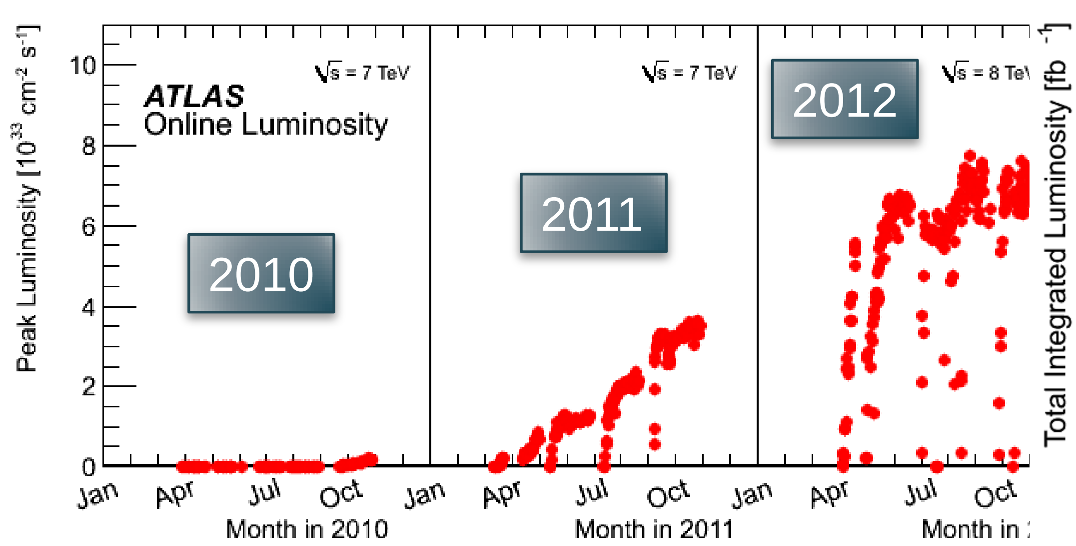
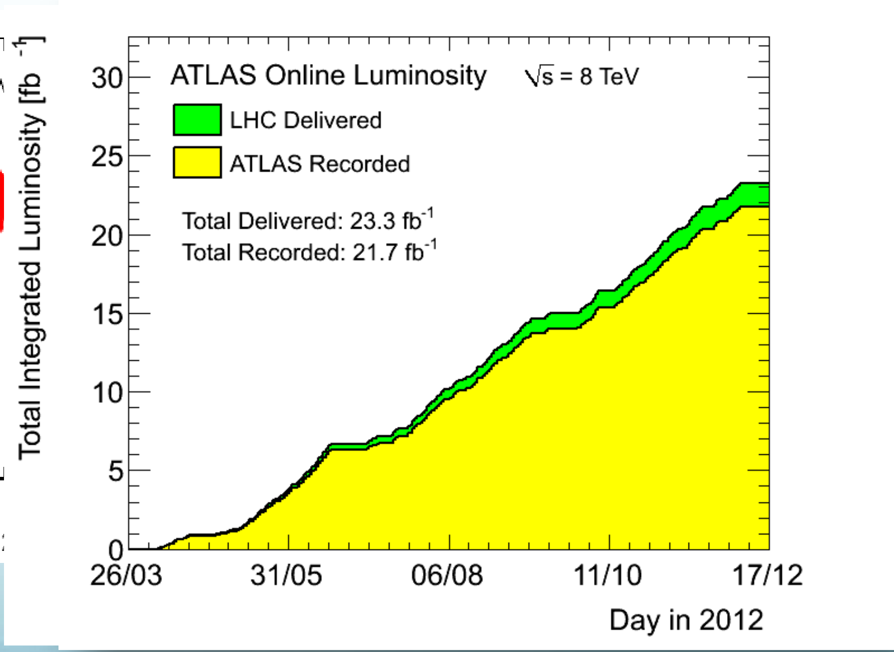
ATLAS activities
Niels Bohr Institute

S.Xella on behalf of the ATLAS NBI group

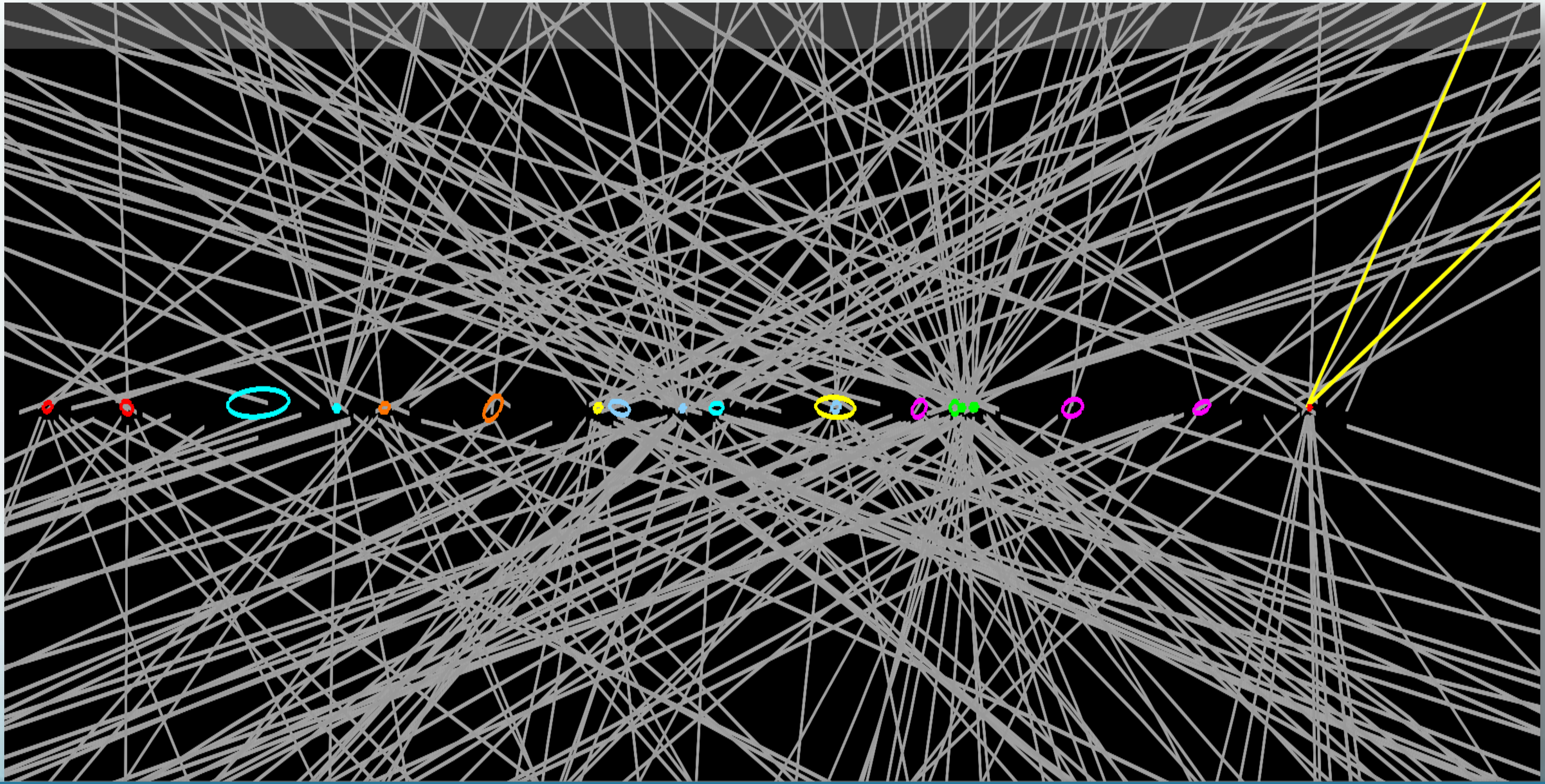
LHC and ATLAS : remarkable operation during Run 1

