Effects of misalignments on Z′ analysis, with the ATLAS experiment at LHC

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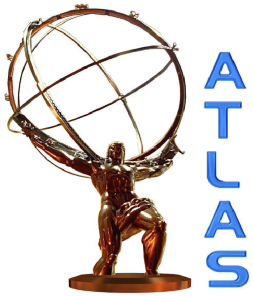
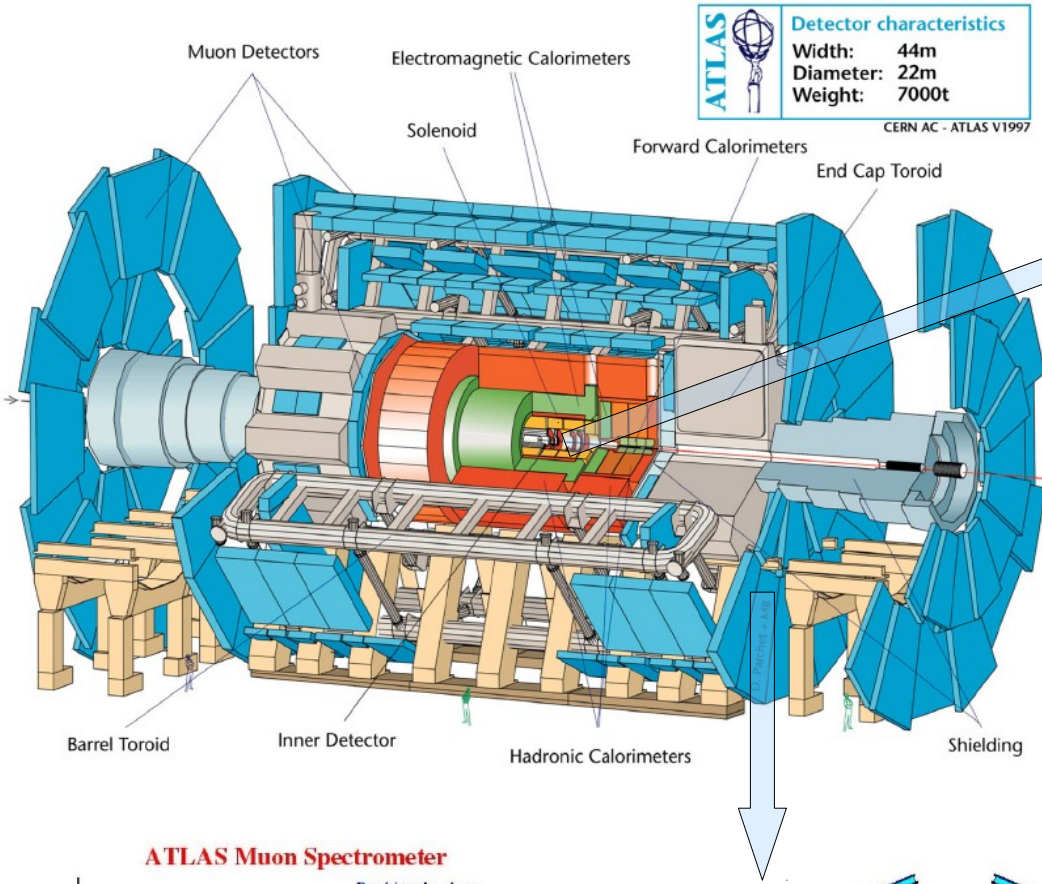
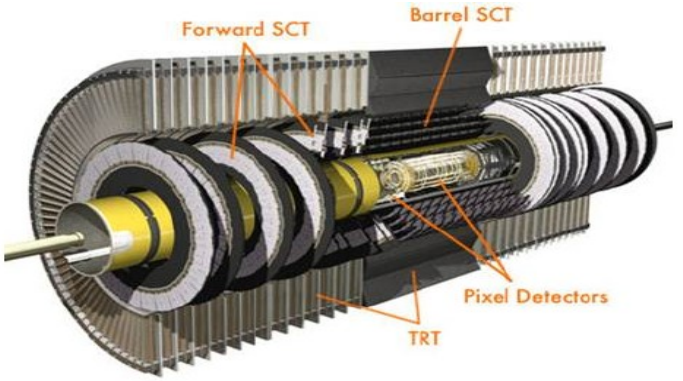


Summary

- The ATLAS experiment on LHC
- Z': actual exclusion limits
- Effects of misalignments
- ATLAS discovery potential
- Momentum-resolution with 7 TeV collisions
- Conclusions

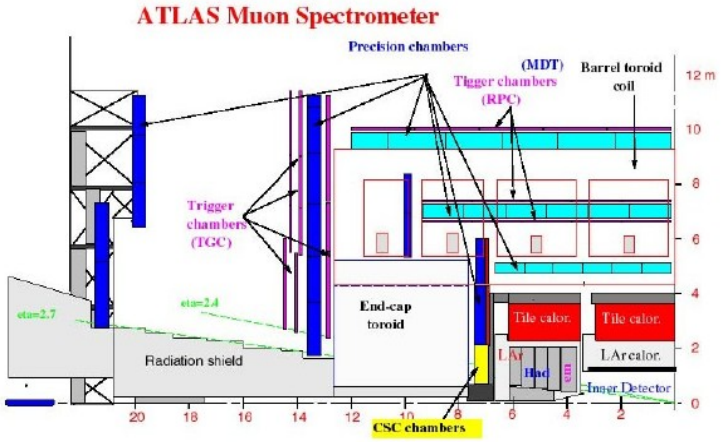
ATLAS Experiment

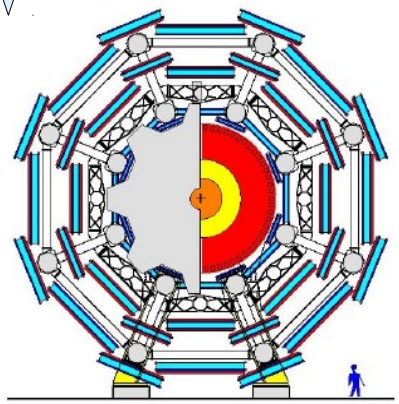


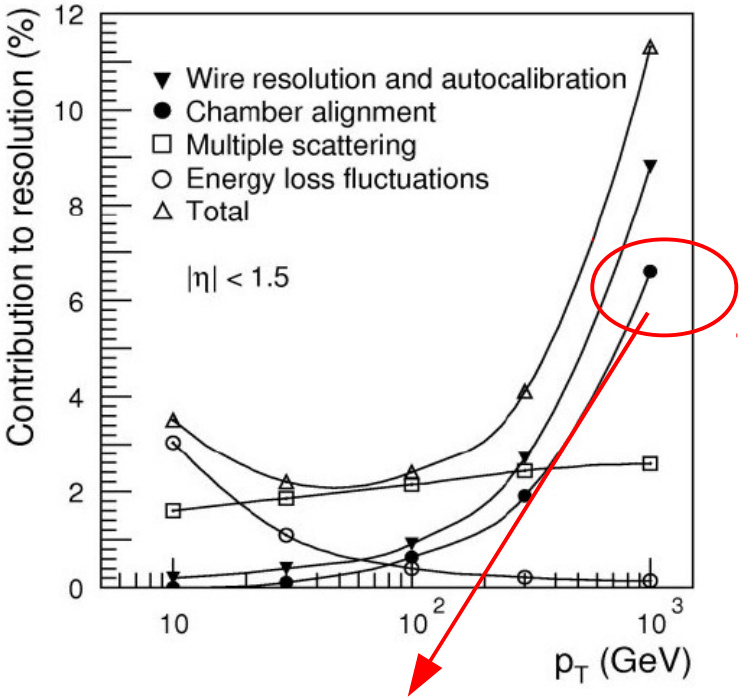


μ standalone → tracks reconstructed only on MS

μ combined → tracks reconstructed both on MS and ID







Alignment is very important at high p_T

Z': actual exclusion limits

Z' is a vectorial boson with mass of the order of TeV (or more)

- Sequential Standard Model (SSM)
- Models based on E_6 group
- …

	(u,d)	u^c	d^c	(ν,e)	ν^c	e^c
T_{3L}	(+1/2, -1/2)	0	0	(+1/2, -1/2)	0	0
Y	+1/6	-2/3	+1/3	-1/2	0	+1
B-L	+1/3	-1/3	-1/3	-1	+1	+1
$Q_{Z'}$	$1/6\tilde{g}_Y+1/3\tilde{g}_{BL}$	$-2/3\tilde{g}_Y-1/3\tilde{g}_{BL}$	$1/3\tilde{g}_Y-1/3\tilde{g}_{BL}$	$-1/2\tilde{g}_Y+\tilde{g}_{BL}$	$\tilde{g}_{BL}$	$\tilde{g}_Y+\tilde{g}_{BL}$

	$M_{Z'}$ (GeV)			
	EW	CDF	D0	LEPII
Z'_{SSM}	1403	1030	780	1787
Z'_{ψ}	147	878	650	481
Z'_{χ}	1141	892	640	673
Z'_{η}	427	904	680	434
Z'_{I}	1204	789	575	
Z'_{S}	1257	821		
Z'_{N}	623	861		
Z'_{LR}	998	630		804
Z'_{string}	1362			

EW → unitariety, CKM

CDF, D0 → $pp \rightarrow l^+l^-+X$

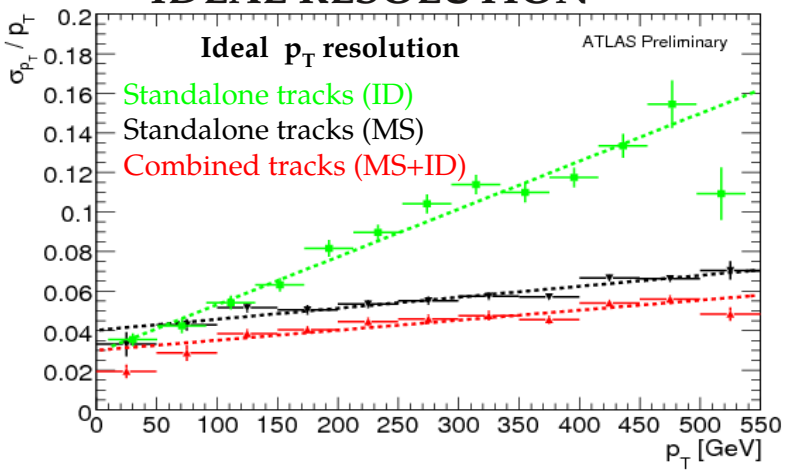
LEPII → $\sigma(e^+e^- \rightarrow ff)$

Effects of misalignments: MS

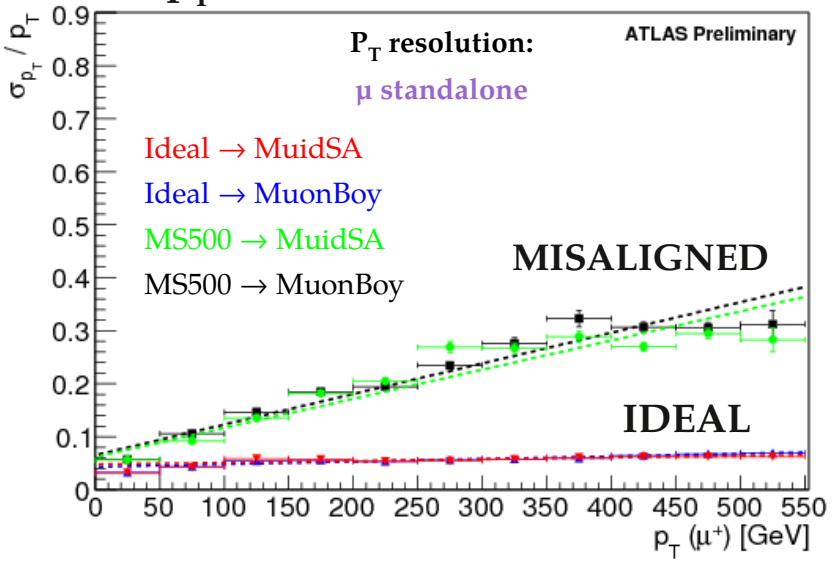
MS ⇒ misalignments of o(30-500 μm) on MS chambers (shifts and rotations)

sample MC Z' $\sqrt{s}=10$ TeV Selection: ⇒ $|\eta|<2.5$, $p_T>20$ GeV, trigger μ20

