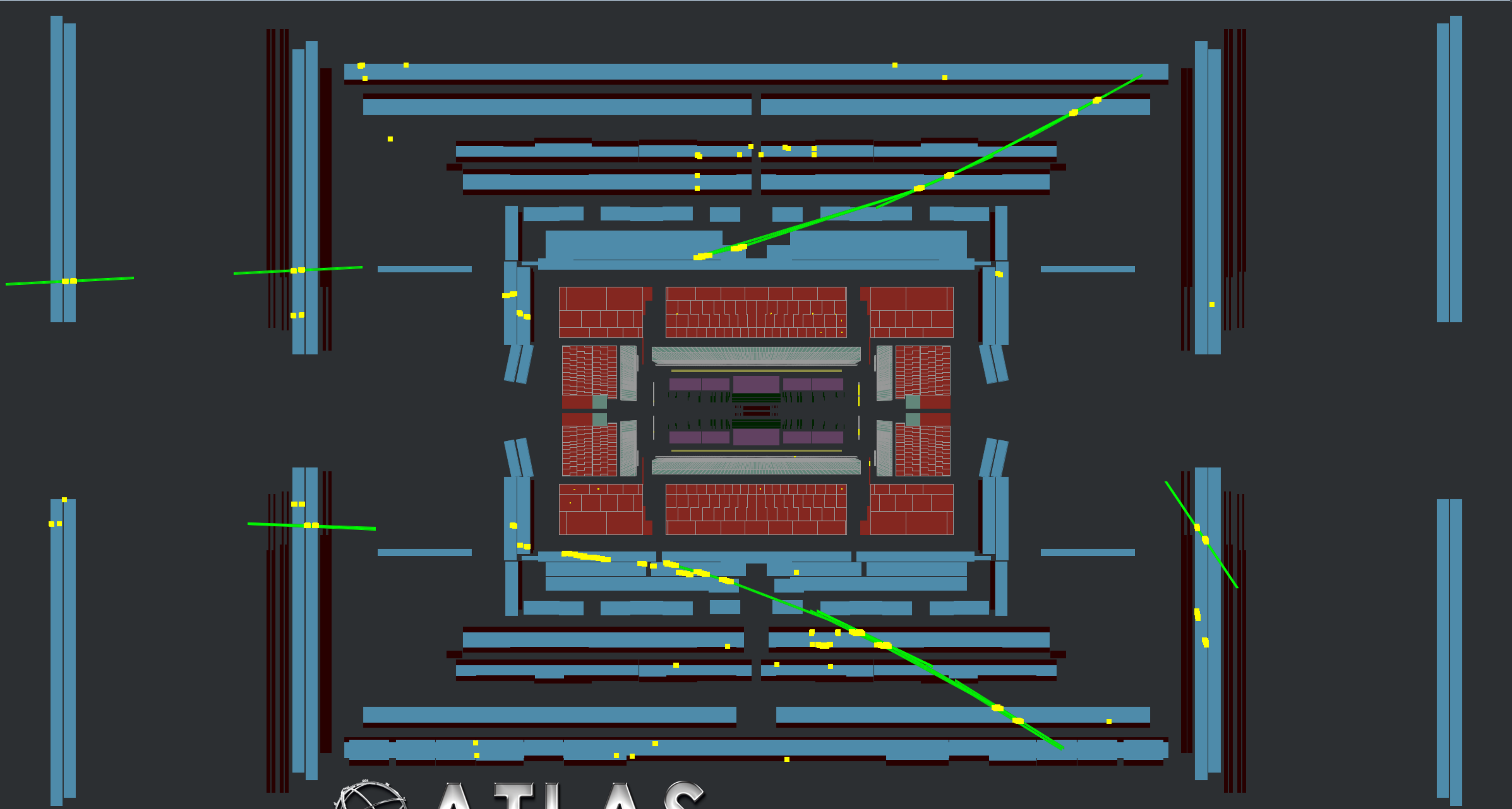
- Inner tracking systems:
  - SCT already well timed-in from cosmics and known cable lengths (better than 2 ns)
  - TRT boards timed-in to better than 2 ns

Beam-1 arriving from A-side: timing as collisions for C-side, but wrong for A-side



TRT Barrel: plot made with collision timing → sensitive to ToF effect on Inner Boards !





ATLAS EXPERIMENT

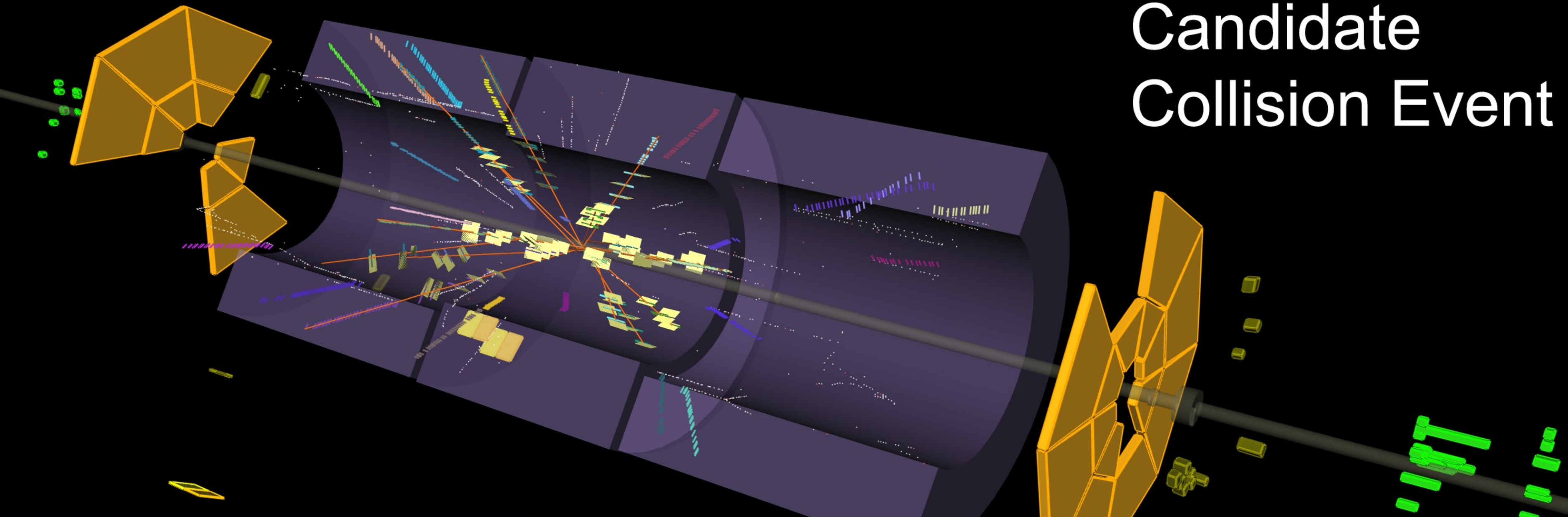
Beam Halo Event

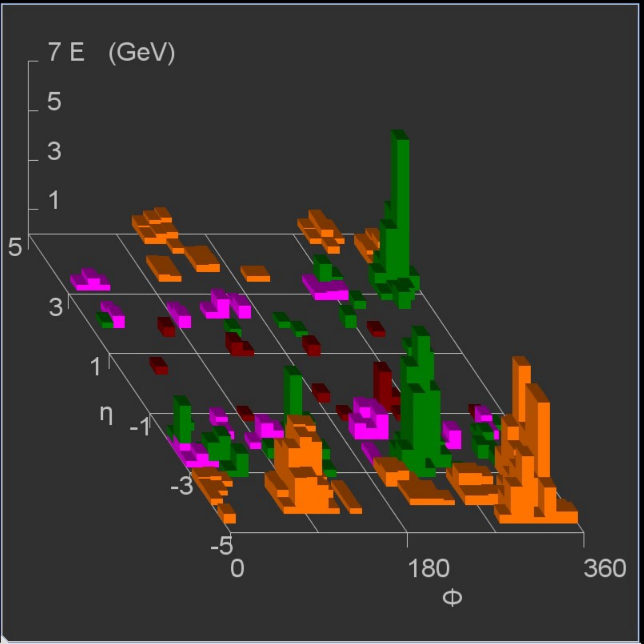
2009-11-21, 00:17 CET

Run 140370, Event 2780

A projection of a "Beam Halo" event showing tracks in the Muon Spectrometer.

Candidate Collision Event





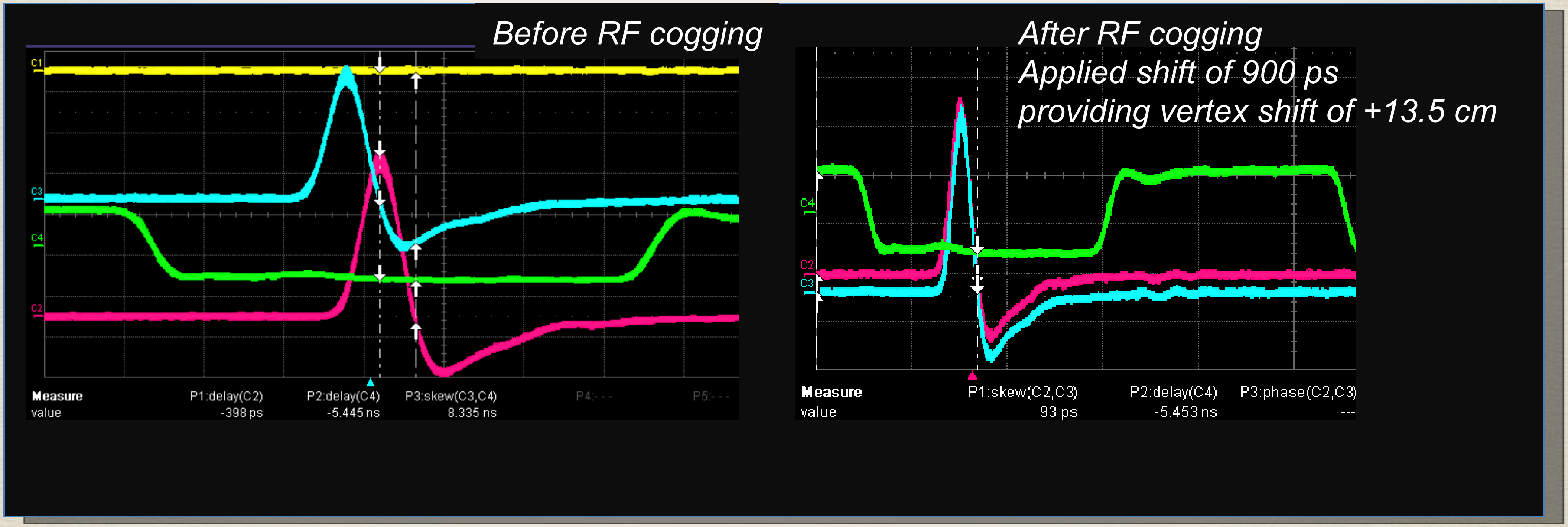
ATLAS
EXPERIMENT

2009-11-23, 14:22 CET
Run 140541, Event 171897

http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Understanding accelerator operation – feedback to LHC