- smaller and smaller beam size σ
- more and more bunches (from 368 to up to 1380 , nominal 2808)
- bunch spacing reduced from 150 to 50 (nominal 25 ns)



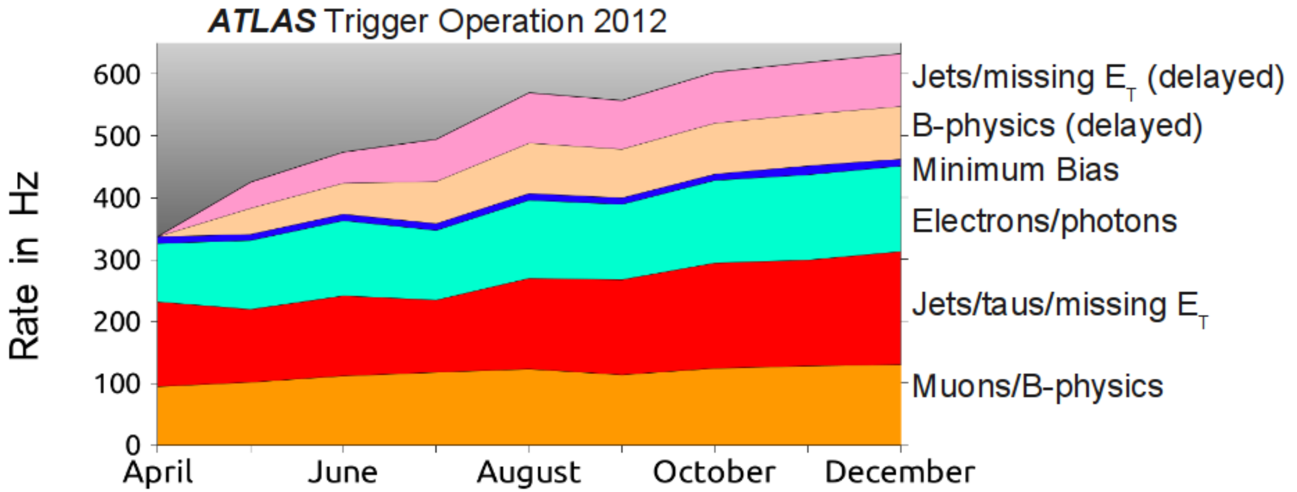


Bring it on !

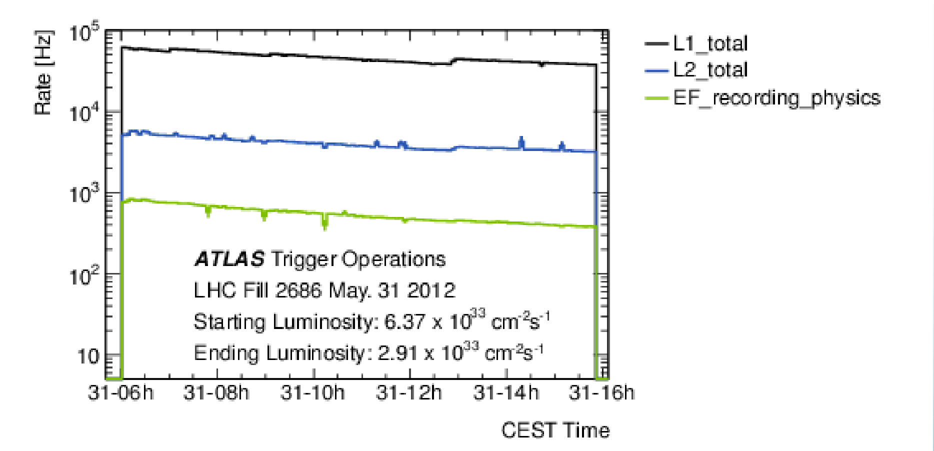


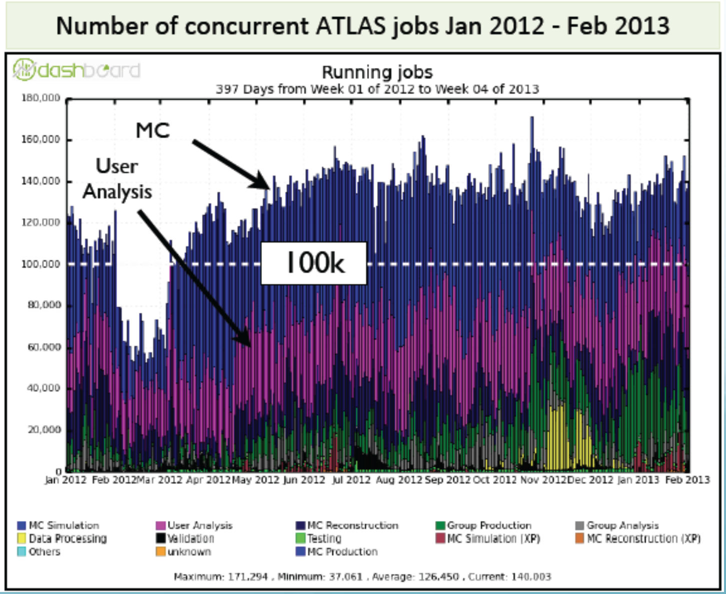
Example of Z → μμ decay with 20 reconstructed vertices
(shown ± 15 cm, p_T (track) > 0.4 GeV)

Trigger was exceptional

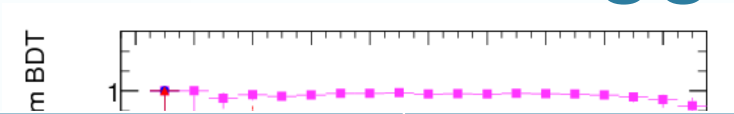


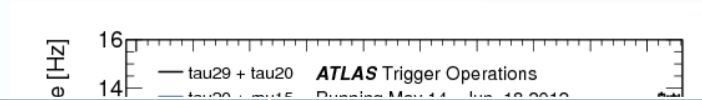
Way above expectations !