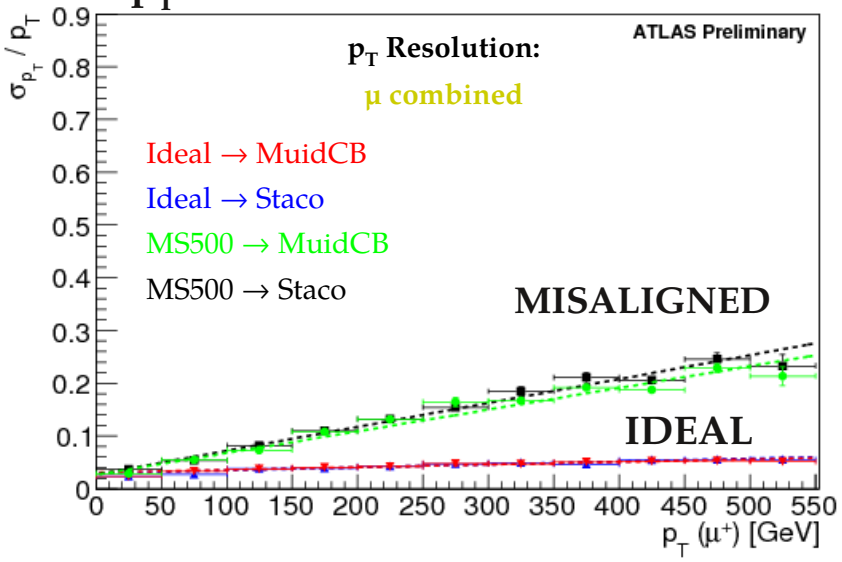
IDEAL RESOLUTION



p_T resolution: standalone tracks



p_T resolution: combined tracks

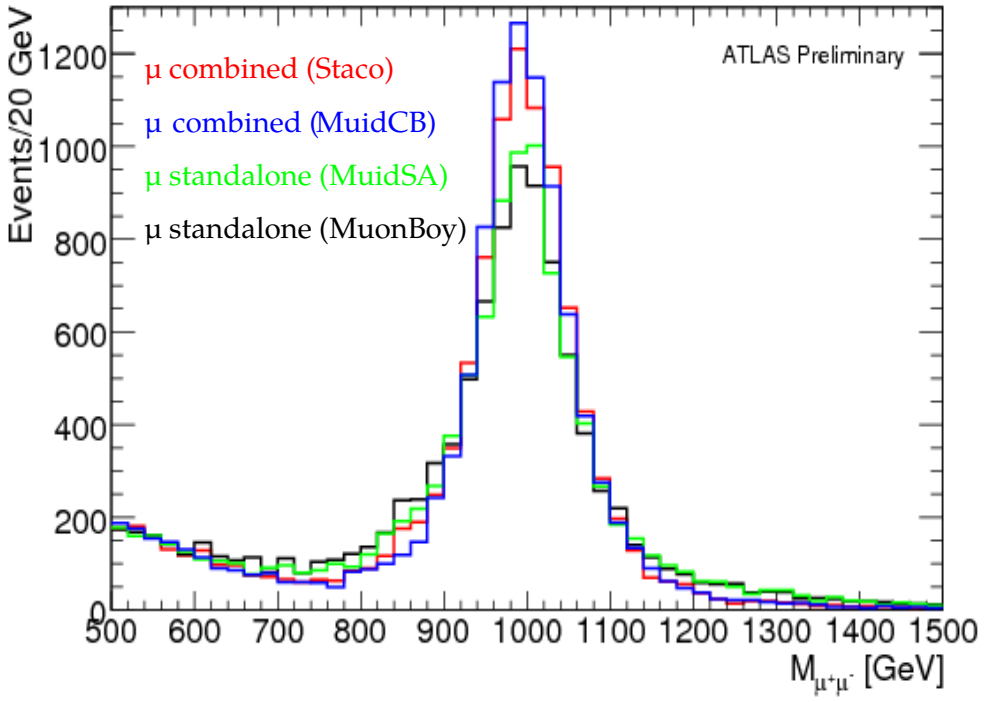


Misalignments of 500 μm on MS (**MS500**) ⇒

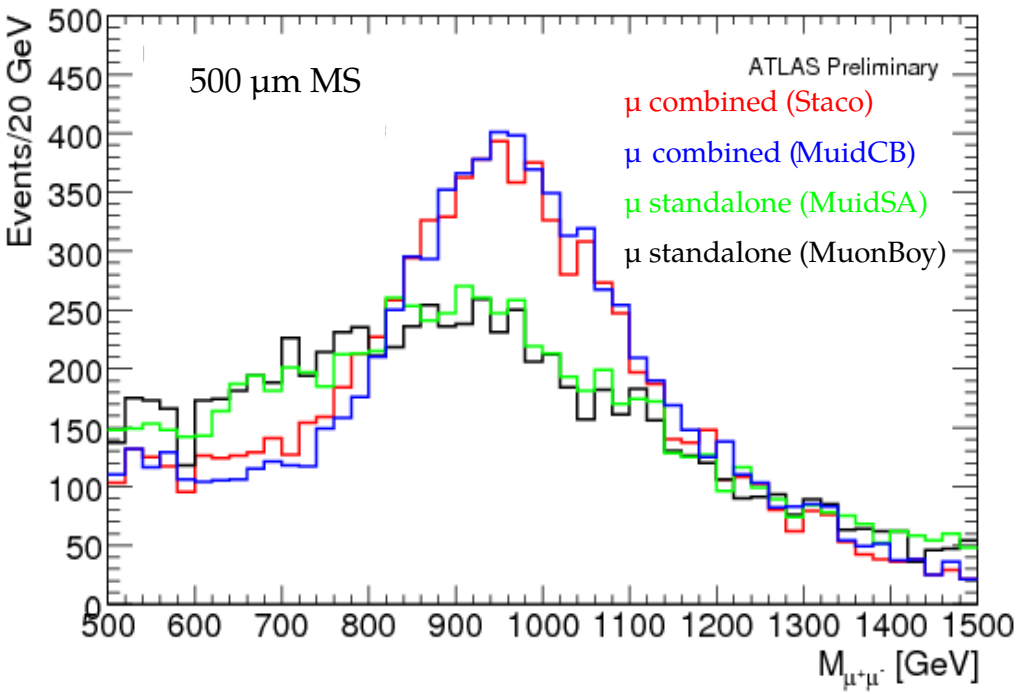
- **μ standalone** → resolution worsens considerably at about 500 GeV
- **μ combined** → part of the effect is recovered

Effects of misalignments: MS

IDEAL ALIGNMENT



MISALIGNMENTS ON MS



The deterioration of the resolution is reflected on invariant mass!

Effects of misalignments: ID

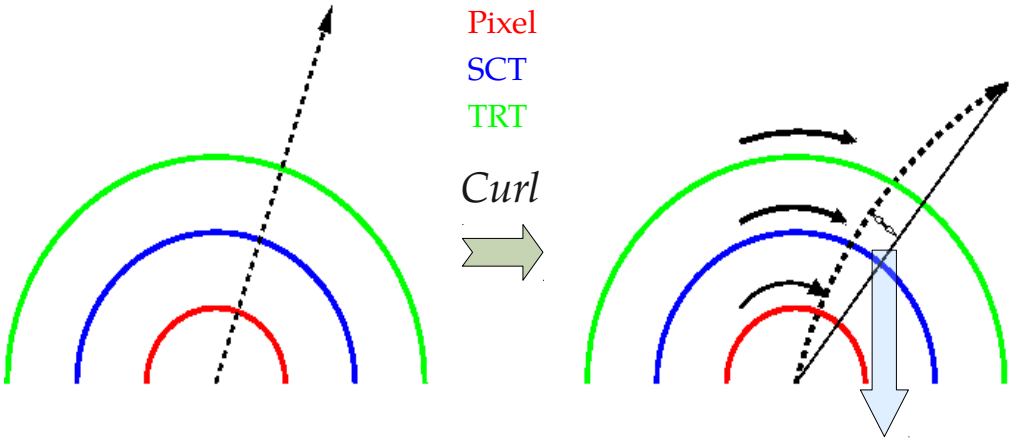
ID ⇒ Misalignments of o(40-200 μm)

⇒ *Curl Weak mode* → charge asymmetry

$$\Delta\phi = c_1 R + \frac{c_2}{R}$$

Leading to bias in curvature and thus reconstructed track transverse momentum

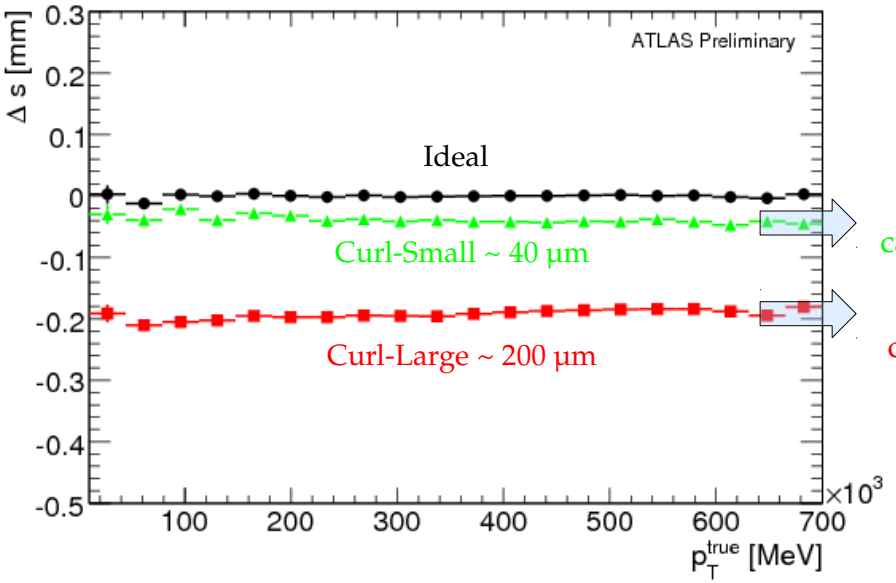
causing a Φ-dependent shift of the reconstructed perigee positions