- The ATLAS beam pickups showed a phase inconsistency of 900 ps causing the primary vertex to be shifted by –13.5 cm in *z*
- Based on this information, at around 14:50, the LHC operators performed an RF cogging to correct the *z* positioning of the beam spot at IP1



Before RF cogging

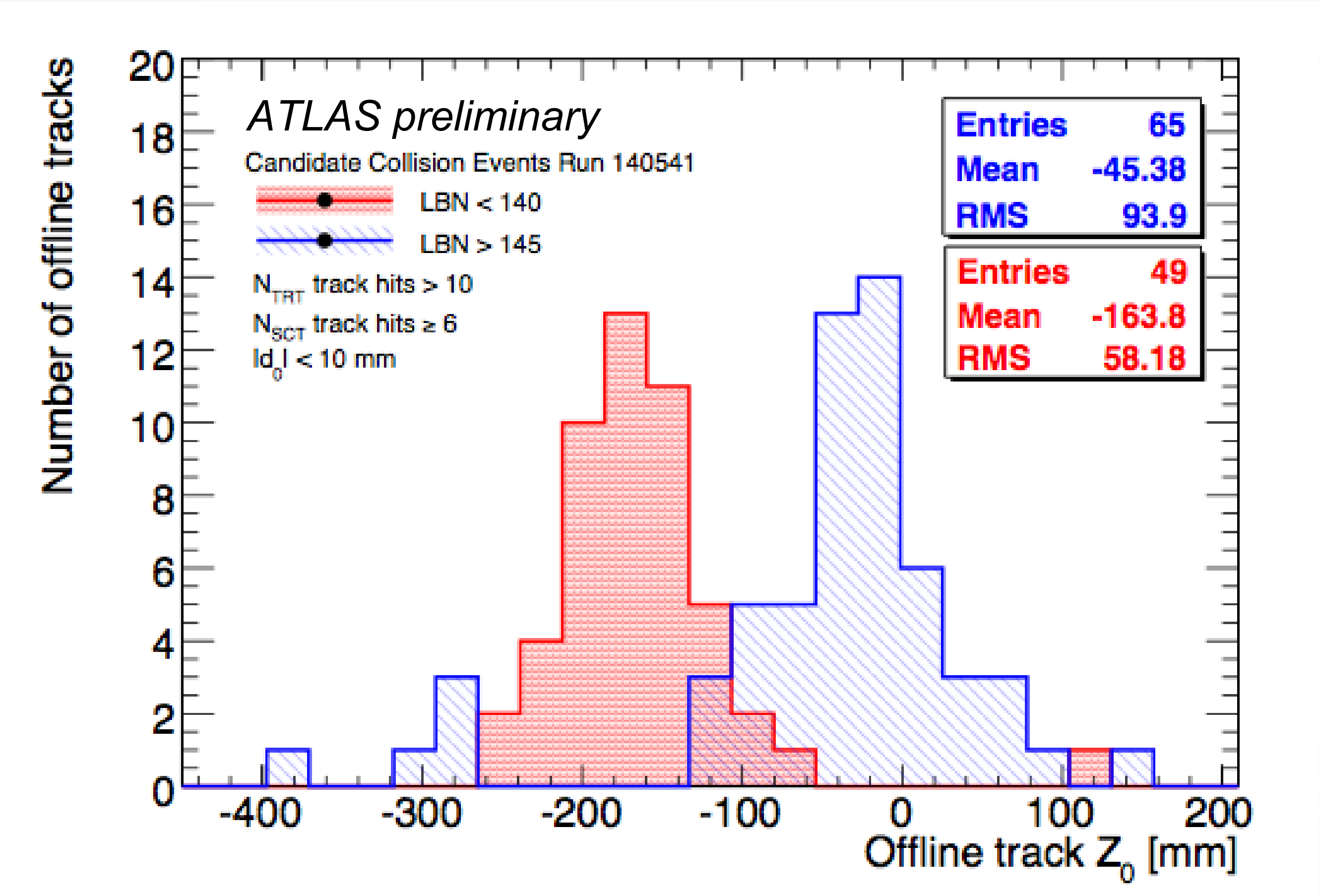
After RF cogging
Applied shift of 900 ps
providing vertex shift of +13.5 cm

Beam pickup scope shots, beam 1 & 2

Bunches stable within 20 ps (RMS) !

Understanding accelerator operation – offline analysis

- ATLAS has taken data before and after the RF cogging
- Must observe shift in $z_0$of tracks if indeed we select collision events!



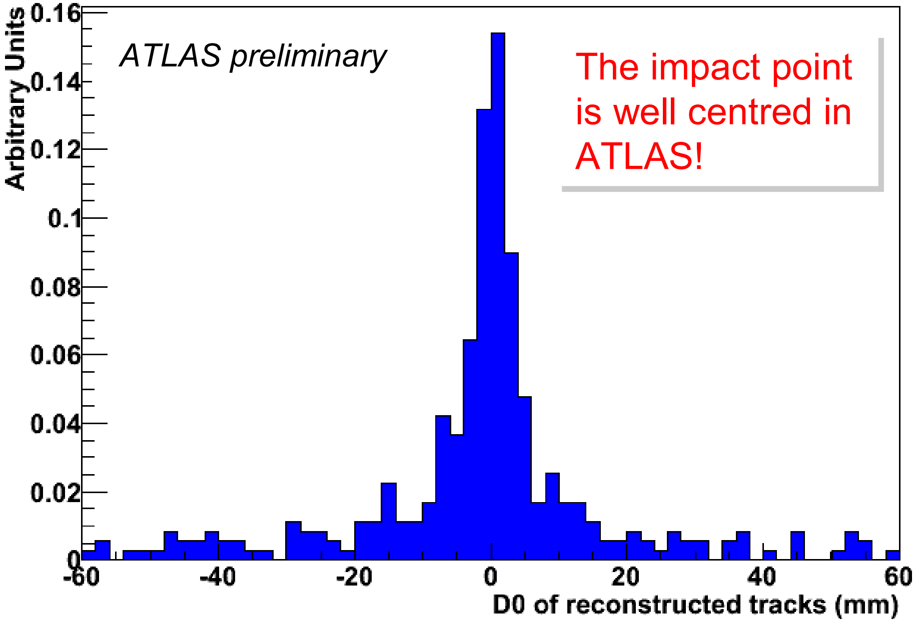
Track z_0 distribution of collision candidate events taken **before** and **after** RF cogging

Observed shift: +12 cm

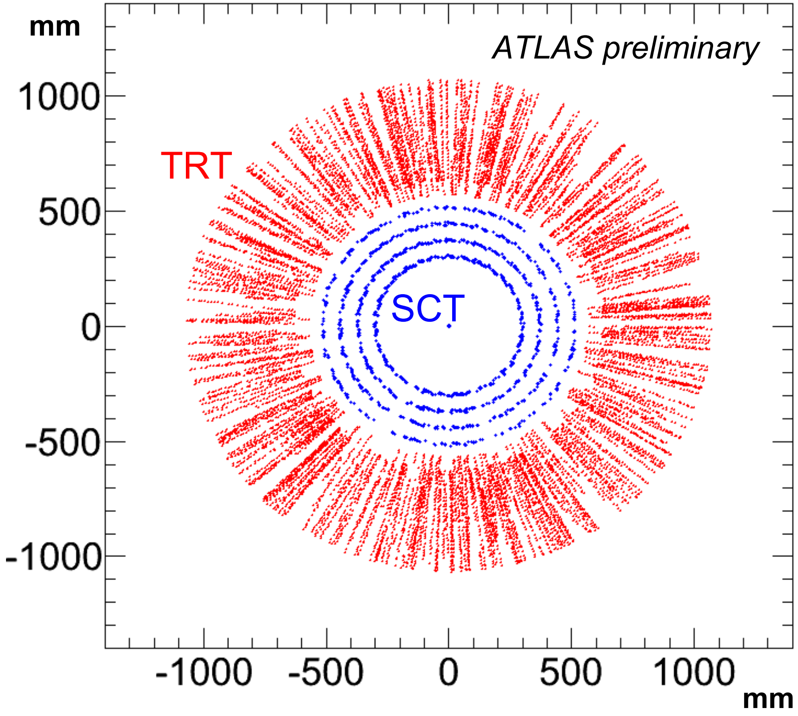
Very early days

Tracking(challenging w/o Pixel, limited SCT and solenoid field off!)