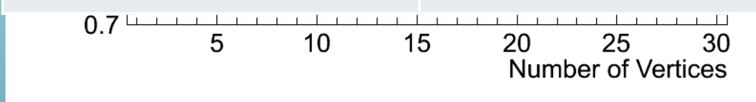


Robust and rich Trigger menu





Trigger		Event Filter Thresholds (GeV)
Single e	Iso	24
Combined		
Single tau		
Combined		
	tau+missing ET	29, 50



~100 primary physics triggers active during a run + support triggers (calibration, background estimations, etc…)

ATLAS @ NBI

I will now highlight the areas where NBI group provides an **important** contribution

Run 1:

- Basic particle reconstruction performance (trigger and offline reconstruction)
- The Standard Model Higgs search
- Physics beyond the Standard Model search
- Luminosity measurement

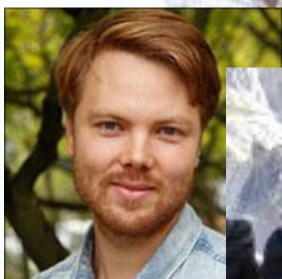
Run 2 and beyond : Upgrade contribution

- Luminosity measurement
- L1 , HLT , L4 trigger

centre for particle physics
Discovery



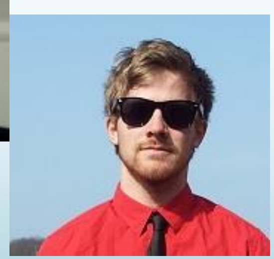
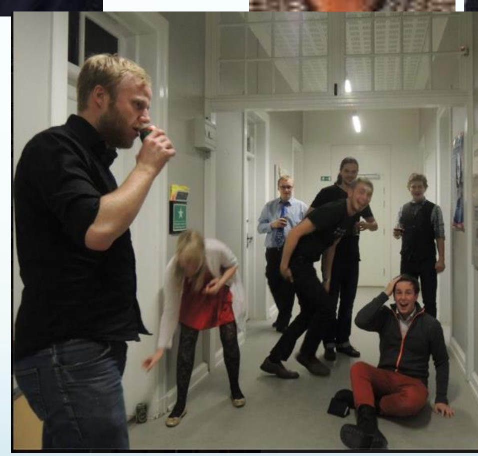


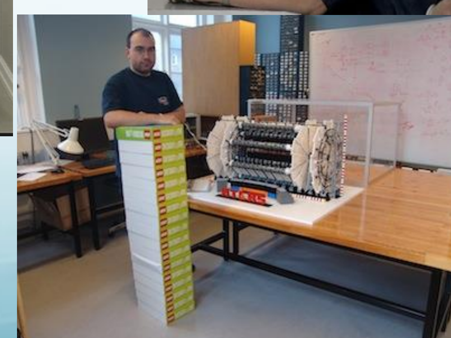









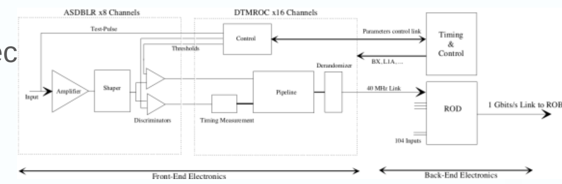



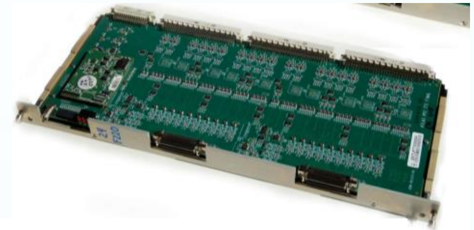


Basic particle reconstruction performance (trigger and offline reconstruction)

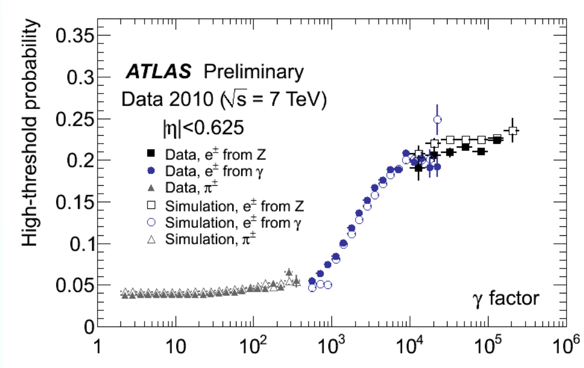
Transition Radiation Tracker

- Electronics:
  - Production of Timing, Trigger Control backend elec
  - Test the front-end electronics

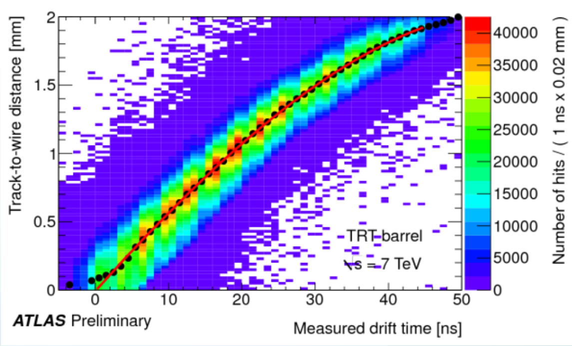




- Operation:
  - Leading role in testbeam campaign
  - Developing of software for reconstruction and simulation

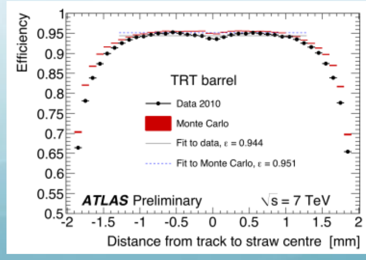


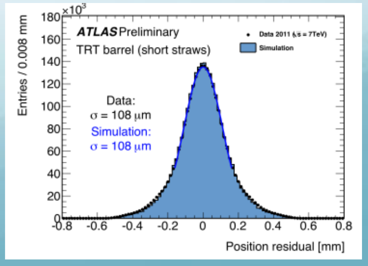
- Electron Identification:
  - Use Transition radiation to separate electrons from pions
  - TRT PID capabilities are **fundamental at trigger and offline for e.g. H->ZZ**



- Tracking Calibration:
  - Method to correct timing changes in the detector
  - Improving the so-called r-t relation
  - All data is calibrated automatically to get the best positions residual

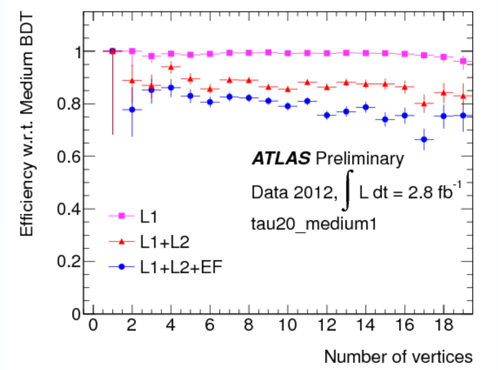
- Detector Simulation:
  - Development of simulation and digitization of the TRT
  - Tuning of the MC to data with very good agreement in the distributions used in analysis