A false sagitta is introduced

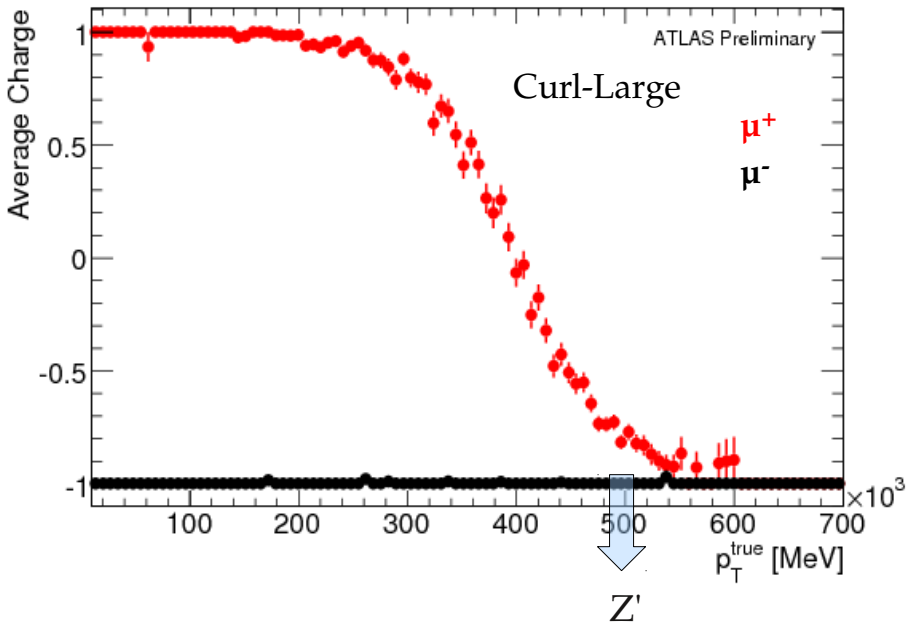
Curl-Large ⇒ before calibration

Curl-Small ⇒ After calibration



After calibration

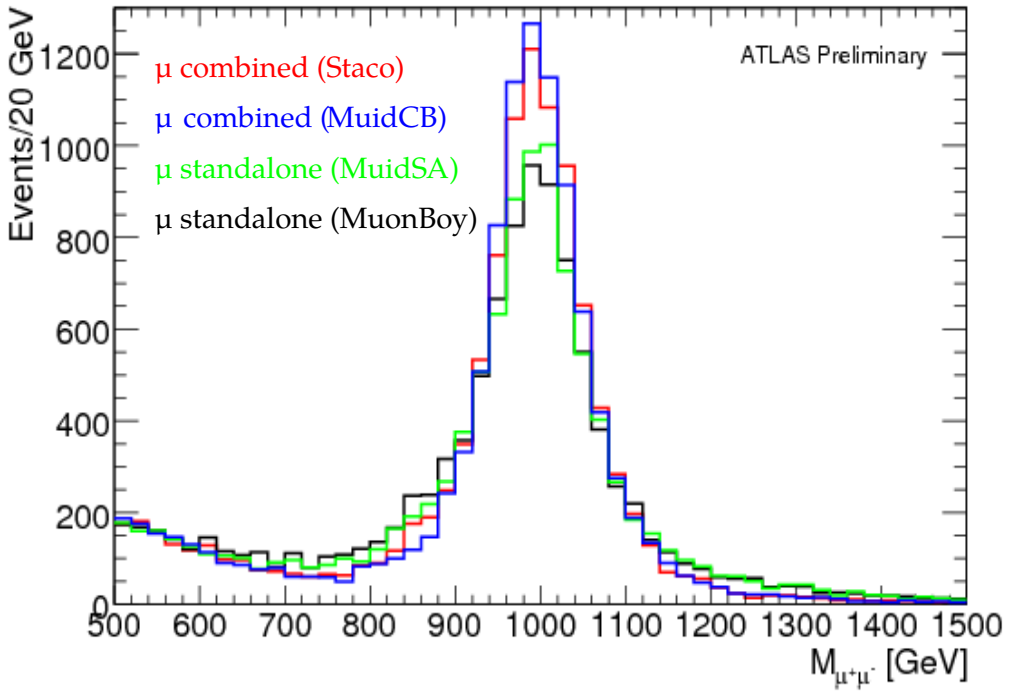
Before calibration



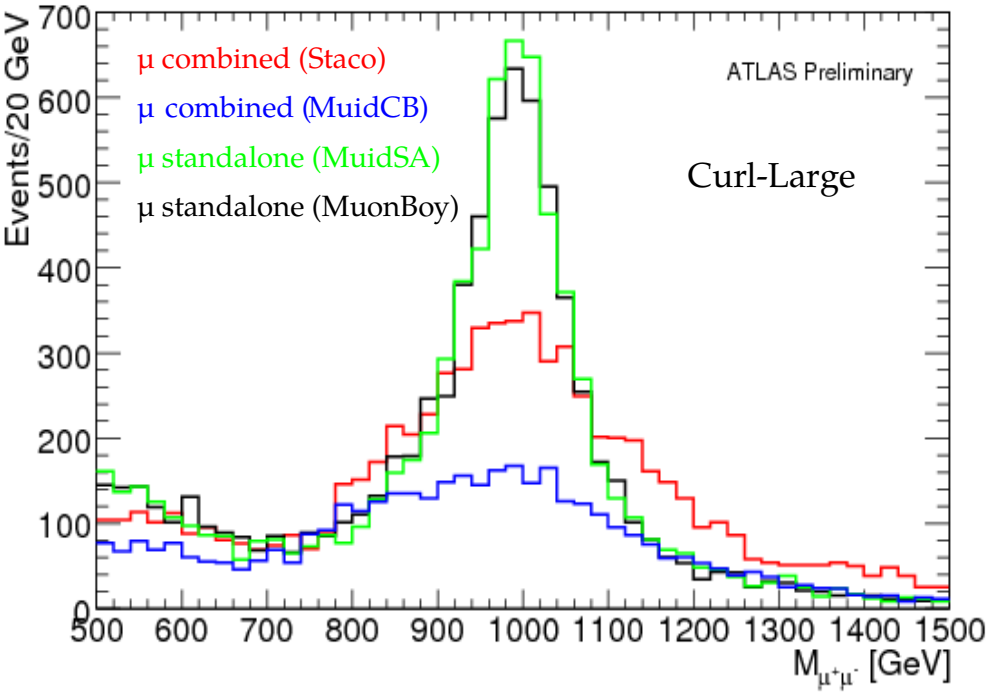
With alignment procedure, part of the effect is recovered

Effects of misalignments: ID

IDEAL ALIGNMENT

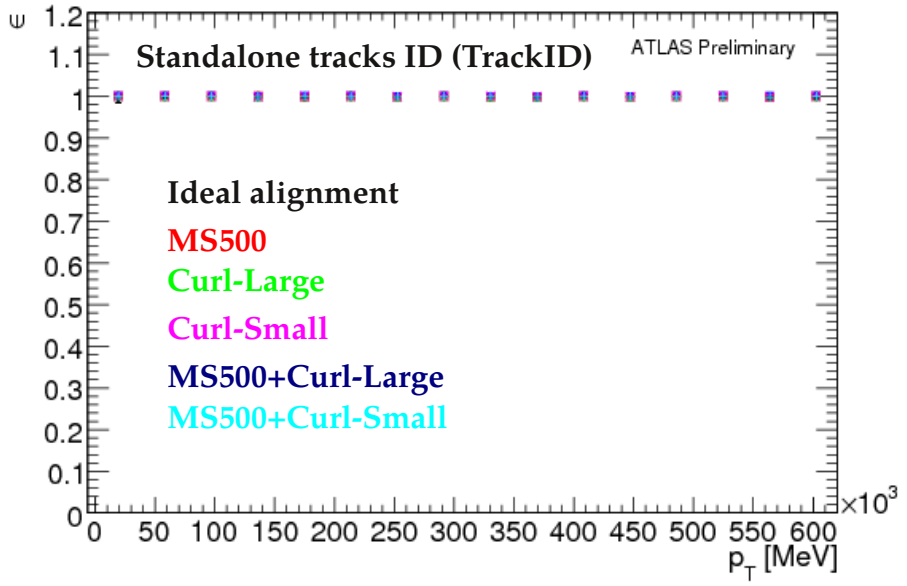


MISALIGNMENTS ON ID



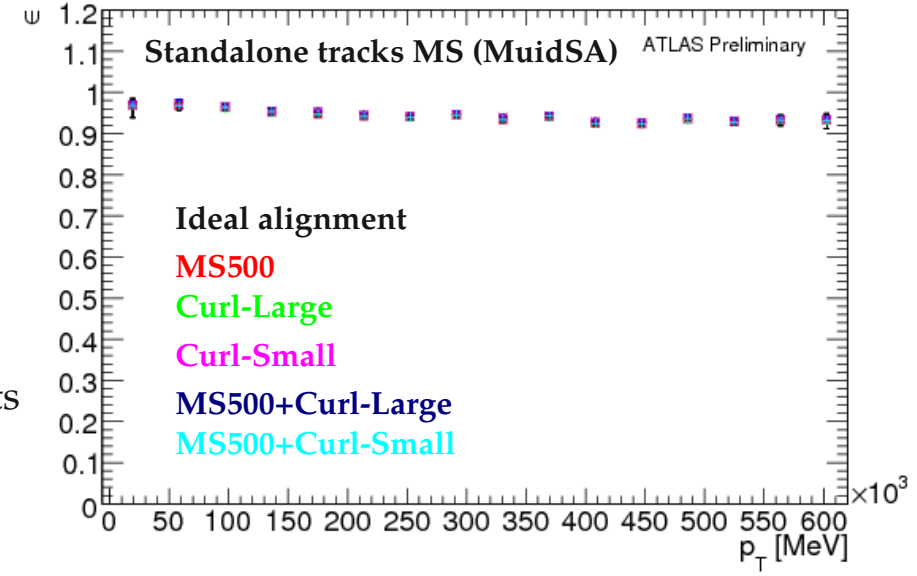
The strong *misalignment introduced by Curl-Large* geometry *is clearly visible* in the *invariant mass* spectrum for *combined muons*!

Effects of misalignments: tracking efficiency



Standalone efficiency

INSENSITIVE to misalignments

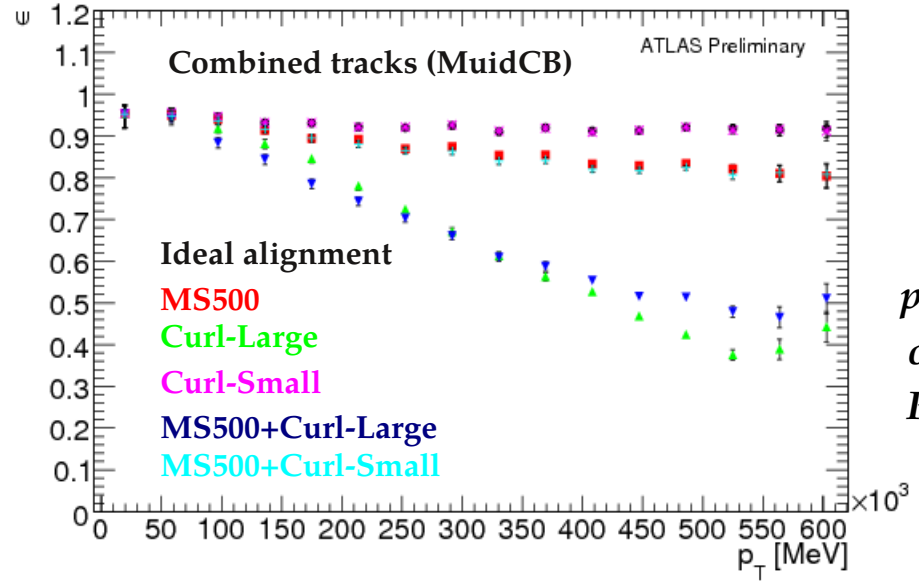


Combined efficiency → MS500 → drops up to 10%; Curl-Large → drops up to 40% → *Effect due to matching tracks between ID and MS!*