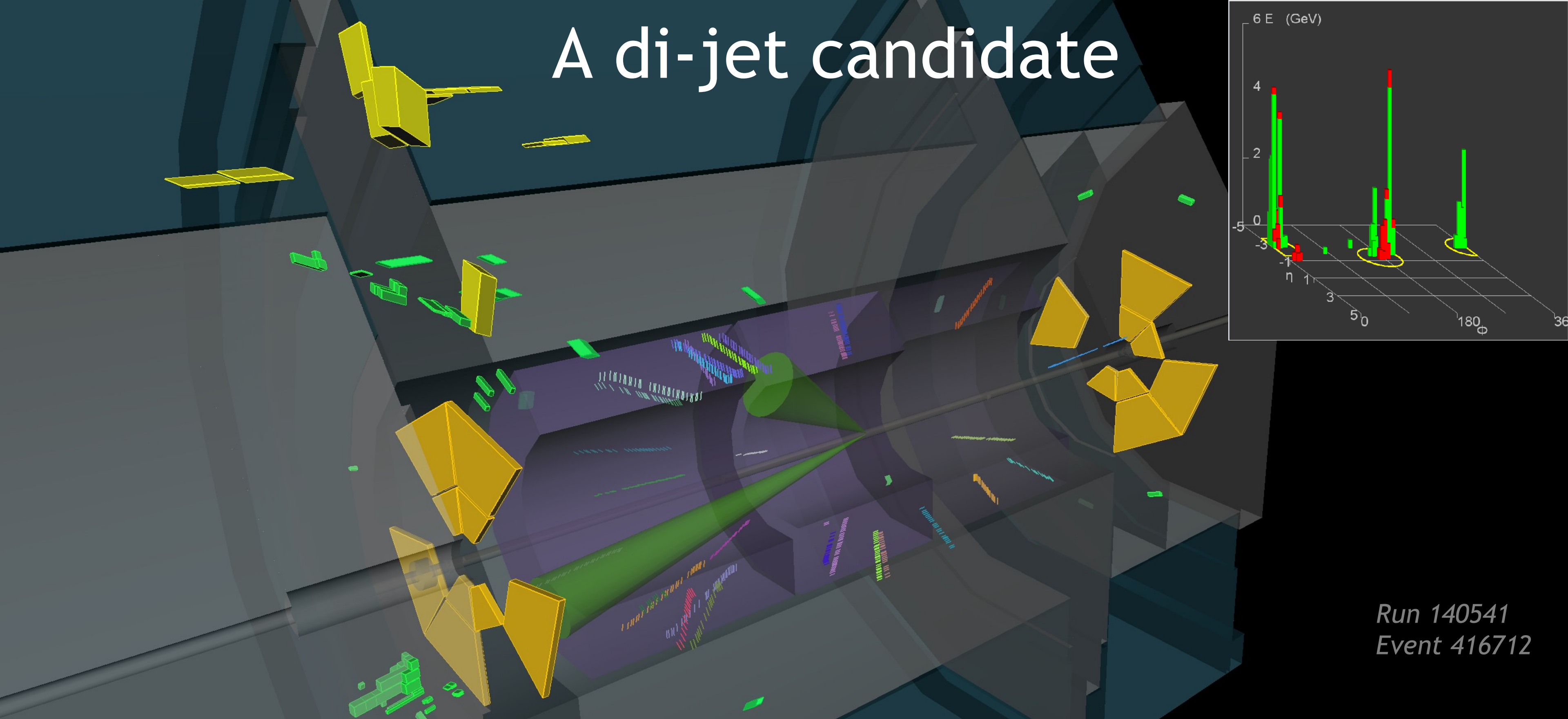
- Without solenoid field no separation of tracks by momenta
- Fit impact parameter in a “silver-plated” sample with SCT >= 20 V and number of SCT hits >= 6 (46 events)



Scatter plot of hits on tracks (barrel, 46 events)



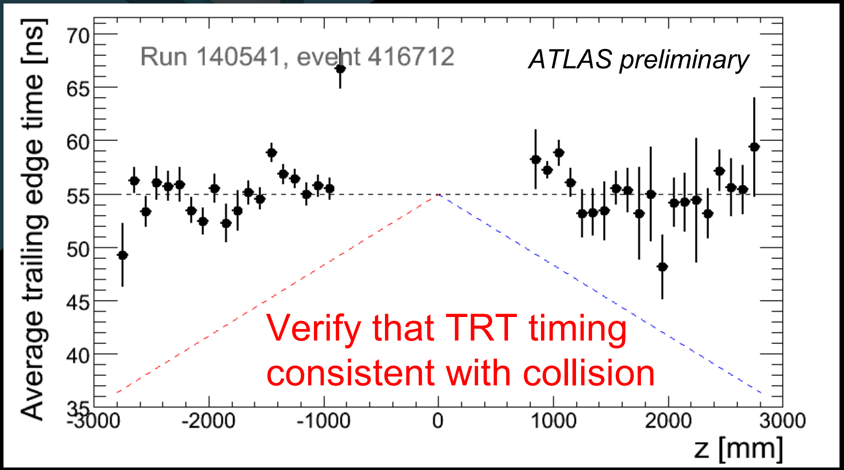
A di-jet candidate



Run 140541
Event 416712

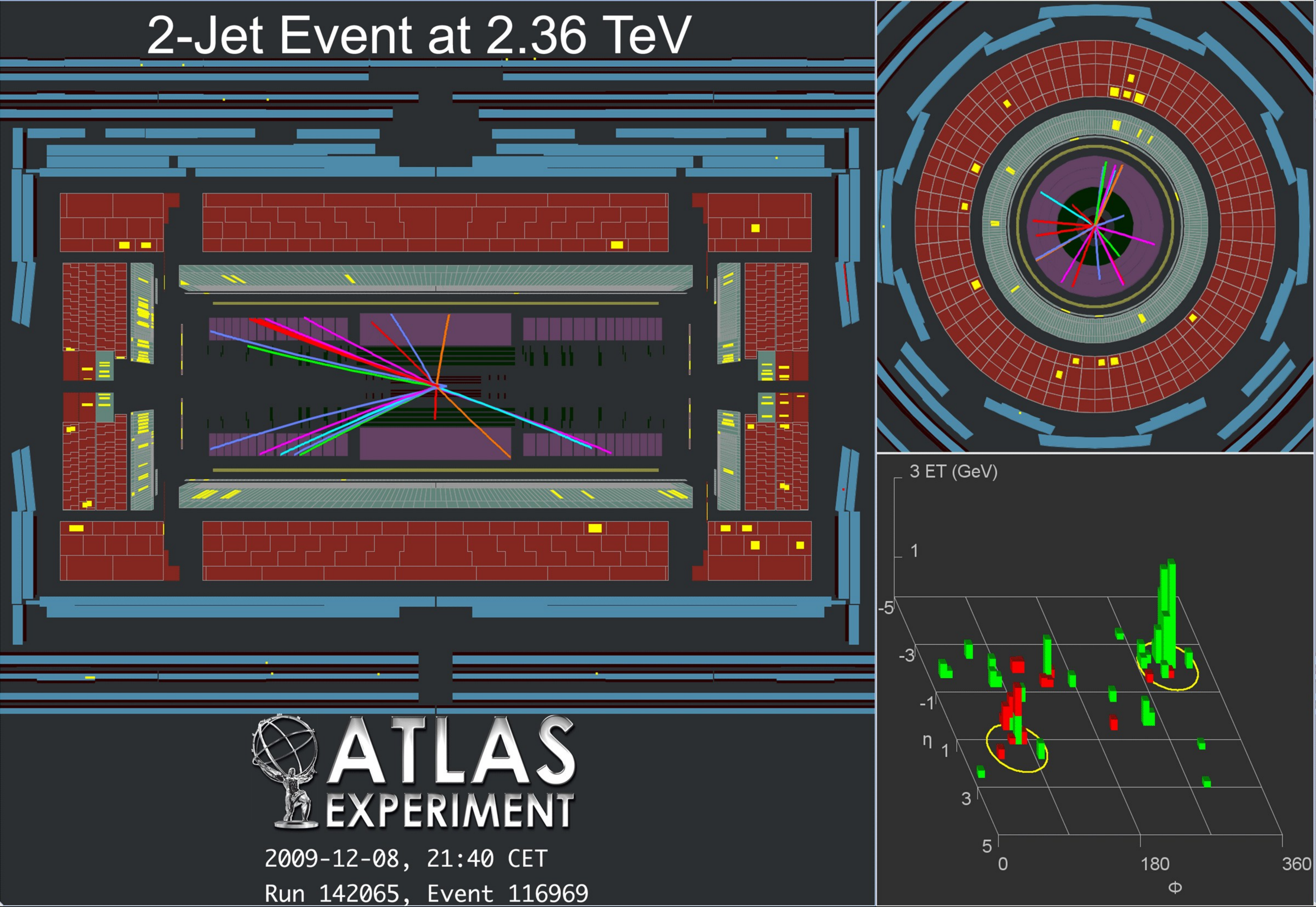
Two jets back-to-back in ϕ, both with (uncalibrated) E_T ~ 10 GeV,
η of –1.3 and –2.5,
~ no missing E_T