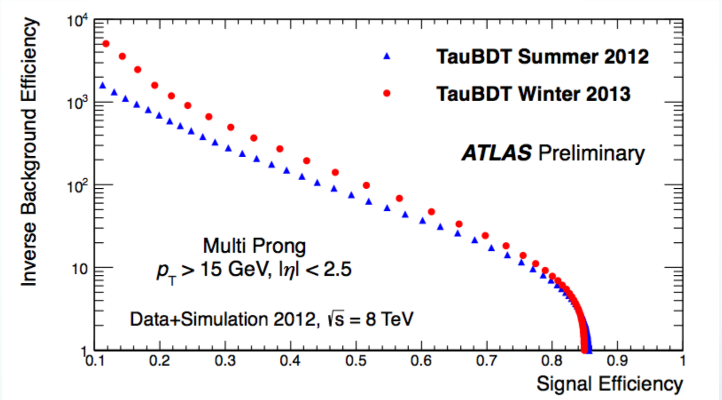


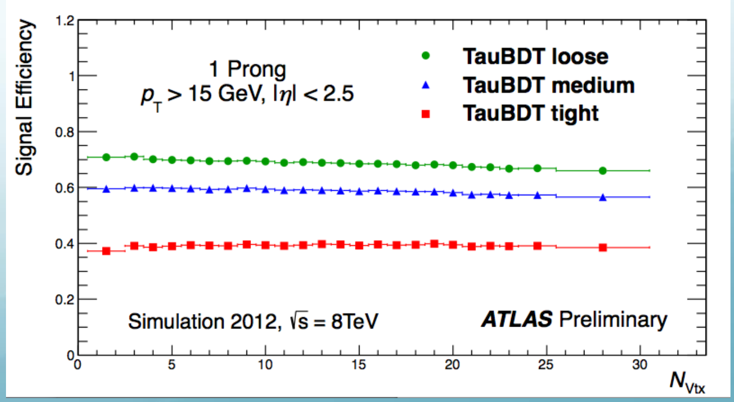
Trigger and tau online/offline identification

- Trigger:
  - Contributed to HLT farm design (experience from Hera-B)
  - NBI is Member of the TDAQ Institute Board
  - Tau trigger coordination (2009-2011)
  - Commissioning tau trigger during 2010-2011 run period + ensure a rich tau+X trigger menu for wide range of tau physics searches
  - Developing of software for tau reconstruction online and offline



- Tau Identification:
  - Tau offline reconstruction coordination (2011-2013)
  - Develop tau identification for 2012 run, align trigger algorithm to this, provide robustness to pile-up
  - Develop tau energy calibration
  - TRT PID capabilities used for electron veto development

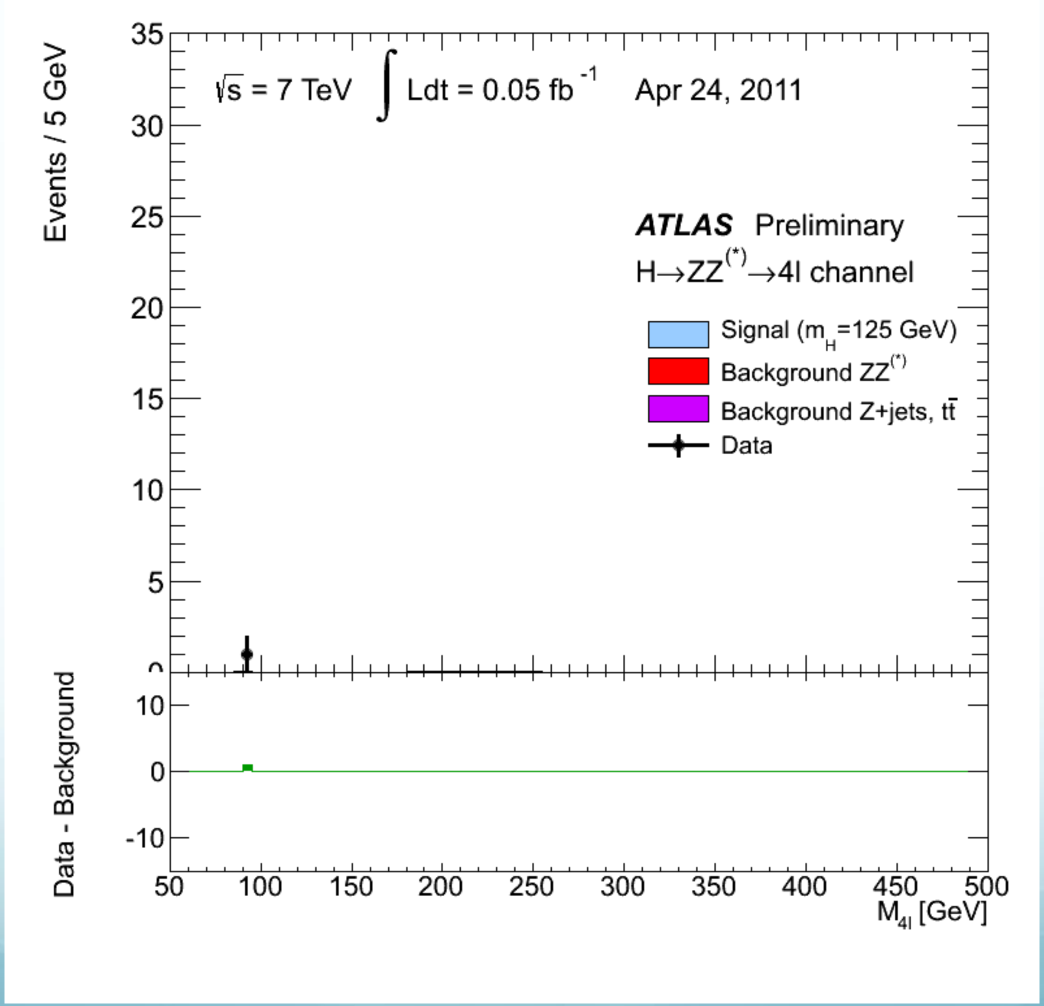




All essential ingredients for H-> ττ search

Higgs search

Higgs decay to ZZ



Higgs Properties

After discovery of 126 GeV Higgs-like particle, we want to measure **properties**

- Mass ➔ Compatible between CMS and ATLAS

  ATLAS **125.5 ± 0.2 (stat) +0.5 -0.6 (sys) GeV**

  CMS **125.8 ± 0.4 (stat) ±0.4(sys) GeV**

- Signal strength ➔ Compatible with SM so far

  ATLAS **1.43 ± 0.16 (stat) ± 0.14 (sys)**

  CMS $\mathbf{0.91^{+0.30}_{-0.24}}$

- Coupling to boson and fermions ➔ Compatible with SM so far, but fermions (bb,ττ, …) missing