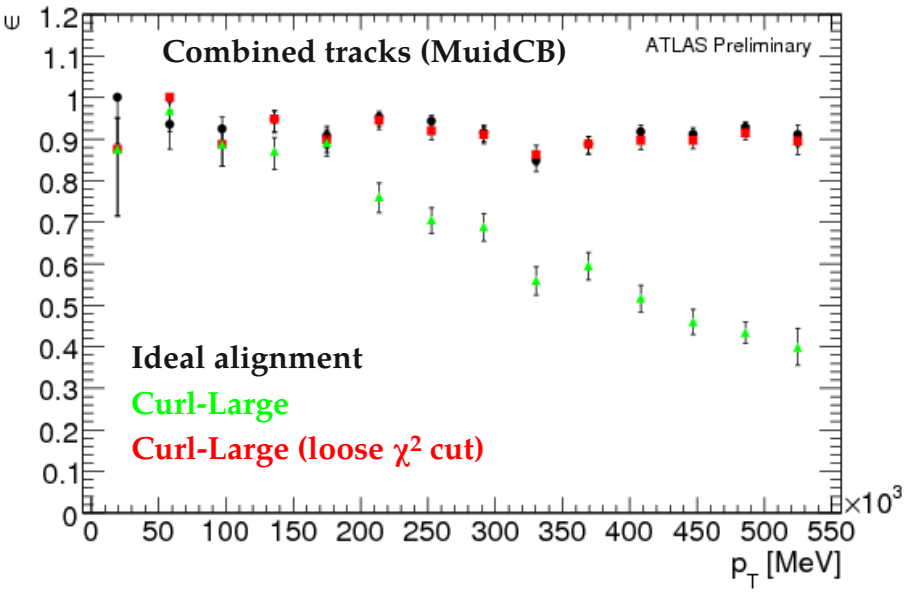
OLD RECONSTRUCTION

ATL-PHYS-INT-2009-067

NEW RECONSTRUCTION



*Introduced an **alignment parameter** in the **official ATLAS Reconstruction***



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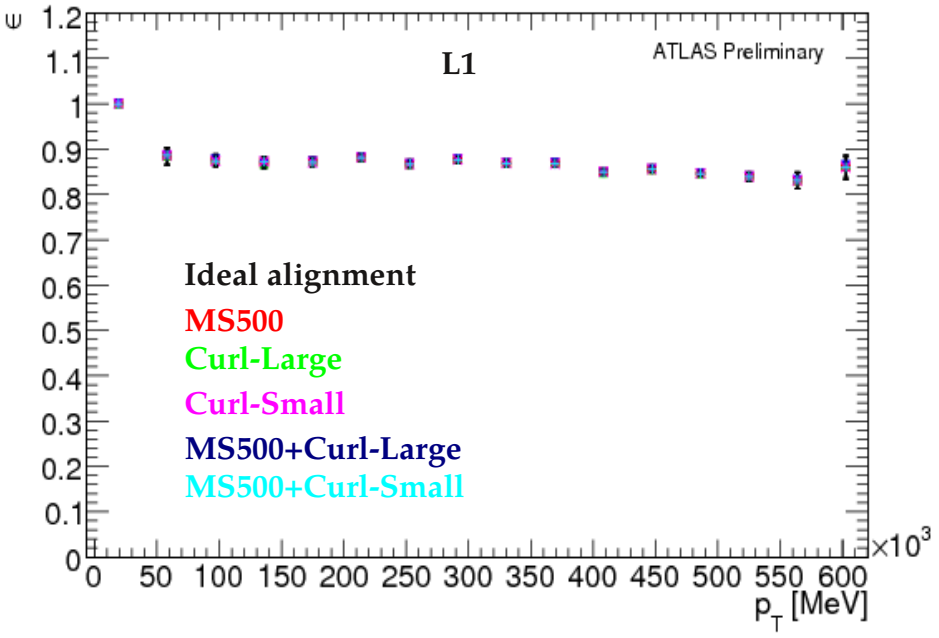
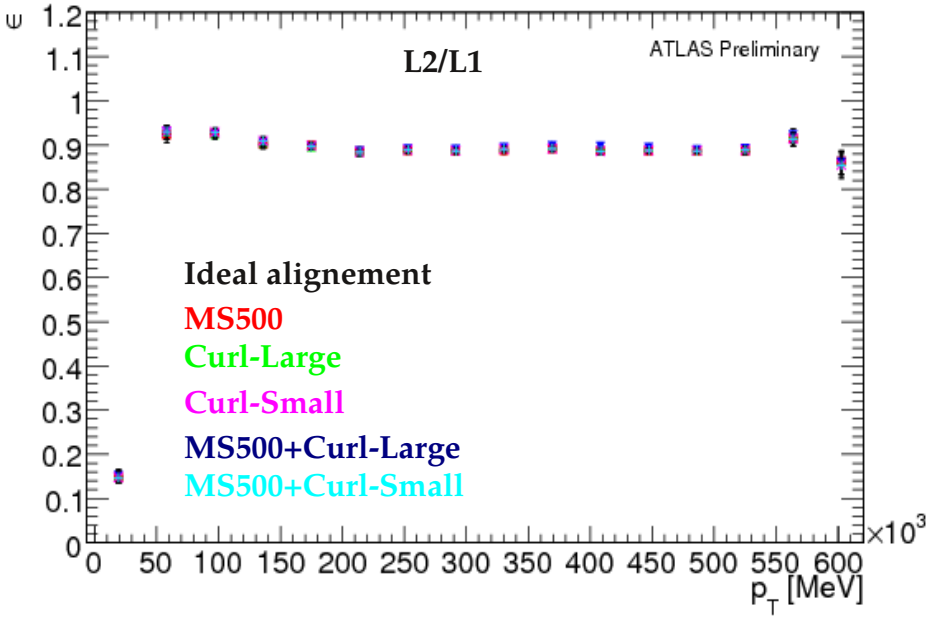
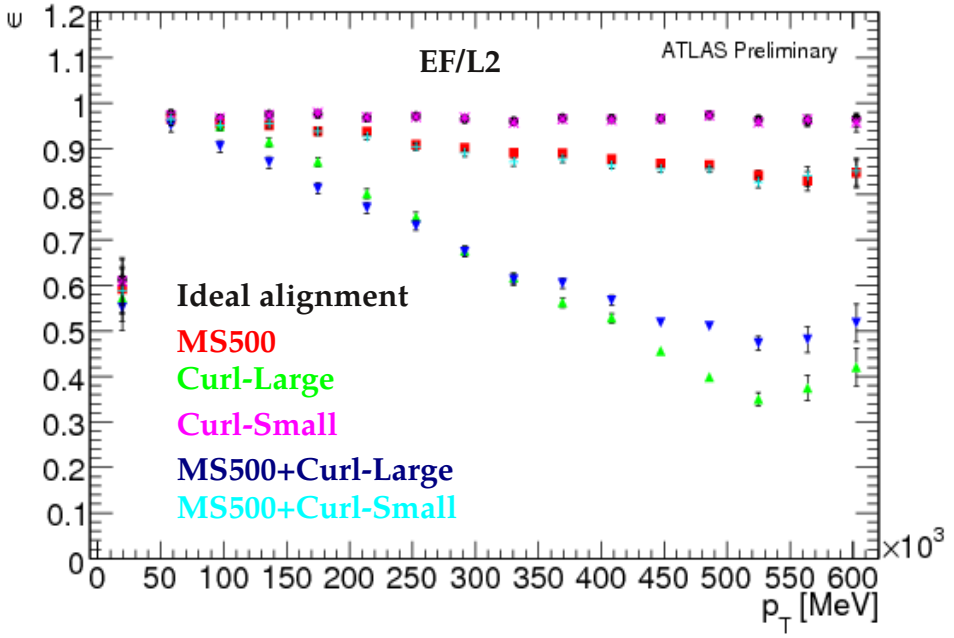
Effects of misalignments: trigger efficiency







The EF *trigger* level uses
MuidCB as tracking algorithm!

The drop seen for tracking efficiency
is reflected on trigger efficiency!

Algorithm	Ideal	MS500	Curl-Large	Curl-Small	MS500 + Curl-Large	MS500 + Curl-Small
MuidSA	67.5 %	52.8 %	50.0 %	67.5 %	42.1 %	52.5 %
MuidCB	69.7 %	56.9 %	26.6 %	69.2 %	27.7 %	55.5 %

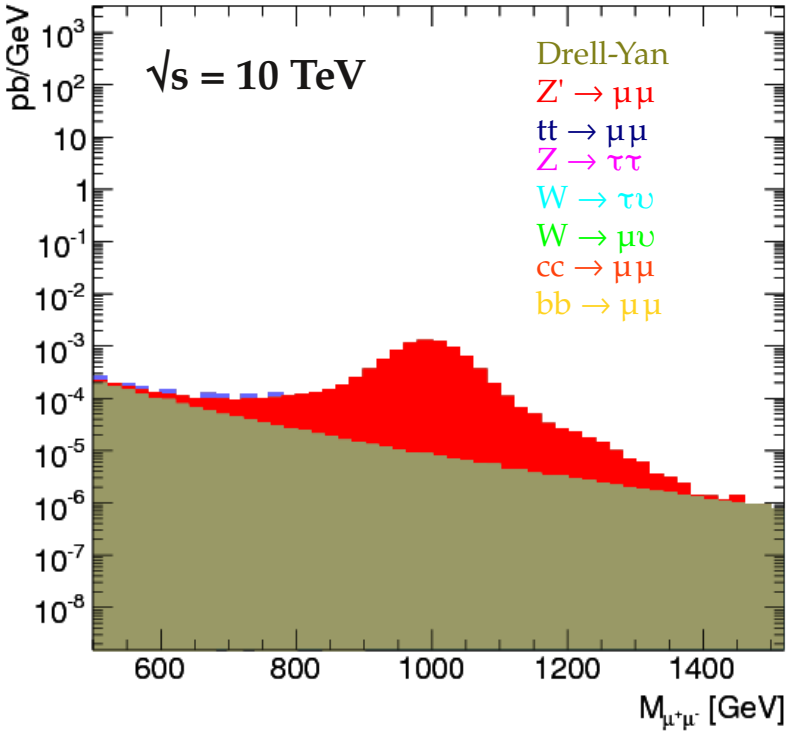
Z' → μμ, ATLAS discovery potential:
backgrounds (√s=10 TeV)

Z' signal considered:

SSM ⇒

- SSM1000 → Z', M=1 TeV, Γ=30GeV, σ=0.238 pb
- SSM1500 → Z', M=1.5 TeV, Γ=45GeV, σ=0.029 pb

IDEAL ALIGNMENT



MC samples $\sqrt{s}=10$ TeV

Selection: ⇒ 2 μ combined (Staco), opposite charge, p_T>20 GeV, $|\eta|$<2.5, isol. p_T^{ID}/p_T<0.2, trigger μ20

	Wμν	Wτν	Zττ	bb	cc	tt	Z'	DY
fraction	0	0	0	0	0	0.03	0.83	0.15

Invariant mass region: 500-2500 GeV

Discovery potential:
confidence level

Statistic method

- only background test
- signal+background test (Likelihood ratio)

$$L_b = -\sum_i n_i \log(b_i) - b_i - \log(n_i!)$$

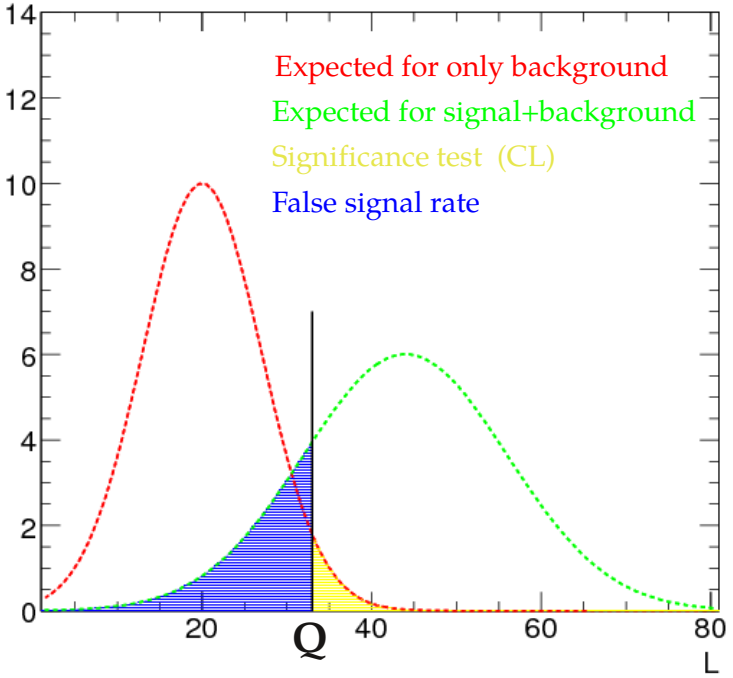
$$L_s = -\sum_i n_i \log(b_i + s_i) - n_i \log(b_i) - s_i$$

$n_i \rightarrow$ events in bin i

$b_i \rightarrow$ background in bin i

$s_i \rightarrow$ signal in bin i

Estimator distributions



$$\int L < 1 - CL$$

CL= 95% (2σ), 99.7% (3σ), 99.9% (4σ)