Triggered by MBTS A/B in time, several hits
Also triggered by L1Calo EM3



Verify that TRT timing consistent with collision

2-Jet Event at 2.36 TeV

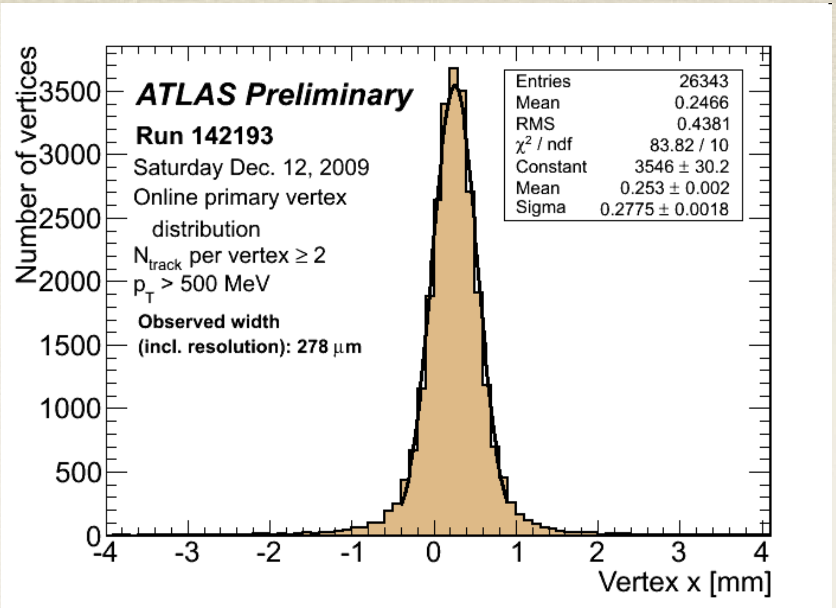


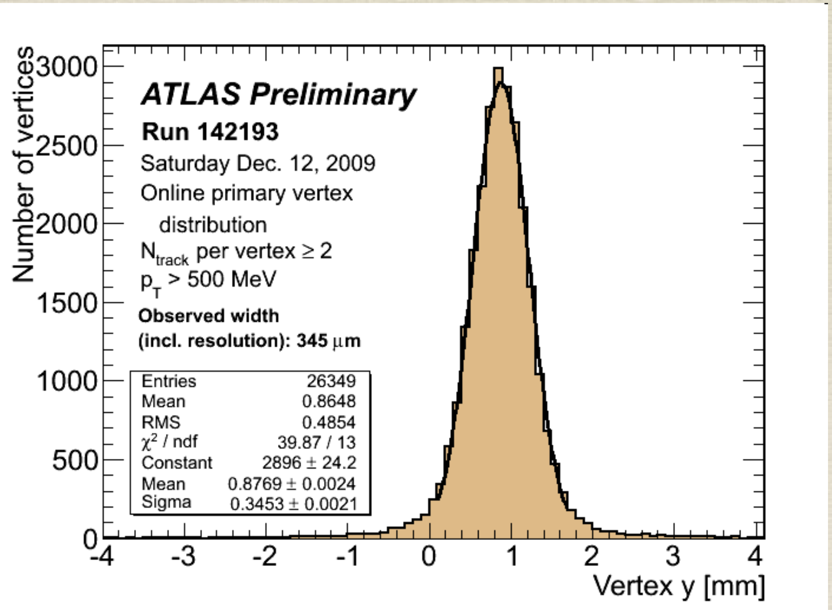
ATLAS EXPERIMENT

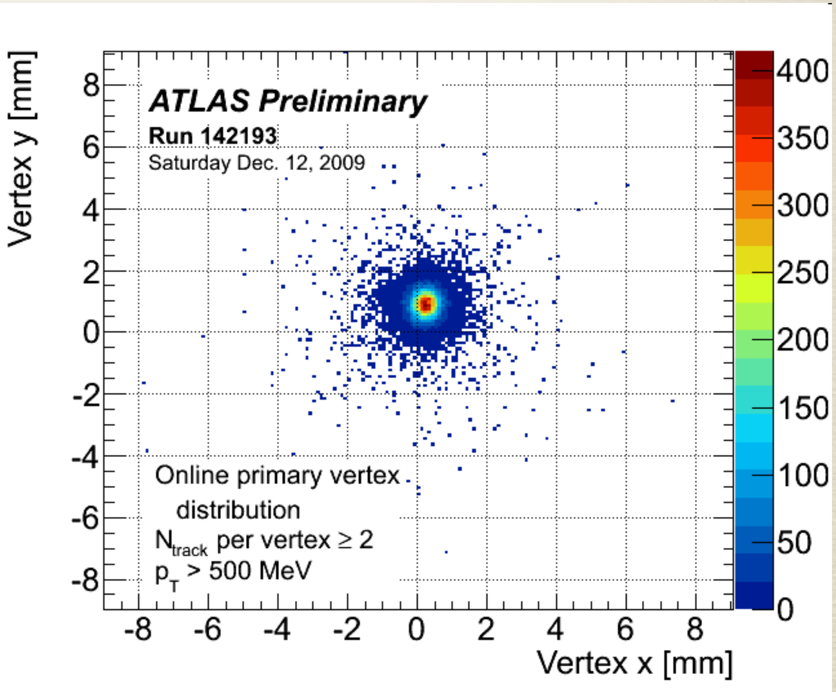
2009-12-08, 21:40 CET

Run 142065, Event 116969

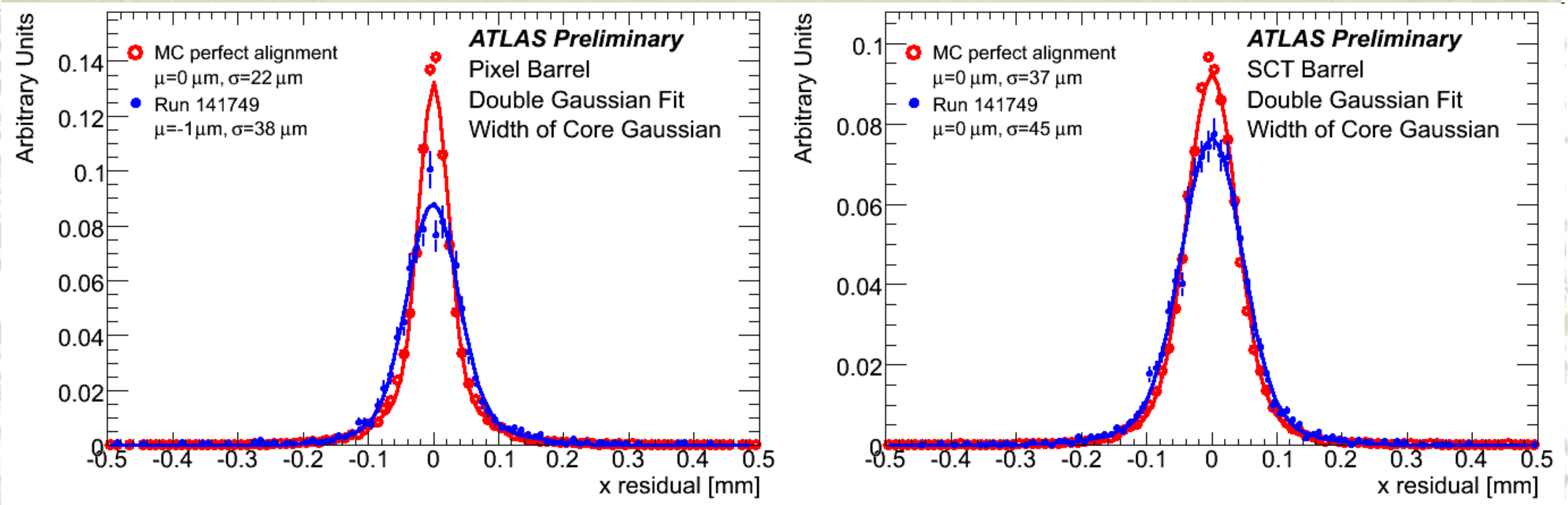
Display of a 2-jet candidate with uncalibrated transverse energies of 23 GeV and 16 GeV, and pseudo-rapidities of -2.1 and 1.4, respectively.





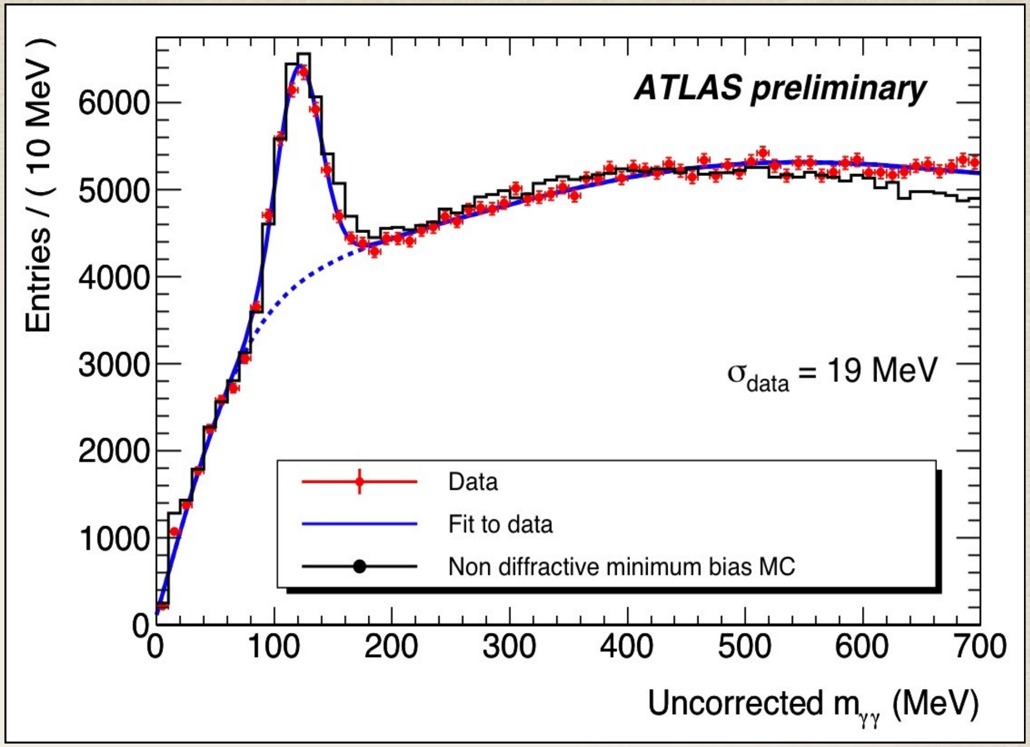


Beam position is monitored OnLine within the L2 HLT algorithms.
BS size ~250 μm



- Silicon alignment obtained from analysis of cosmic events works surprisingly well for the collision tracks.
- Note: cosmic muon illumination was very poor in the horizontal direction!
- First attempts to realign the entire Inner Detector with collision data are now underway. End-cap disk alignment has already marked a spectacular improvement.