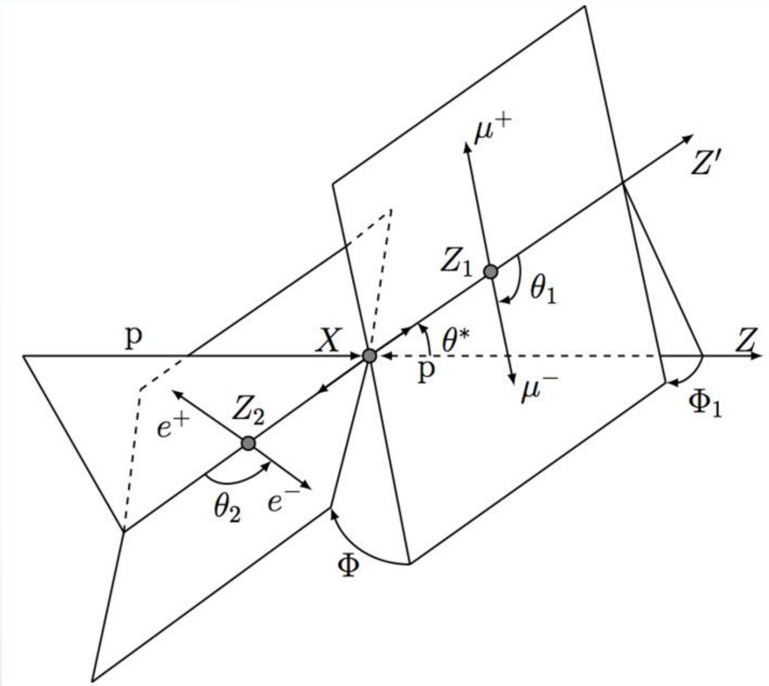
- Spin ➔ most likely 0

- Parity ➔ most likely 0+ ➔ SM like !

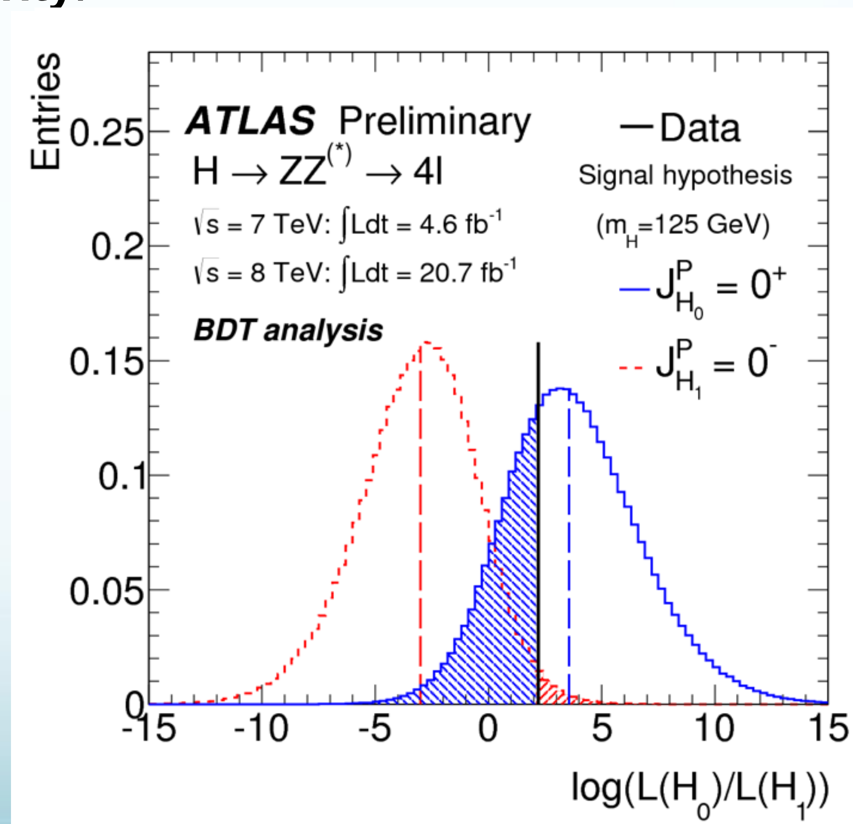
There is still lots to measure ! We just started !

Higgs Spin and Parity

H →ZZ channel dominates the **parity** determination (H →γγ is "blind" to parity!).



H →ZZ channel has **five** angles and **two** invariant masses sensitive to **spin** and **parity**.

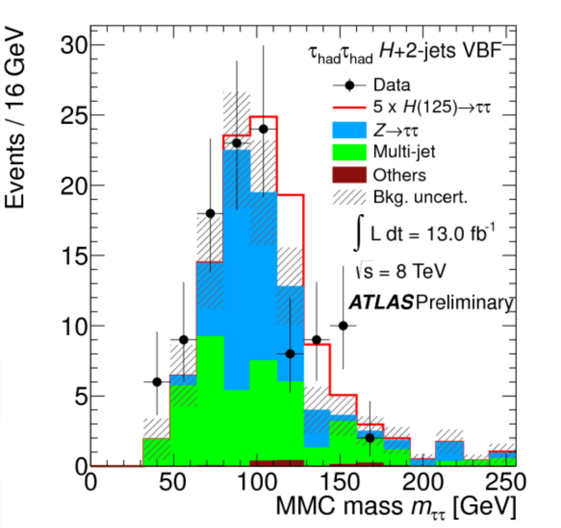


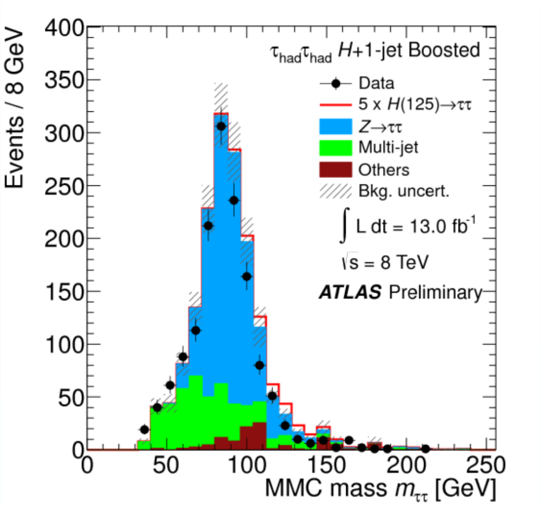
Combining these in a Boosted Decision Tree (BDT) yields maximum pr. event separation between 0^+ and 0^- hypothesis.