All distribution are obtained generating 2 samples of 10^5 pseudo-esperiments

- one with only backgrounds events
- one with signal and background events

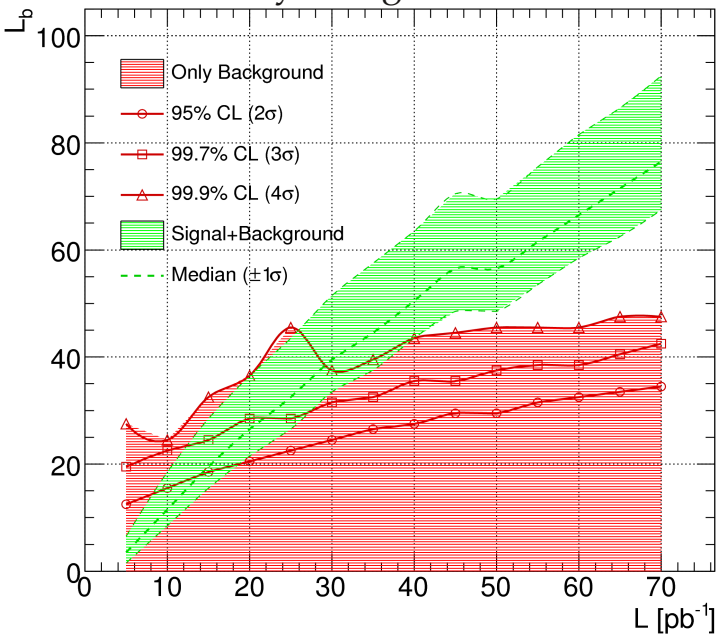
$$N_{bkg} = \epsilon \cdot \sigma_{bkg} \cdot L$$

$$N_{sig} = \epsilon \cdot \sigma_{sig} \cdot L$$

Z' → μμ, ATLAS discovery potential:

ideal alignment (√s=10 TeV)

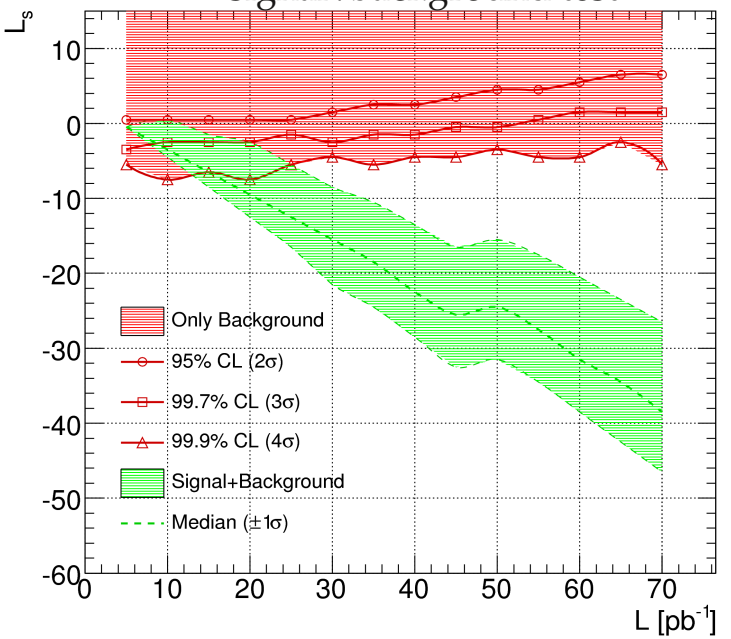
only background test



Z' SSM1000

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Lb	14	22	29
Ls	6	8	15

signal+background test



Background confidence level

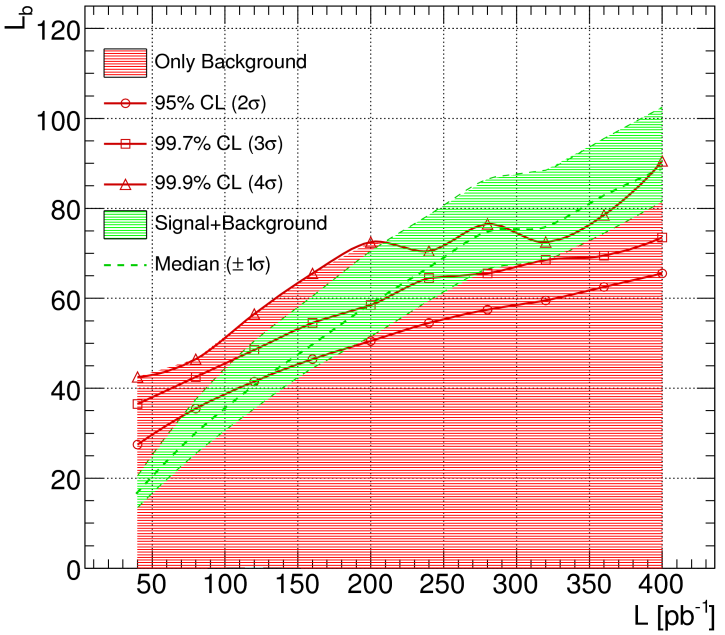
Signal confidence level

△ 95% Exclusion

□ 99.7% Exclusion

○ 99.9% Exclusion

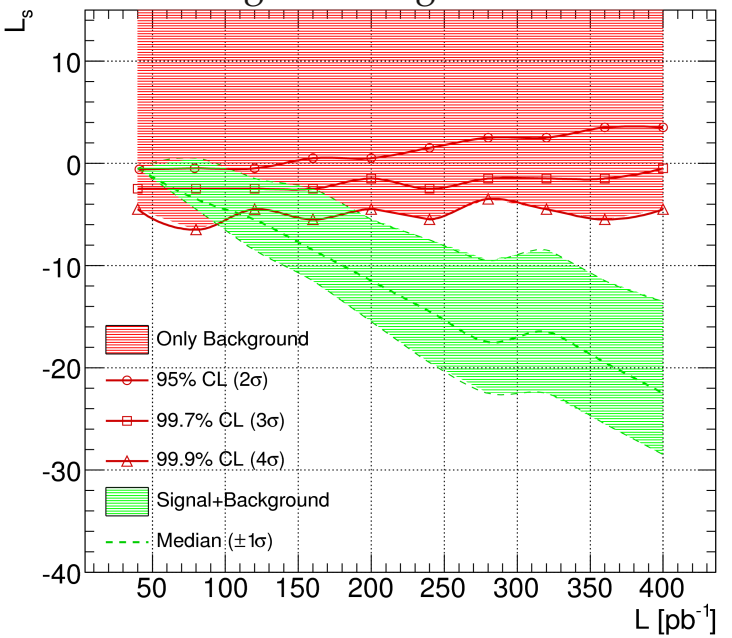
only background test



$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Lb	130	200	300
Ls	42	65	110

Z' SSM1500

signal+background test



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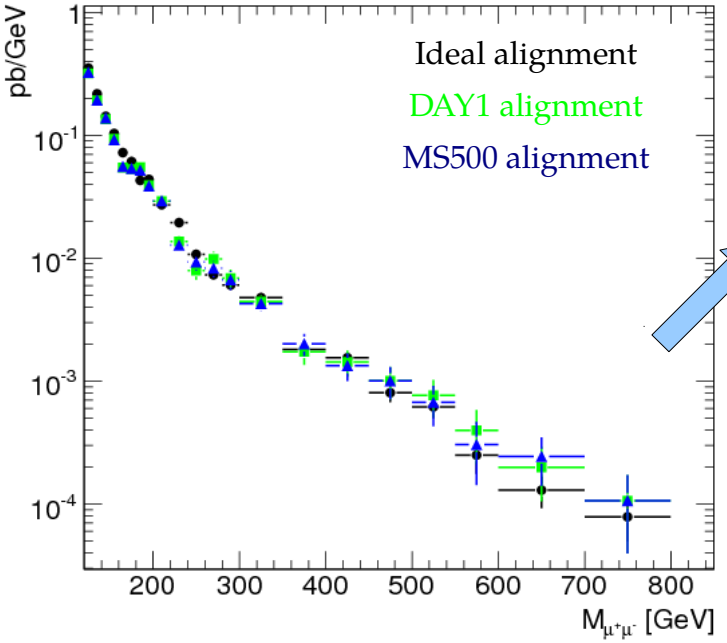
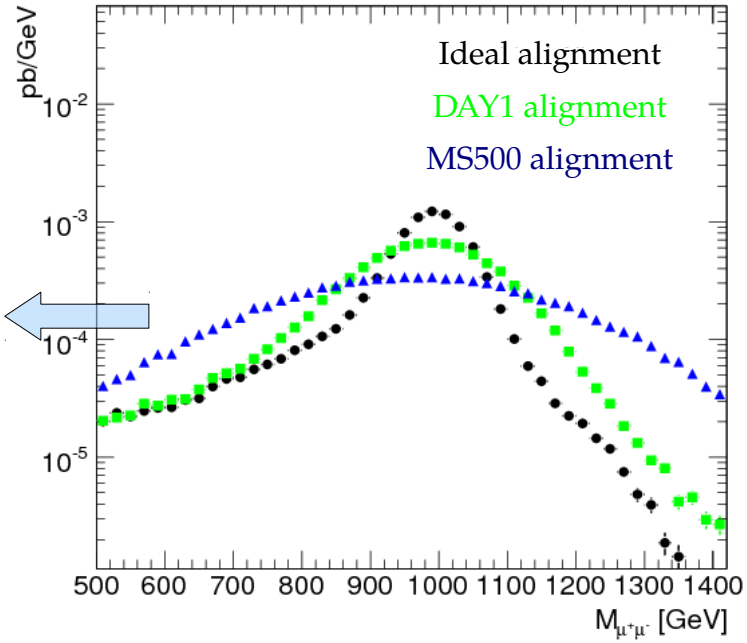
ATLAS discovery potential:

Effects of misalignments (√s=10 TeV)



Minimal effect

Significant effect

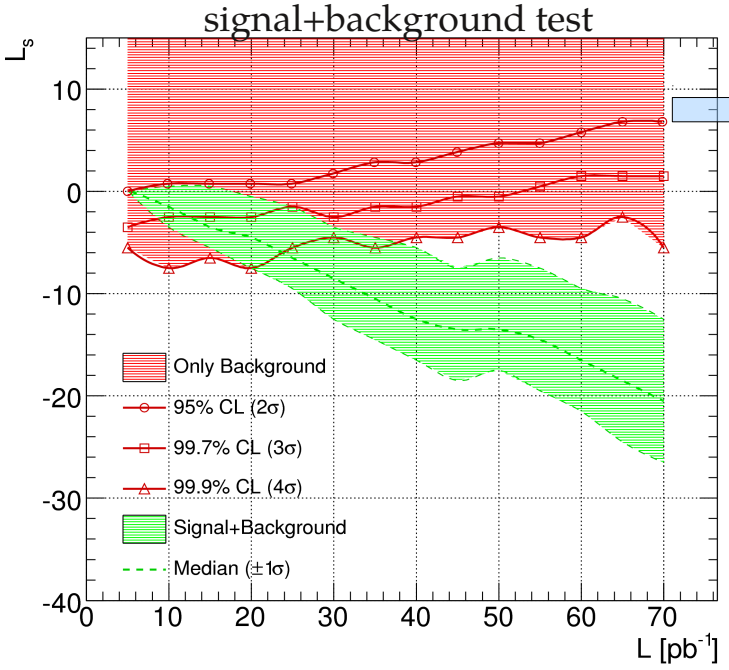


Since the effect of misalignments on background events is minimal, I only considered misalignments on signal events.

Consequently, the only background test is insensitive to the misalignments introduced and it provides the same results.