$\pi^0 \rightarrow \gamma\gamma$



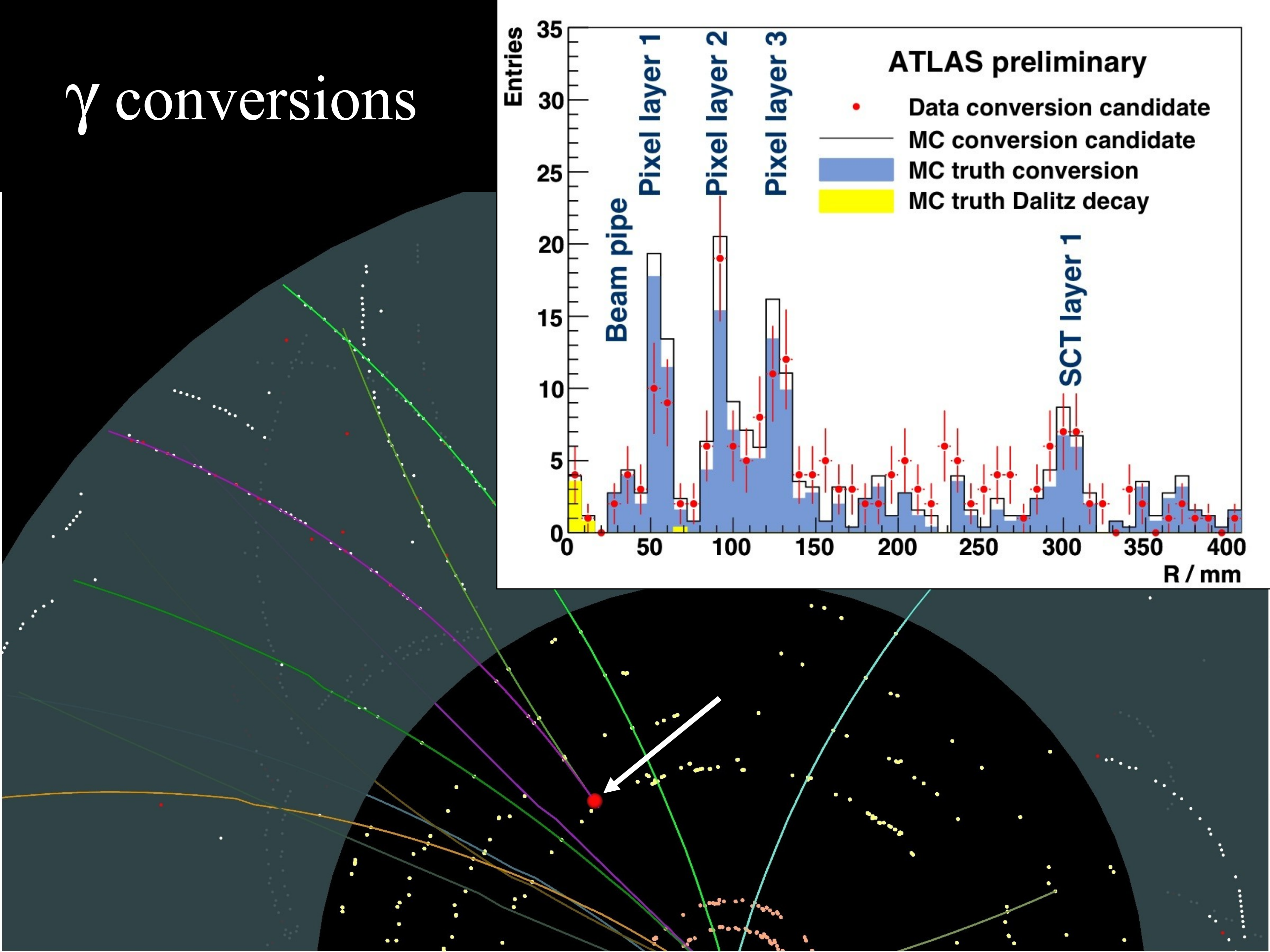
The analysis is based on EM topocluster (with 4σ above noise for the seed, 3σ for the seed neighbour and 0σ for the next neighbour).

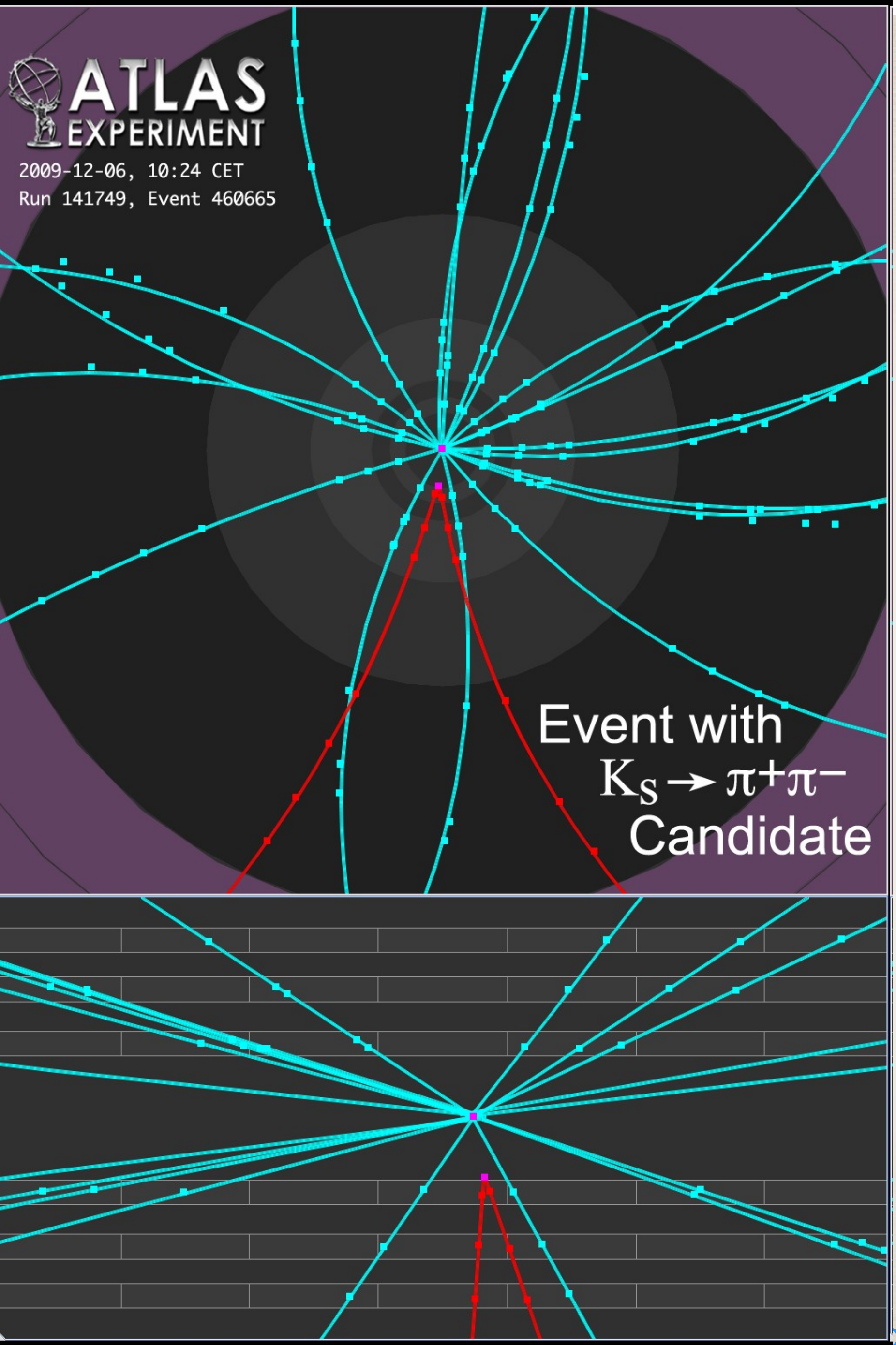
π^0 selection cuts :

- E_t of each cluster > 300 MeV
- E_t of π^0 candidate > 900 MeV
- Shower shapes compatible with photons

All combinatorial pairing are included in the distribution. The distribution is normalized to the number of entries. The cells are only calibrated at the electromagnetic energy scale (no dead material correction applied).