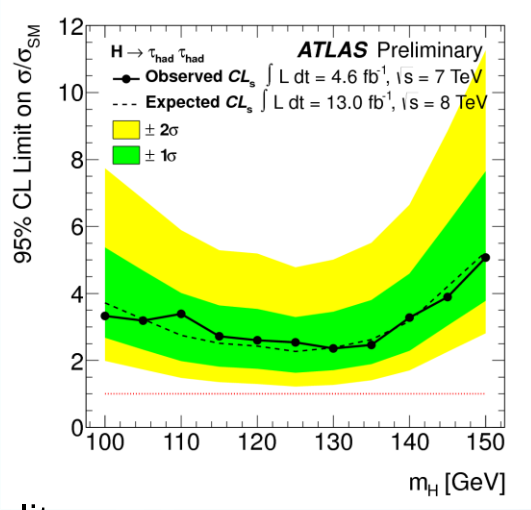
p-value for 0^- state **0.015 (excluded at more than 2σ)**

Higgs decay to ττ(had)τ(had)

Already in combination with other H->ττ since 2011.
Very important part of the current ATLAS sensitivity to ττ final state (total expected 95% CL is 1, observed 2).







NBI group effort, from beginning of 2009, has made this channel a reality:
- Double hadronic trigger in trigger menu
- Tau trigger design and optimization
- Tau identification and energy resolution
- Robustness to pileup
- Analysis

Benefit also the H->ττ -> lep had + neutrinos

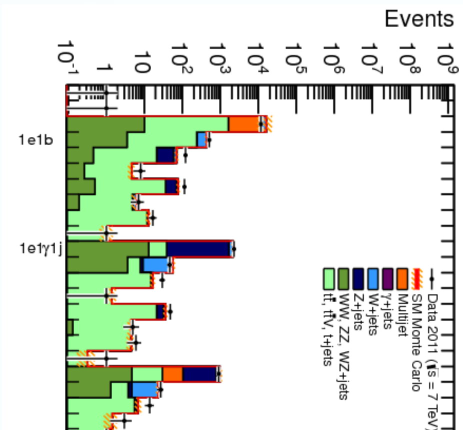
Now working on further improvements on energy and identification (using substructure information). And adding VH ->ττ channel. 2015 will be tough (very high pileup).

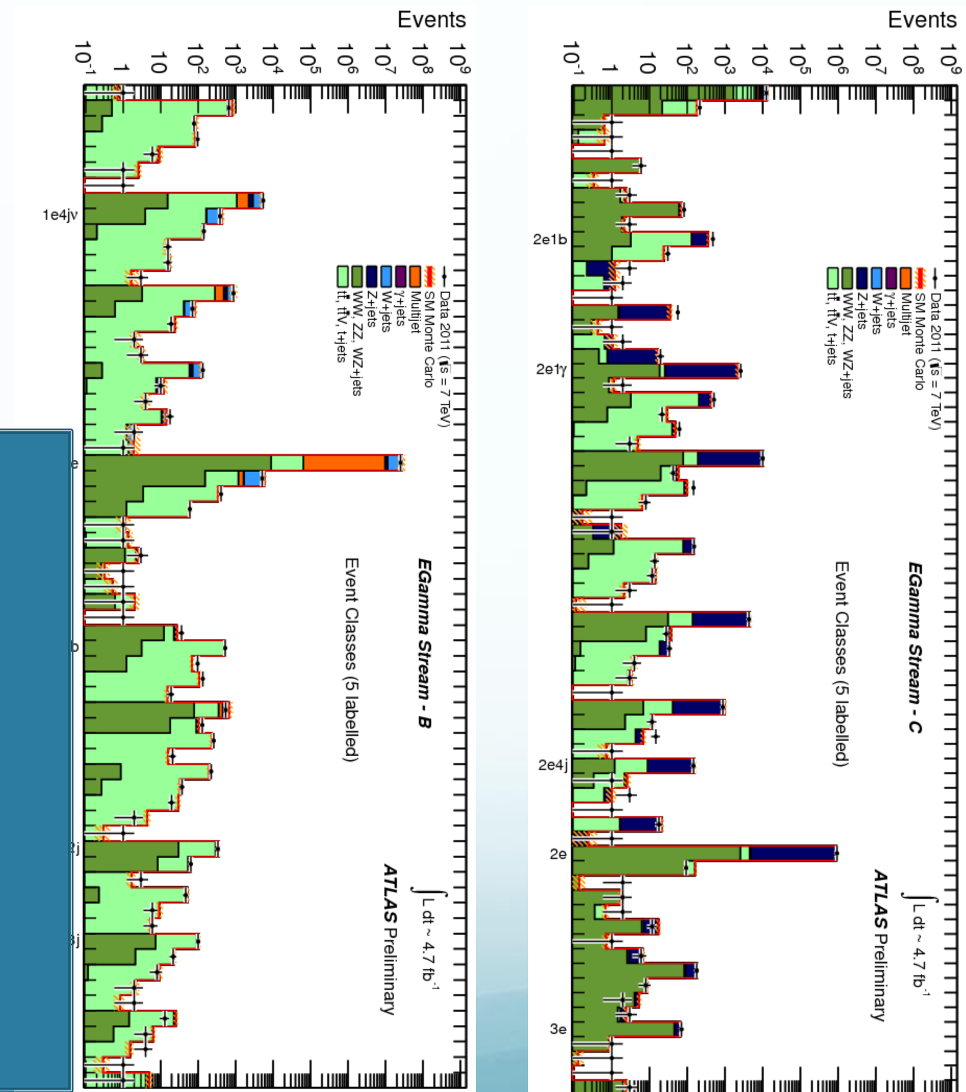
Search for new physics:

- direct or indirect searches
- model dependent or general

Search for new physics

2011 data





Model independent analysis
of all channels with high pt
electron, muon, jet or MET trigger
in all 7 TeV data

➔ Data found in 655 channels
➔ Scan for deviations
➔ Nothing found !

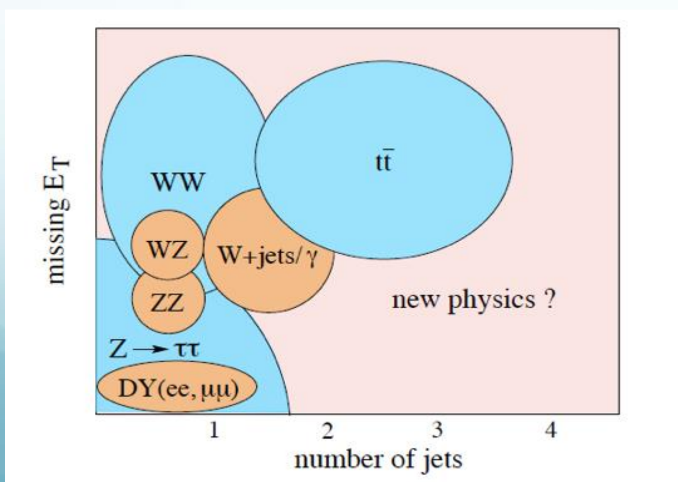
Question is: is this the best way to do this ?