Z' → μμ, ATLAS Discovery potential:

500 μm MS misaligments and ideal resolution hypothesis (√s=10 TeV)

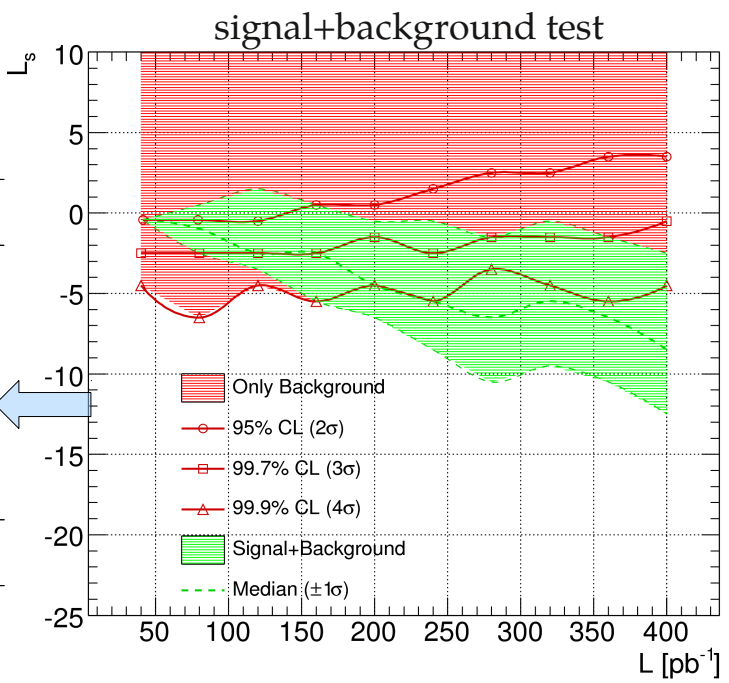


Z' SSM1000

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	6	13	24
Ls (ideal)	6	8	15

Z' SSM1500

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	42	160	240
Ls (ideal)	42	65	110



Experiments generated with misalignments of o(500 μm) on MS.
In the test function, I considered ideal resolution of MS

95% CL → insensitive to misalignments

99.7%, 99.9% CL → The integrated luminosity needed to observe signal events increase significantly

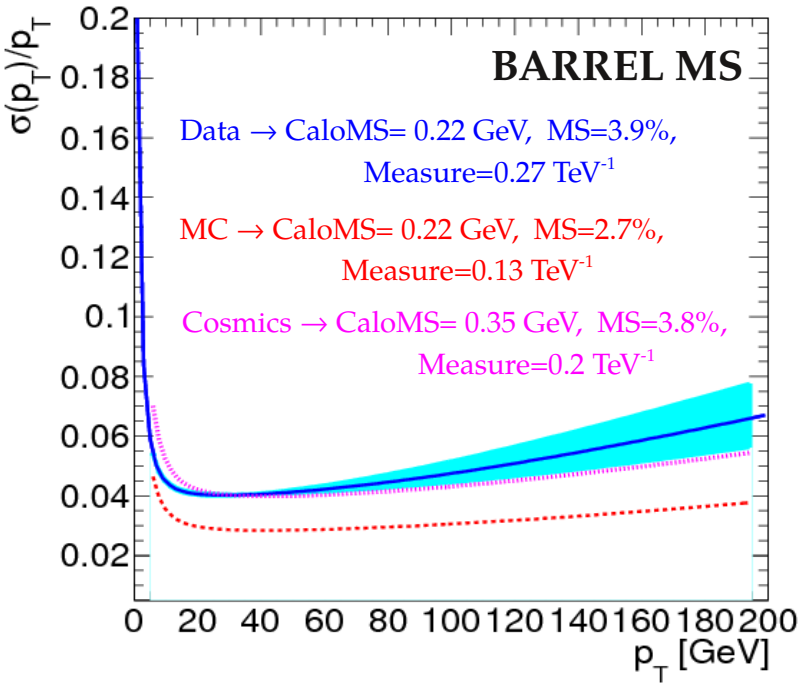
99.9% CL (4 σ)

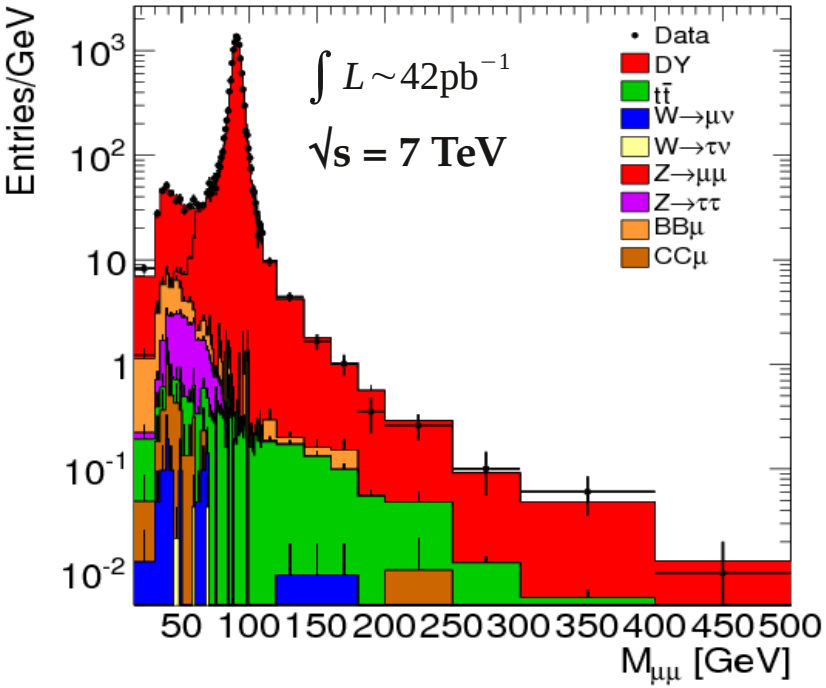
Z' (1 TeV) → from 15 pb^{-1} to 24 pb^{-1}

Z' (1.5 TeV) → from 110 pb^{-1} to 240 pb^{-1}

Detector resolution

It can be determined from Z lineshape in the process $pp \rightarrow Z \rightarrow \mu\mu$ with data driven techniques.





Z' SSM1000

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	6	12	20
Ls (ideal)	6	8	15

Z' SSM1500

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	42	100	170
Ls (ideal)	42	65	110

99.9% CL (4 σ)

Z' (1 TeV) → from 24 pb^{-1} to 20 pb^{-1}

Z' (1.5 TeV) → from 240 pb^{-1} to 170 pb^{-1}

The effects of misalignments can be *partially recovered*: it reduced *up to 50%*.

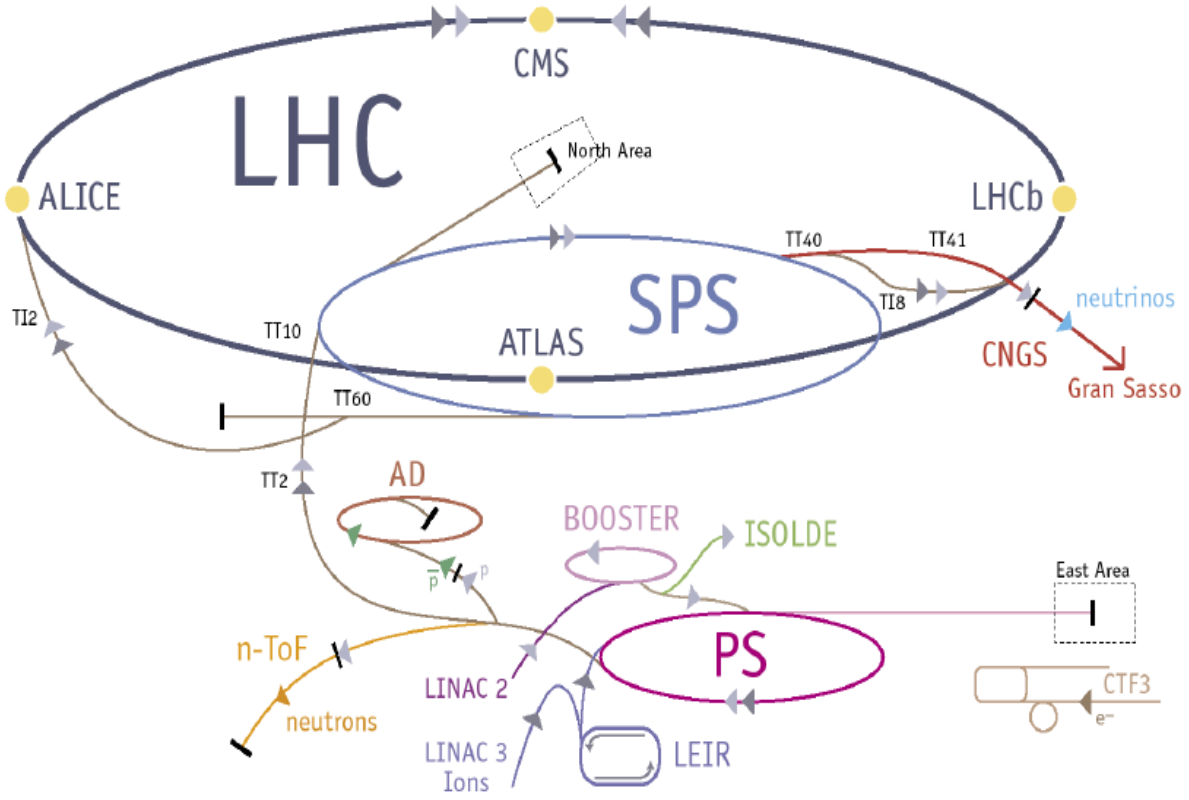
Conclusions

- With MC Samples, I studies the production and decay of new gauge heavy boson, Z';
- I studied the performance of tracking system, MS and ID, such as momentum-resolution and it's tracking and trigger efficiencies in different alignment conditions;
- I studied the impact of misalignments on reconstruction efficiency: I improved the tracking algorithm (MuidCB), used by EF trigger level;
- I studied the ATLAS discovery potential, concluding that we could observe Z' events (1 TeV) from an integrated luminosity of about 6 pb^{-1} ($\sqrt{s}$=10 TeV);
- Results shown are for $\sqrt{s}$=10 TeV, but it's possible to convert them for $\sqrt{s}$=7 TeV: for example, the integrated luminosity at $\sqrt{s}$=7 TeV is about a factor 3 more than one at $\sqrt{s}$=10 TeV; so, for a Z' with mass 1 TeV, the integrated luminosity is about 20 pb^{-1} (95%CL);
- Recently, we are studying the momentum-resolution with data driver techniques. Preliminary results are in agreement with the values obtained from cosmic data;
- With current data (~ 42 pb^{-1}), we can probably exclude Z' SSM in a mass region between 1 and 1.5 TeV with 95% CL.

Backup slides

LHC

LHC is the p-p collider, completed at CERN of Geneva in the 27 km long gallery, which previously hosted the e^+e^- collider LEP.



This collider provided first collisions with an energy in the center mass of

900 GeV → during 2009
7 TeV → since March, 30, 2010

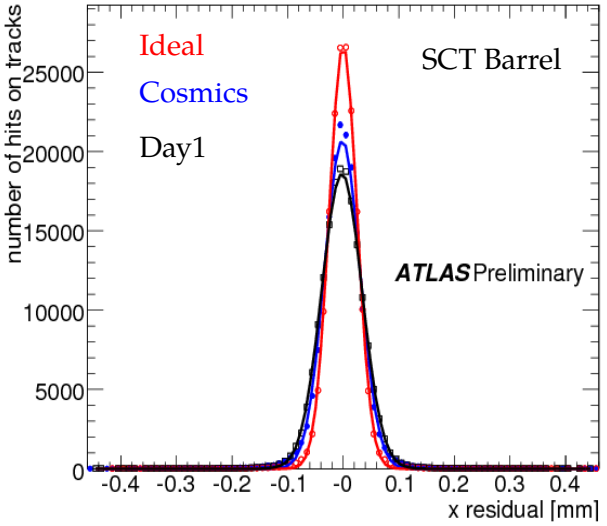
In 2012, it will lead to an energy of 14 TeV.