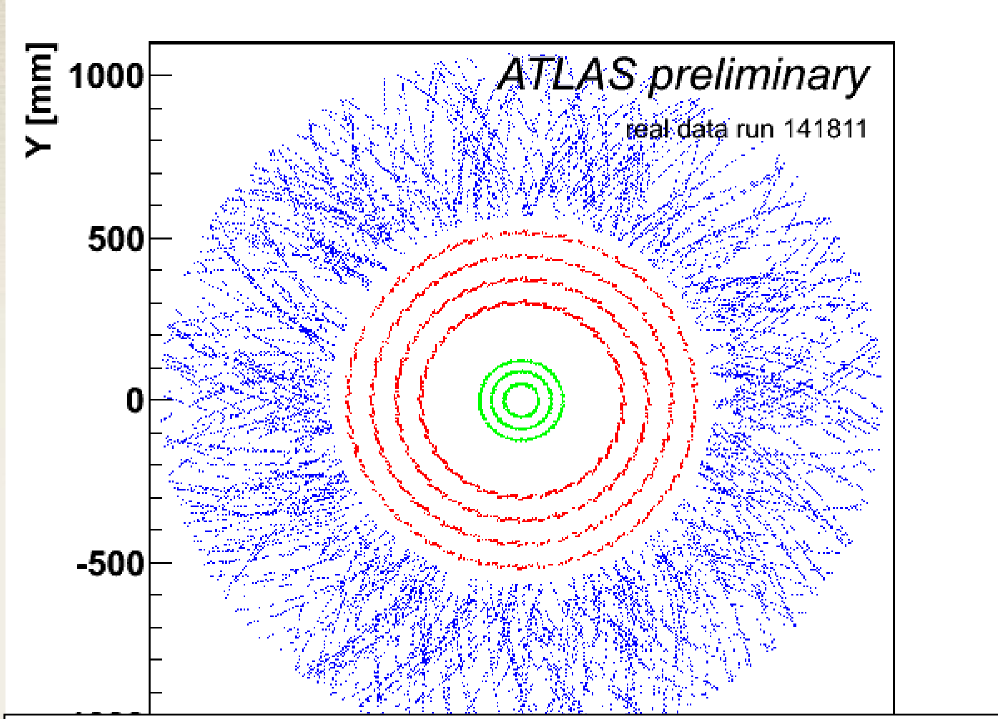
γ conversions

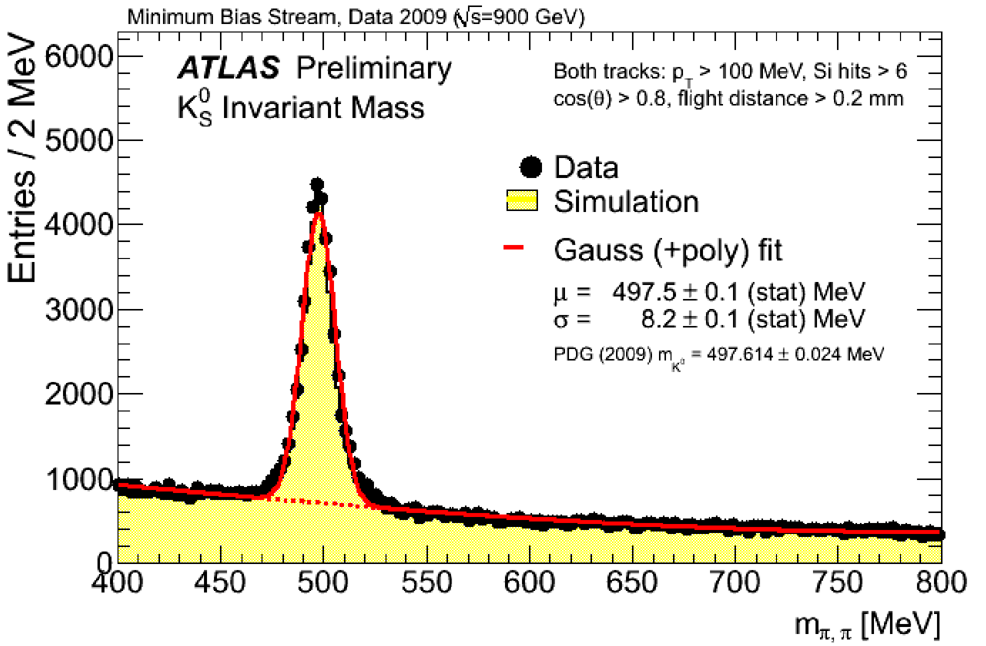




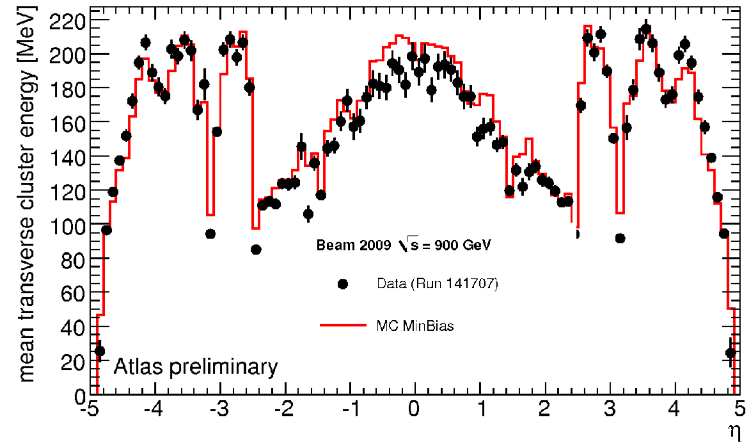
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

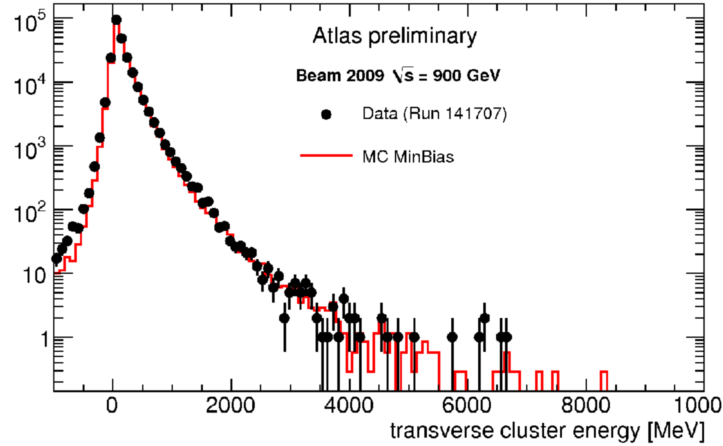
Scatter Plot of Hits on Tracks

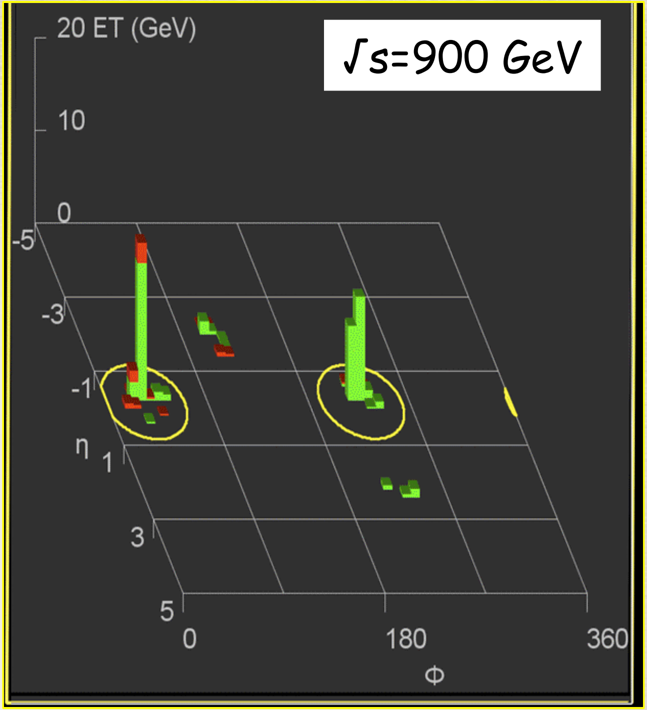


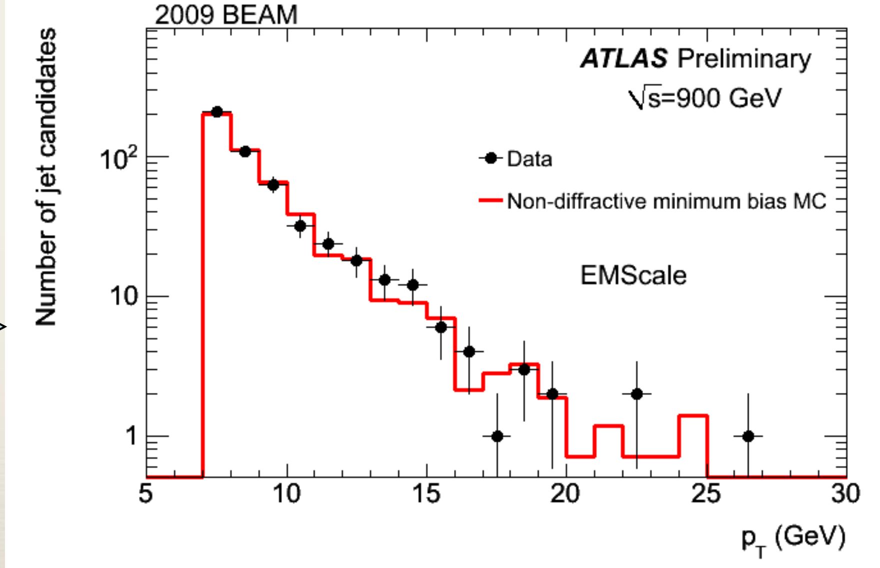


Jets







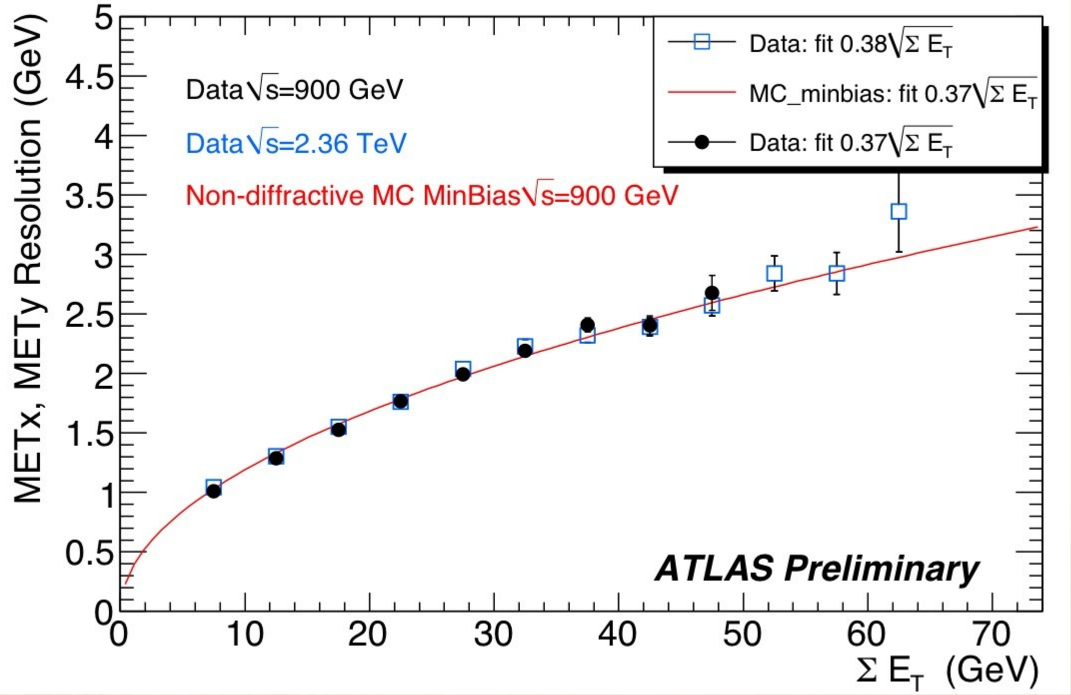


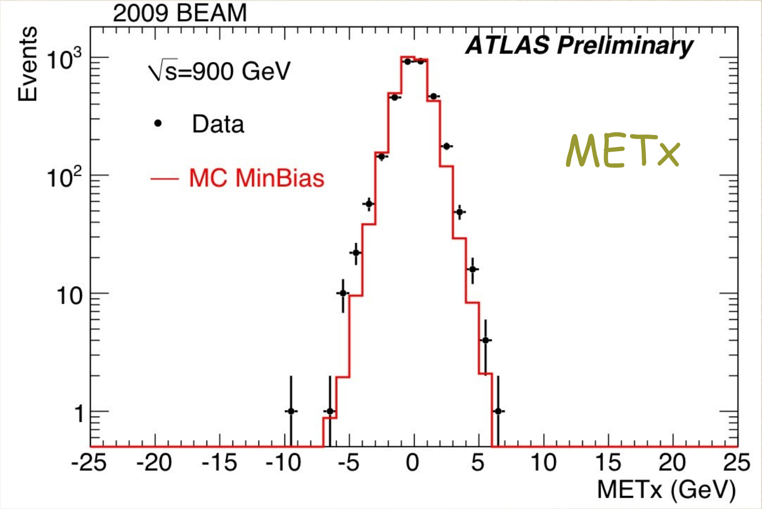
Only cells in topological clusters are used. Minimum bias trigger.
No calibration is applied (em-scale).