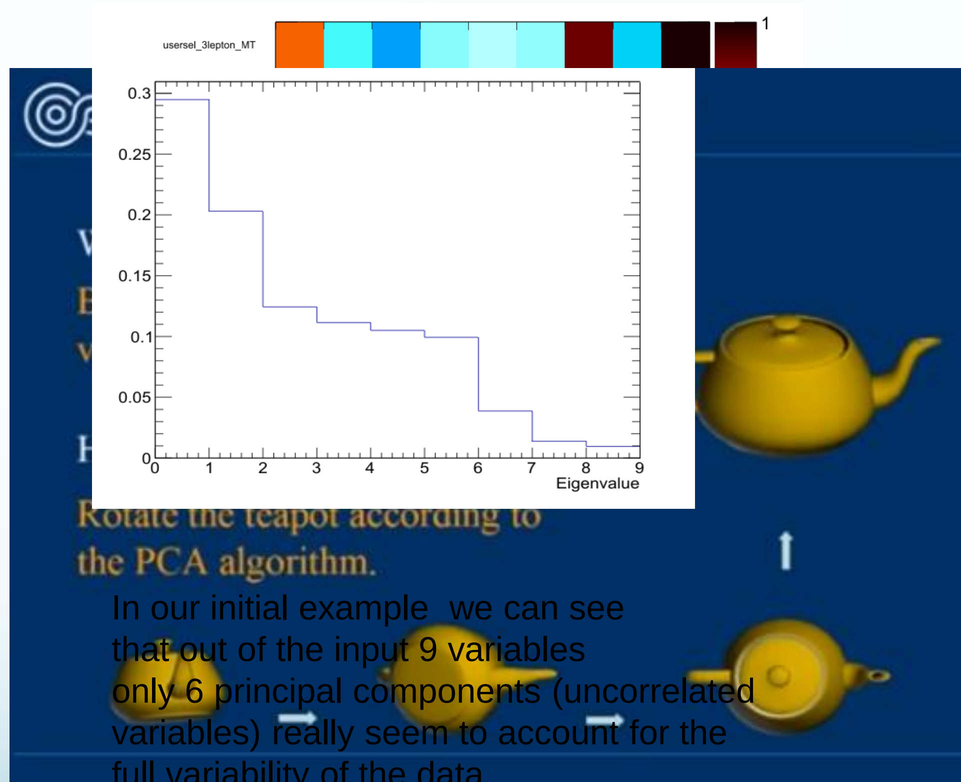
Novel use of statistical methods for general searches in multilepton final states

Using *Principal Component Analysis* to get uncorrelated observables.

Combining several observables into one simultaneous fit will probe a much larger phase-space, and help seeing deviances from the Standard Model.

To probe a larger phase space a “Principal Component Analysis” (PCA) is performed.

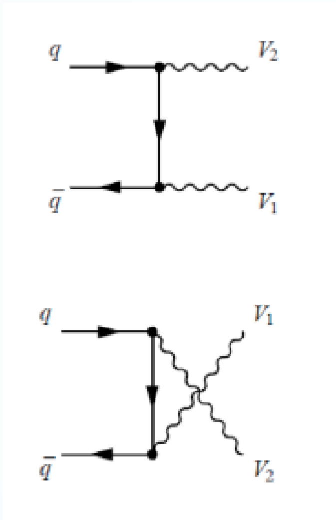




In our initial example we can see that out of the input 9 variables only 6 principal components (uncorrelated variables) really seem to account for the full variability of the data.

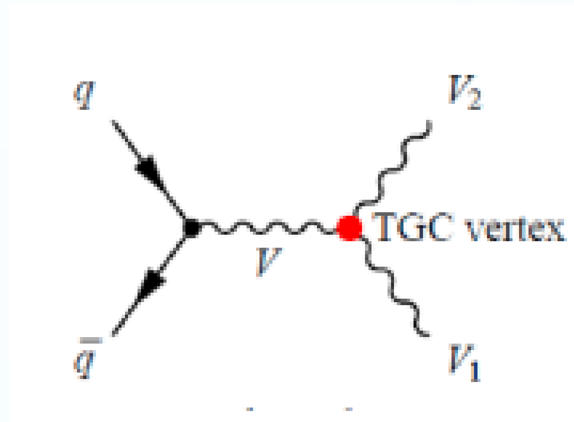
possible, and each succeeding component accounts for as much of the remaining variability as possible.

Triple gauge couplings in ZZ production



SM ☺

V1, V2 = Z



Z

SM : sorry no can't do ☹

Triple Gauge Coupling studies :

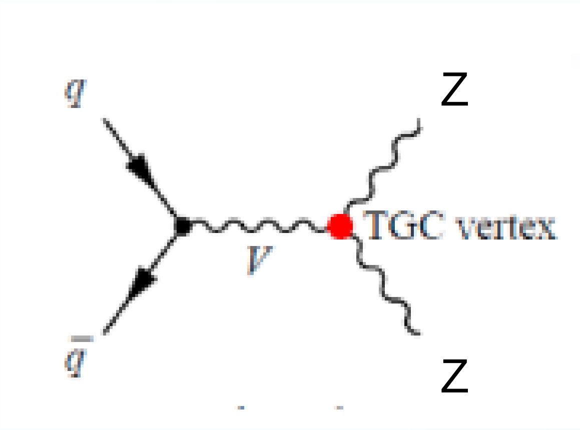
Vector boson self interactions are a fundamental predictions of the SM gauge symmetry

- they are not yet well measured
- neutral couplings do not exist in SM

➔ sensitive to new physics , eg new heavy particles that couple to vector bosons, compositness of the bosons

Triple gauge couplings in ZZ production

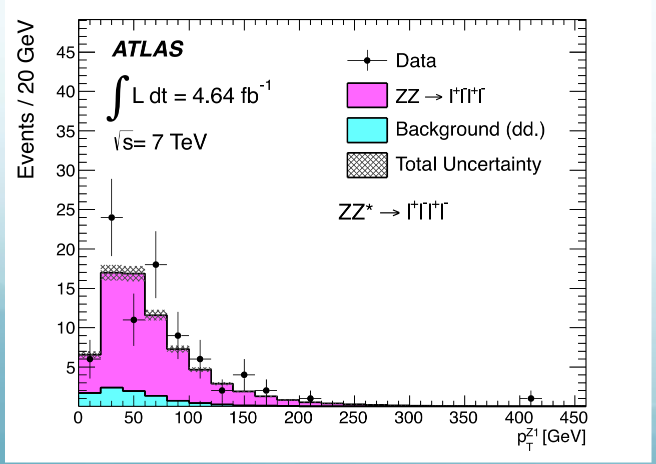
Model independent parametrisation of new physics operating at a much higher scale : parameters f^V_i in an effective lagrangian

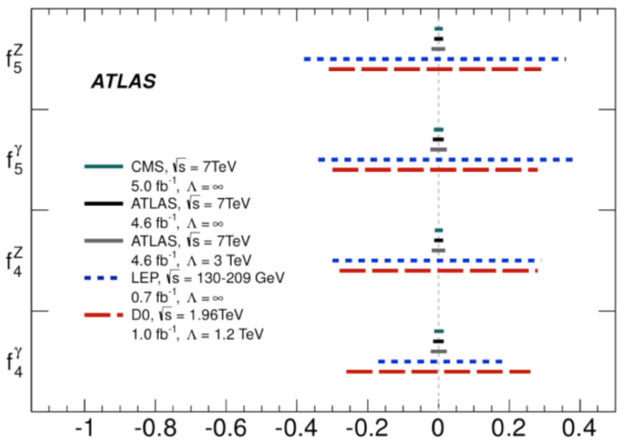


$$\mathcal{L}_{TGC} = \frac{e}{m_Z^2}\left[f_4^V(\partial_\mu V^{\mu\beta})Z_\alpha(\partial^\alpha Z_\beta) + f_5^V(\partial^\sigma V_{\sigma\mu}\tilde{Z}^{\mu\beta}Z_\beta)\right]$$

$$f_i^V \text{ where } V = \{Z,\gamma\} \text{ and } i = \{4,5\}$$

The signature is an enhanced differential cross section at high center of mass energies and large scattering angles.