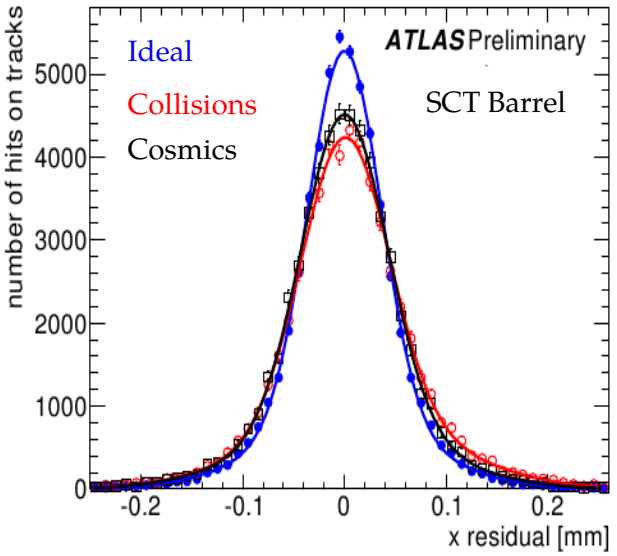
Based on design parameters, the expected luminosity is of the order of 10^{34} $cm^{-2}s^{-1}$, but, in this early stage, the luminosity is about $2 \cdot 10^{31}$ $cm^{-2}s^{-1}$(August 2010).

Detector status with cosmic data: ID

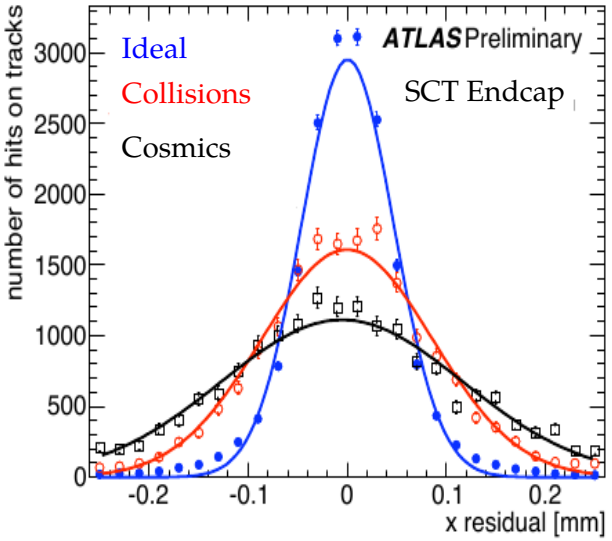
First alignment procedures of IDD and MS → cosmic data acquired between 2008 and 2009.

ID → DAY1 geometry, alignment obtained from cosmic data

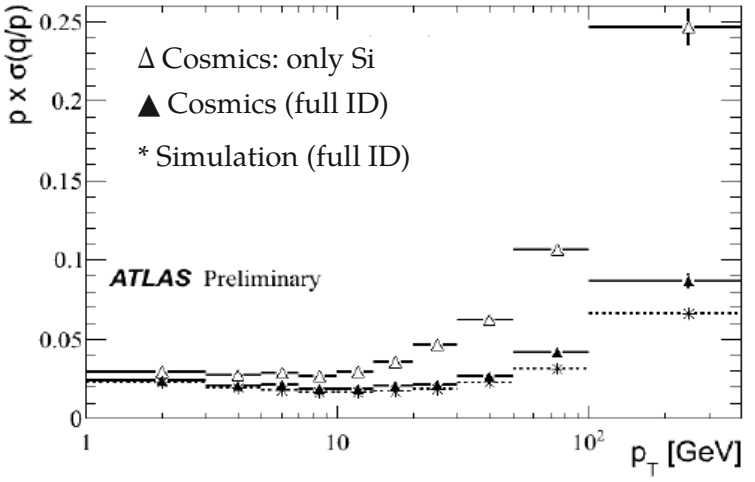




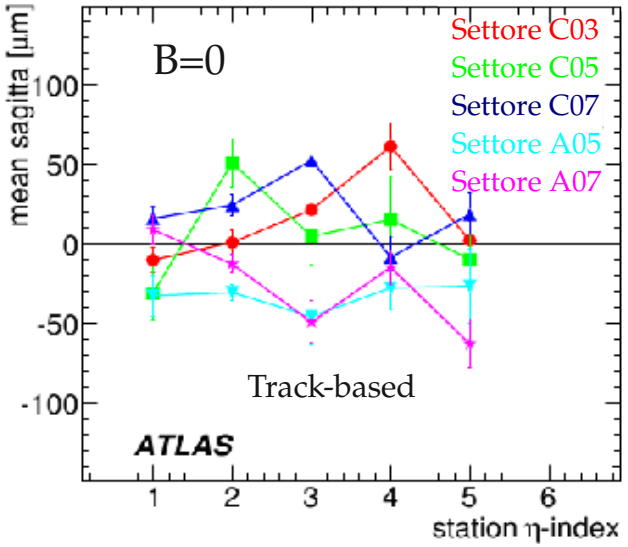
	DAY1	Ideal
Pixel	20 µm	10 µm
SCT	20 µm	10 µm
TRT	100 µm	50 µm



momentum-resolution
track-split method

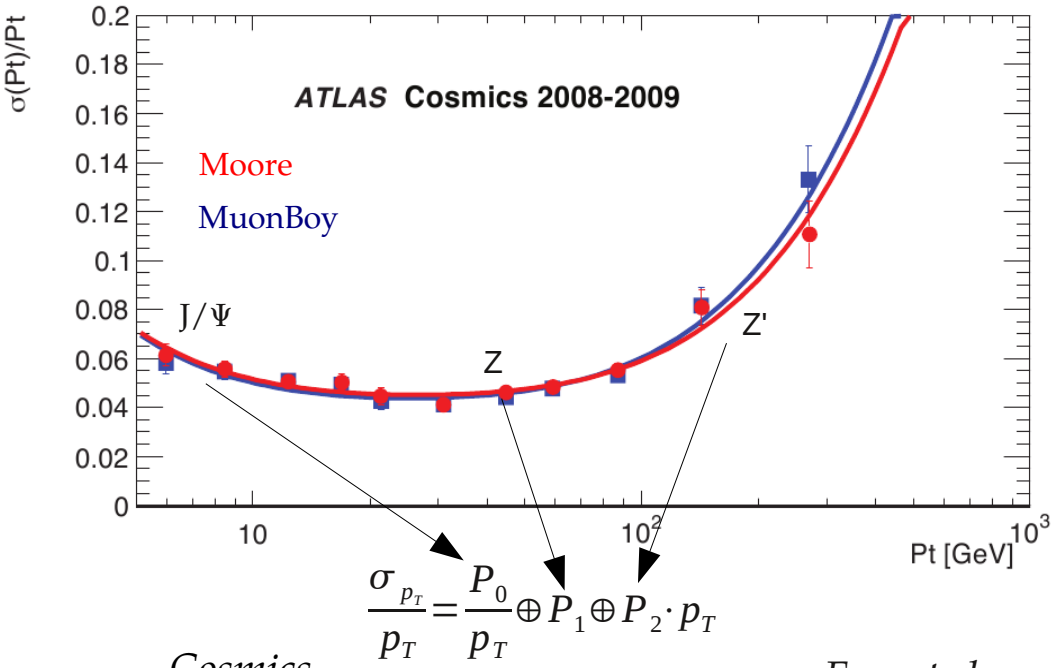


Detector status with cosmics data: MS

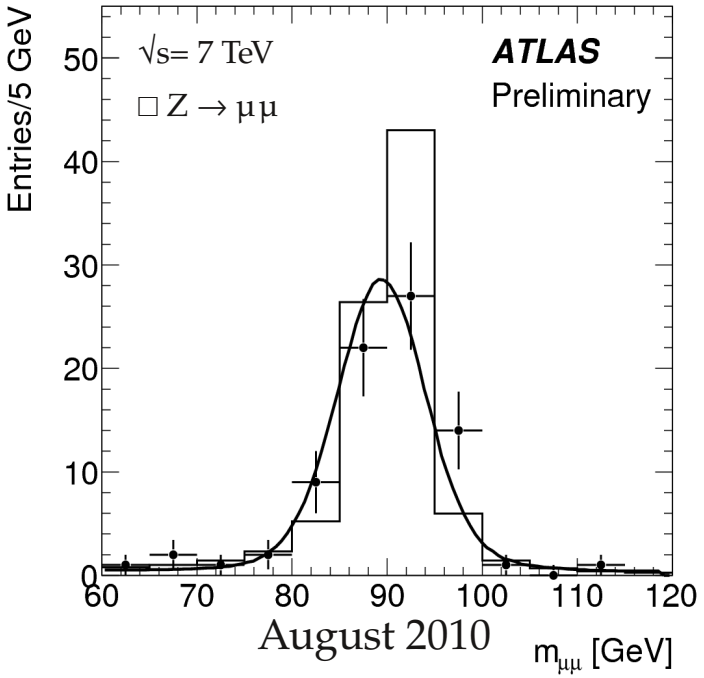


MS ⇒ With magnetic field off, alignment is absolutely determined using straight tracks

Cosmic data ⇒ Global alignment ~100-200 um

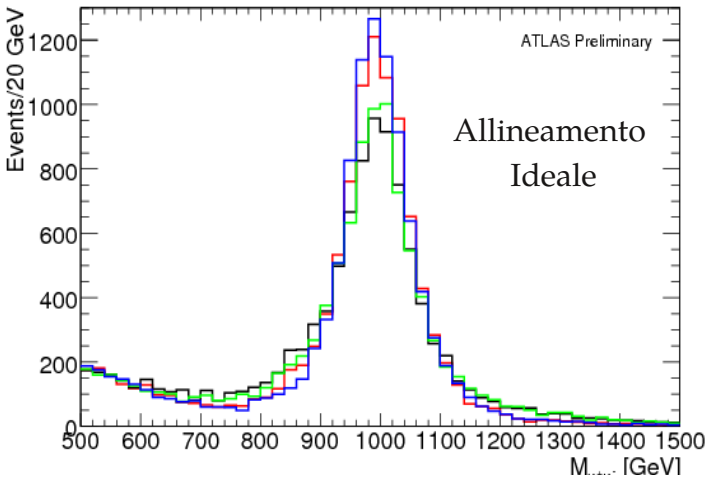


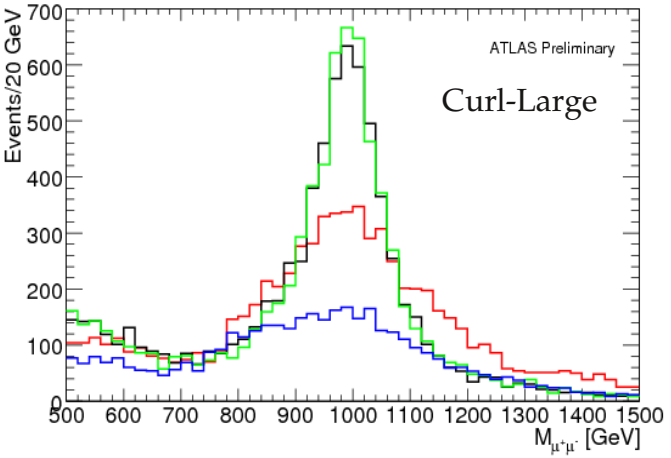
$$\frac{\sigma_{p_T}}{p_T} = \frac{P_0}{p_T} \oplus P_1 \oplus P_2 \cdot p_T$$