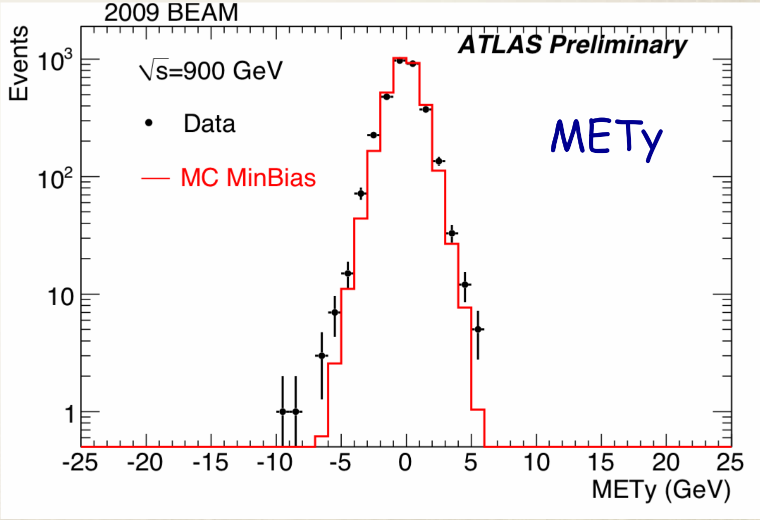
Missing transverse energy

(essential for SUSY searches!)

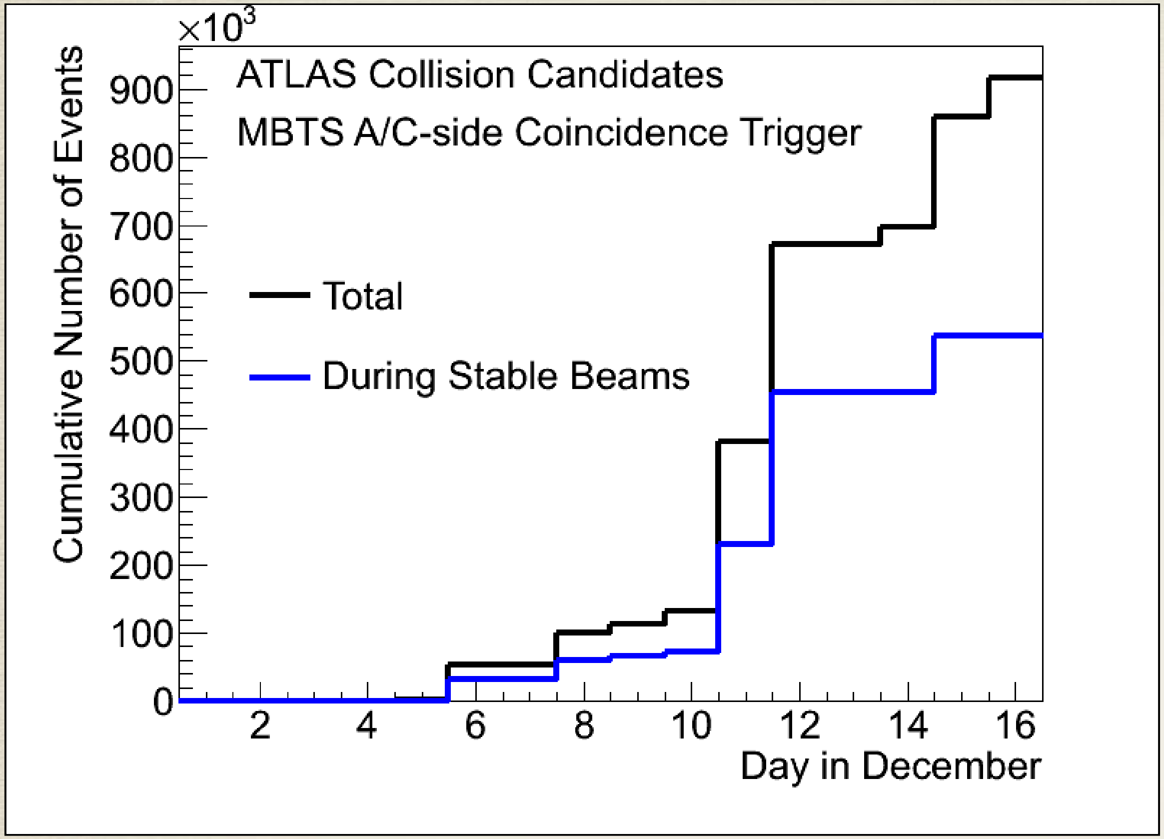
- Sensitive to calorimeter performance (noise, coherent noise, dead cells, mis-calibrations, cracks, etc.) and backgrounds from cosmics, beams, …
- Measurement over full calorimeter coverage (360⁰ in φ, |η| < 5, ~ 200000 cells)







Statistics of collision events collected to date



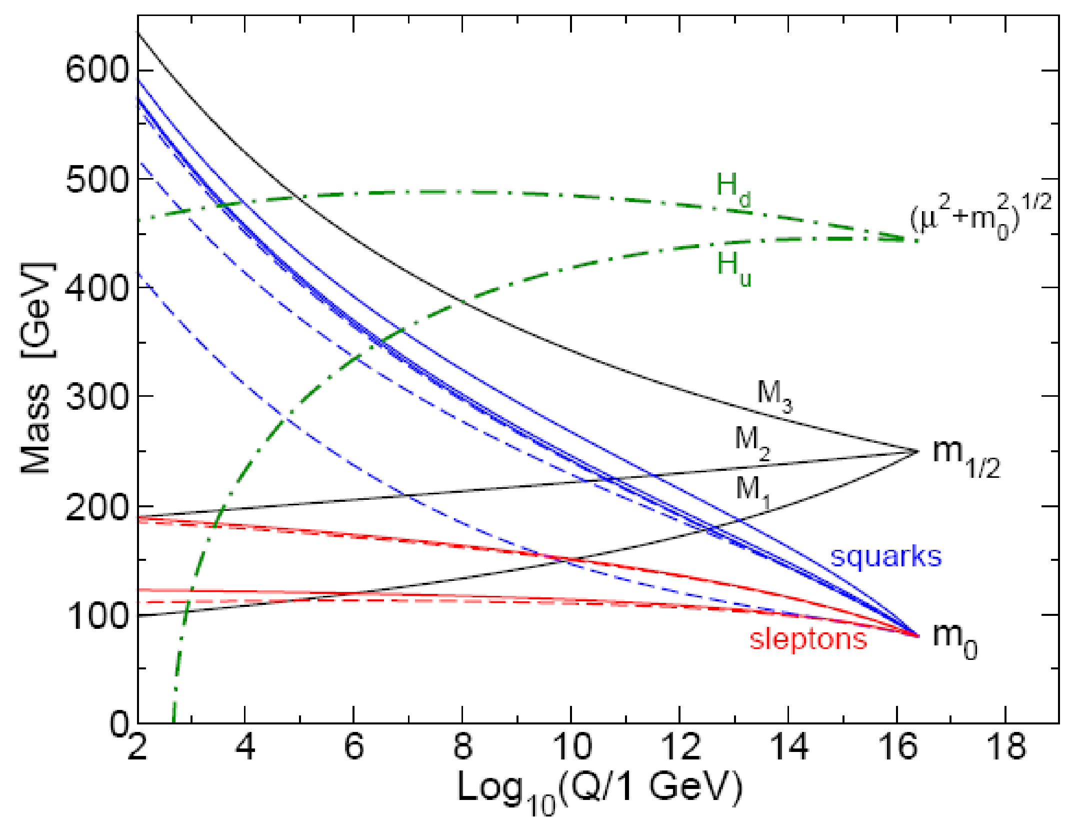
≈ 34k (≈ 1 μb^{-1}) events at the record $\sqrt{s}=2.36$ TeV

Average data-taking efficiency: ~ 90%

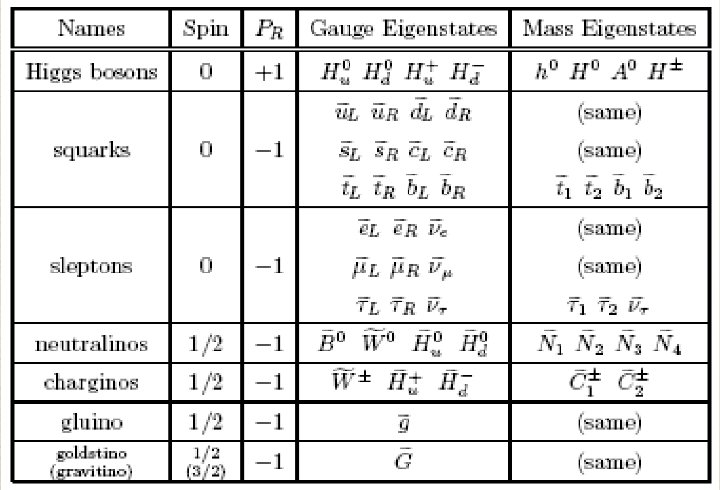
- ☐ LHC stopped for the Christmas shut-down on 16/12
- ☐ Restart planned for mid-February
- ☐ 2010 goal: 3.5TeV on 3.5TeV (+?), Lumi<10^{32}, intL~100pb^{-1}

Thank you

BACKUP SLIDES

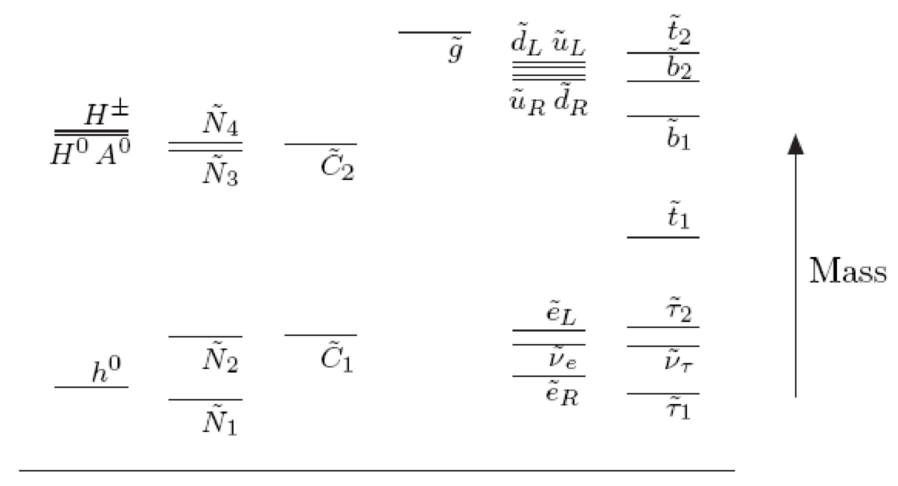


RG evolution of scalar and gaugino masses in a typical SUGRA



Names	Spin	P_R	Gauge Eigenstates	Mass Eigenstates
Higgs bosons	0	+1	$H_u^0\ H_d^0\ H_u^+\ H_d^-$	$h^0\ H^0\ A^0\ H^\pm$
squarks	0	−1	$\tilde{u}_L\ \tilde{u}_R\ \tilde{d}_L\ \tilde{d}_R$ $\tilde{s}_L\ \tilde{s}_R\ \tilde{c}_L\ \tilde{c}_R$ $\tilde{t}_L\ \tilde{t}_R\ \tilde{b}_L\ \tilde{b}_R$	(same) (same) $\tilde{t}_1\ \tilde{t}_2\ \tilde{b}_1\ \tilde{b}_2$
sleptons	0	−1	$\tilde{e}_L\ \tilde{e}_R\ \tilde{\nu}_e$ $\tilde{\mu}_L\ \tilde{\mu}_R\ \tilde{\nu}_\mu$ $\tilde{\tau}_L\ \tilde{\tau}_R\ \tilde{\nu}_\tau$	(same) (same) $\tilde{\tau}_1\ \tilde{\tau}_2\ \tilde{\nu}_\tau$
neutralinos	1/2	−1	$\tilde{B}^0\ \widetilde{W}^0\ \tilde{H}_u^0\ \tilde{H}_d^0$	$\tilde{N}_1\ \tilde{N}_2\ \tilde{N}_3\ \tilde{N}_4$
charginos	1/2	−1	$\widetilde{W}^\pm\ \tilde{H}_u^+\ \tilde{H}_d^-$	$\tilde{C}_1^\pm\ \tilde{C}_2^\pm$
gluino	1/2	−1	$\tilde{g}$	(same)
goldstino (gravitino)	1/2 (3/2)	−1	$\tilde{G}$	(same)

Typical sparticle mass spectrum of SUGRA



LSP (NLSP) annihilation mechanisms:

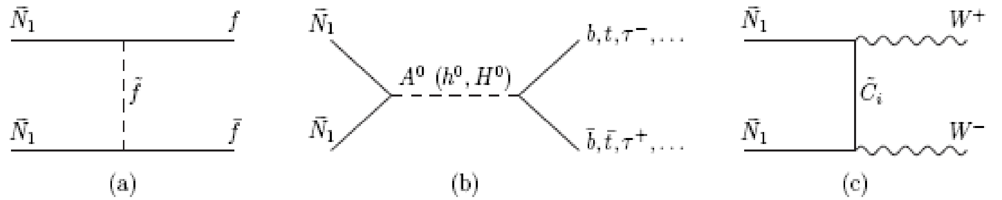


Figure 9.13: Contributions to the annihilation cross-section for neutralino dark matter LSPs from (a) t-channel slepton and squark exchange, (b) near-resonant annihilation through a Higgs boson (s-wave for A^0, and p-wave for h^0, H^0), and (c) t-channel chargino exchange.

a) bulk region
b) funnel region
c) focus point

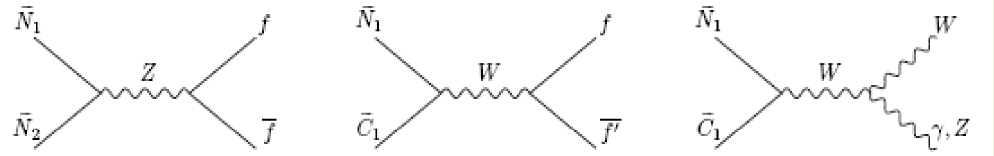


Figure 9.14: Some contributions to the co-annihilation of dark matter $\tilde{N}_1$ LSPs with slightly heavier $\tilde{N}_2$ and $\tilde{C}_1$. All three diagrams are particularly important if the LSP is higgsino-like, and the last two diagrams are important if the LSP is wino-like.

focus point

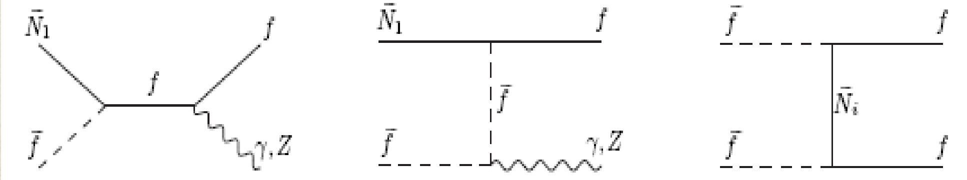


Figure 9.15: Some contributions to the co-annihilation of dark matter $\tilde{N}_1$ LSPs with slightly heavier sfermions, which in popular models are most plausibly staus (or perhaps top squarks).

sfermion co-annihilation

Simulation of SUSY signal and backgrounds

- ttbar: MC@NLO + HERWIG for fragmentation
- W+jets, Z+jets: ALPGEN + HERWIG + NNLO k-factors
- N<4 jets PYTHIA for W & Z backgrounds
- WW, ZZ, WZ: HERWIG + NLO k-factors
-
- SUSY benchmark points: PROSPINO 2.0.6 + CTEQ6M
- SUSY scans: ISAJET 7.75

SUSY scan strategy

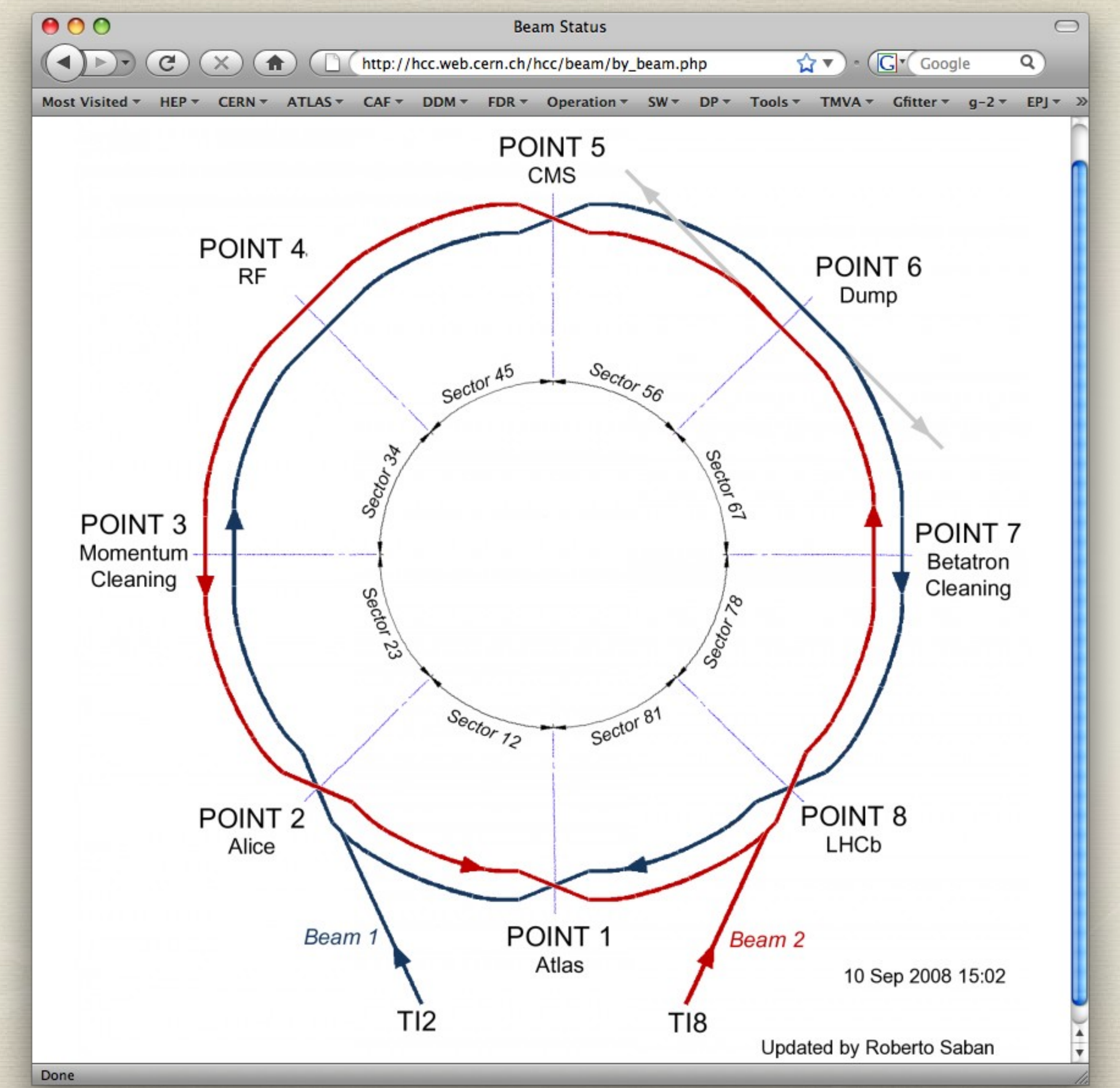
- Scan of the parameter space using fast detector simulation (ATLFAST)
- Only direct exclusions from LEP&Tevatron are considered (not cosmological!)
- Pile-up not included
- Signal uses LO HERWIG without further corrections (CONSERVATIVE!)
- Background from the full simulation + assumption about the DD methods (50% QCD, 20% W, Z & top) – NLO Monte Carlo
- Separate grids for mSUGRA tanβ=10, tanβ=50, GMSB, NUHM...
- “Multiple comparisons” correction to significance is always applied.
- Significance (Z$_n$) is given by the convolution of Poisson distribution (statistical fluctuation) and a Gaussian (systematic uncertainty):

$$Z_n = \sqrt{2}\,\mathrm{erf}^{-1}(1-2\mathrm{p})$$

with

$$p = A \int_0^{\infty} db\, G(b; N_b, \delta N_b) \sum_{i=N_{\mathrm{data}}}^{\infty} \frac{e^{-b} b^i}{i!},$$

normalisation


Beam Status
http://hcc.web.cern.ch/hcc/beam/by_beam.php
Google
Most Visited
HEP
CERN
ATLAS
CAF
DDM
FDR
Operation
SW
DP
Tools
TMVA
Gfitter
g-2
EPJ
POINT 5
CMS
POINT 4
RF
POINT 6
Dump
POINT 3
Momentum
Cleaning
POINT 7
Betatron
Cleaning
POINT 2
Alice
POINT 8
LHCb
POINT 1
Atlas
Sector 45
Sector 56
Sector 34
Sector 67
Sector 23
Sector 78
Sector 12
Sector 81
Beam 1
Beam 2
TI2
TI8
10 Sep 2008 15:02
Updated by Roberto Saban
Done