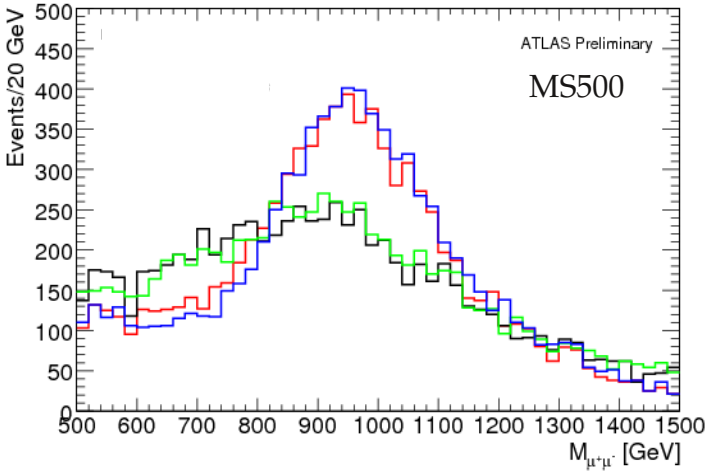


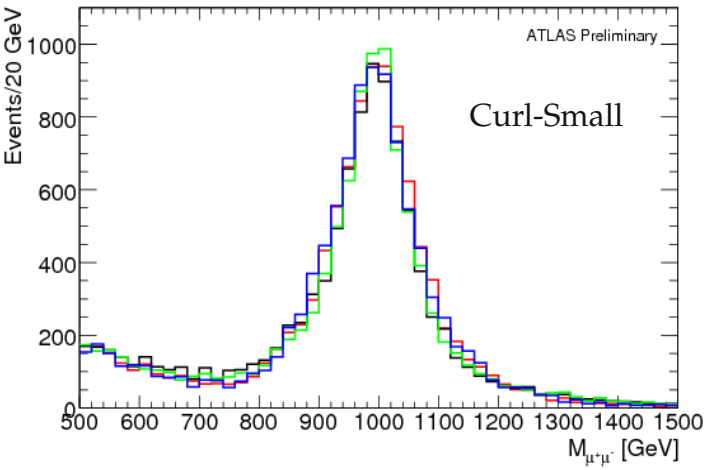
Cosmics		*Expected*
$P_0 = 0.29 \oplus 0.03$ GeV	energy loss	$P_0 = 0.35$ GeV
$P_1 = 0.043 \oplus 0.002$	Multiple scattering	$P_1 = 0.035$
$P_2 = (4.1 \oplus 0.4) \times 10^{-4}$ GeV^{-1}	Intrinsic resolution	$P_2 = 1.2 \times 10^{-4}$ GeV^{-1}

Effects of misalignments: Selection Efficiency





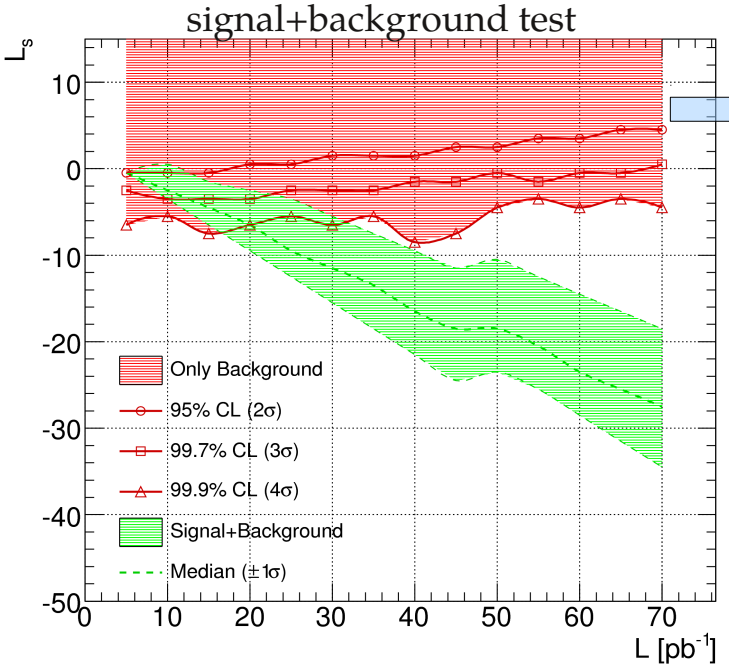




Algorithm	Ideal	MS500	Curl-Large	Curl-Small	MS500+Curl-Large	MS500+Curl-Small
MuidSA	67.5 %	52.8 %	50.0 %	67.5 %	42.1 %	52.5 %
MuidCB	69.7 %	56.9 %	26.6 %	69.2 %	27.7 %	55.5 %

ATLAS discovery potential:

misalignments of 500 μm on MS and extrapolated resolution

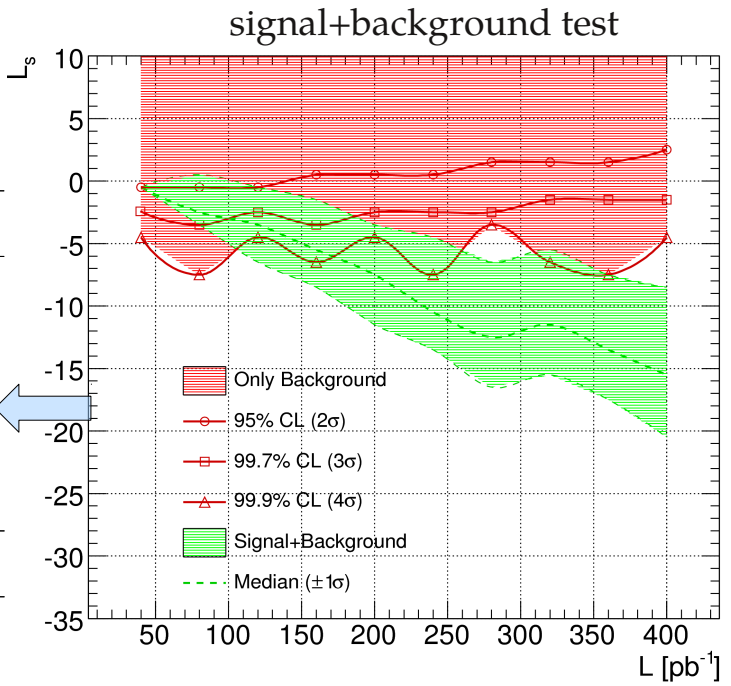


Z' SSM1000

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	6	12	20
Ls (ideale)	6	8	15

Z' SSM1500

$\mathcal{L}$ (pb^{-1})	95% (2σ)	99.7% (3σ)	99.9% (4σ)
Ls	42	100	170
Ls (ideale)	42	65	110



95% CL → insensitive to misalignments

99.7%, 99.9% CL → The integrated luminosity needed to observe signal events increase significantly

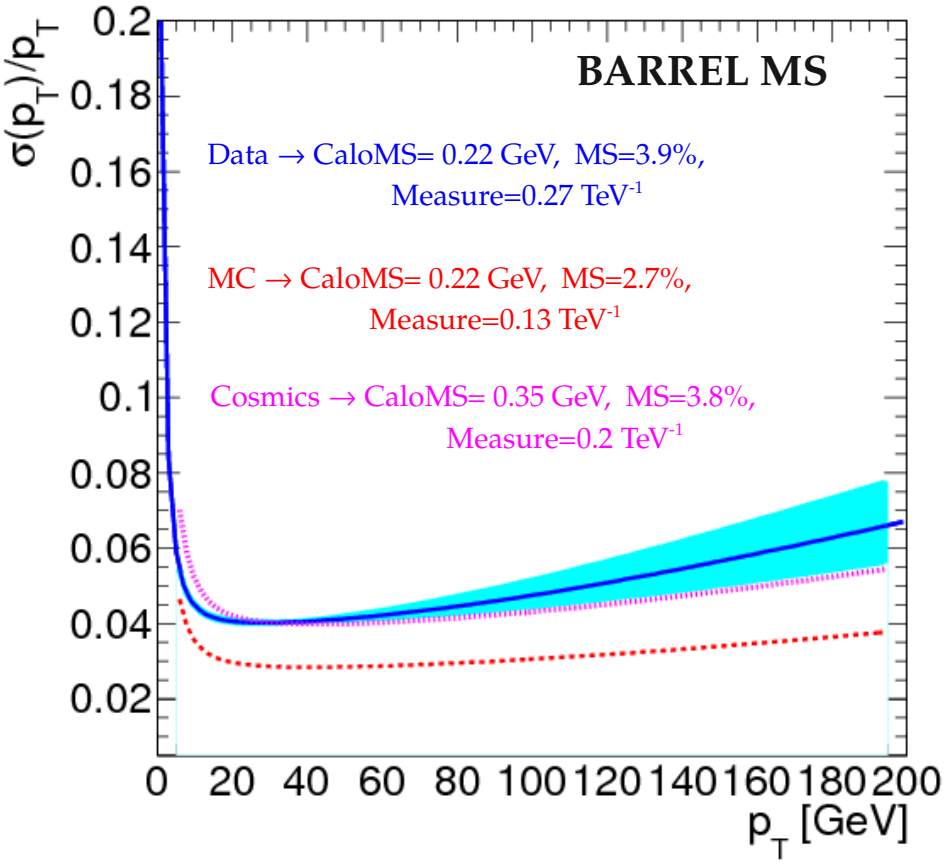
99.9% CL (4 σ)

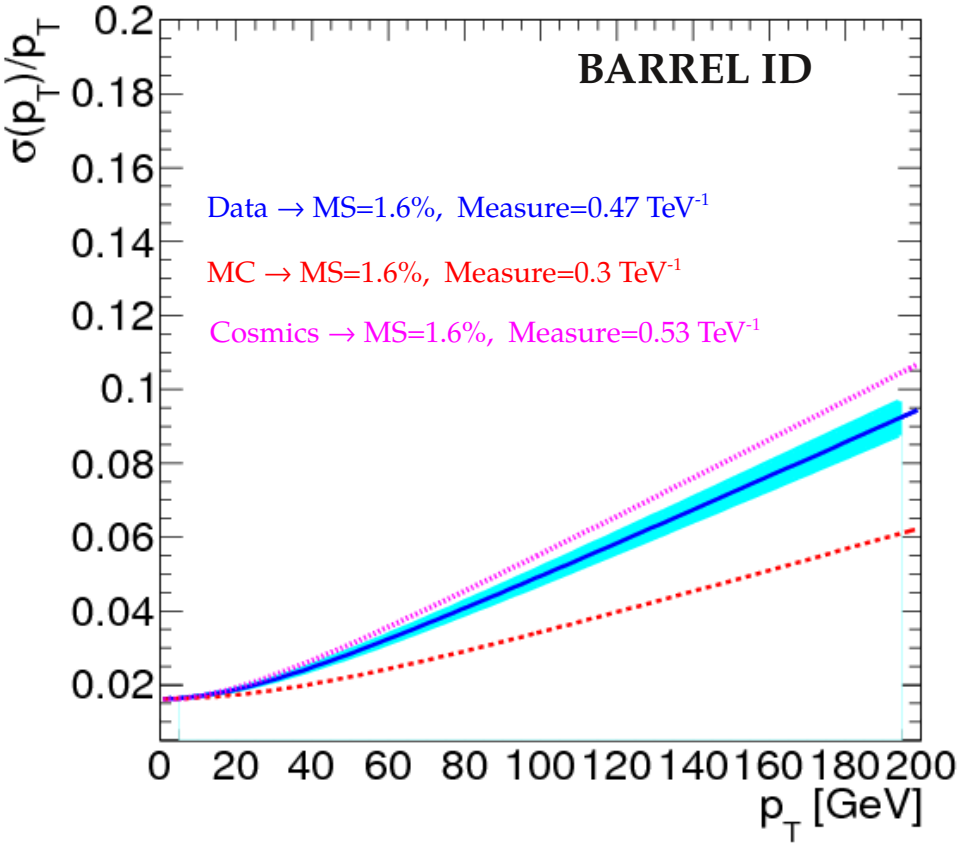
Z' (1 TeV) → from 15 pb^{-1} to 20 pb^{-1}

Z' (1.5 TeV) → from 110 pb^{-1} to 170 pb^{-1}

Detector resolution

It can be determined from Z lineshape in the process $pp \rightarrow Z \rightarrow \mu\mu$ with data driven techniques.





Preliminary results are in agreement with values obtained from cosmic data!