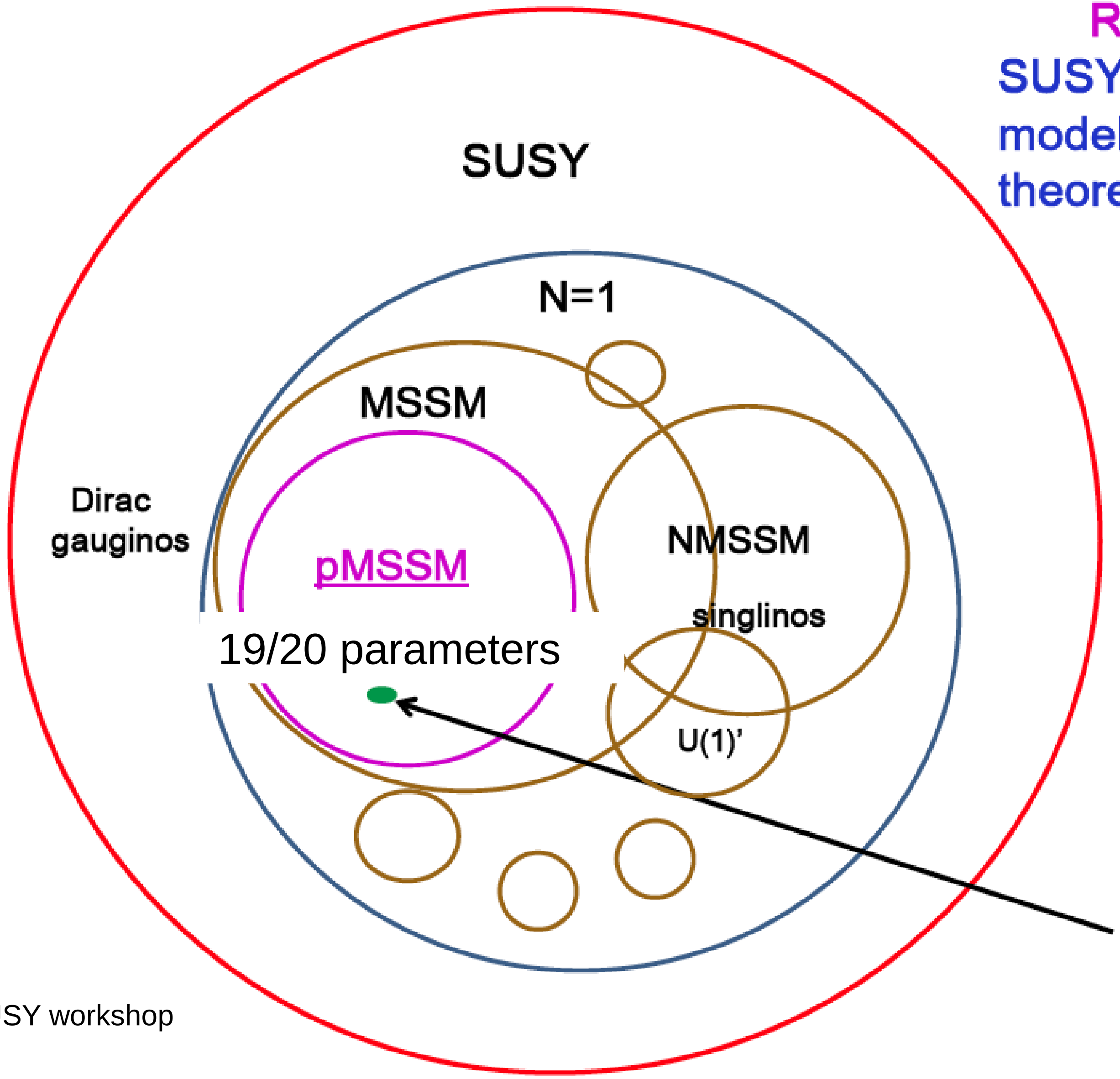




Factor 10 better than Tevatron/LEP

Factor 10 to go to reach SM prediction h.o. diagrams(10^{-3})

SUSY



Reminder:
SUSY is *not* a single model but a very large theoretical framework

These are in trouble now!

mSUGRA
cMSSM quite similar

T.Rizzo
ATLAS SUSY workshop
April 2013

Stable Massive Particles (SMPs)

SMPs are one of the “classical” extentions for BSM physics. One of the largest **loop holes** in covering the (simplified 19 parameter) pMSSM SUSY phase space.

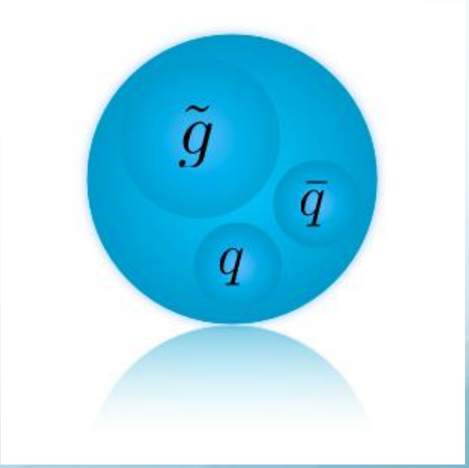
We consider two classes of SMPs:
- R-hadrons (gluino, stop & sbottom)
- Sleptons (stau)

7 TeV Searches

Search	Reference	Fraction Excluded of pMSSM
2-6 jets	ATLAS-CONF-2012-033	21.2%
multijets	ATLAS-CONF-2012-037	1.6%
1-lepton	ATLAS-CONF-2012-041	3.2%
HSCP	1205.0272	4.0%
Disappearing Track	ATLAS-CONF-2012-111	2.6%
Gluino → Stop/Sbottom	1207.4686	4.9%
Very Light Stop	ATLAS-CONF-2012-059	<0.1%
Medium Stop	ATLAS-CONF-2012-071	0.3%
Heavy Stop (0l)	1208.1447	3.7%

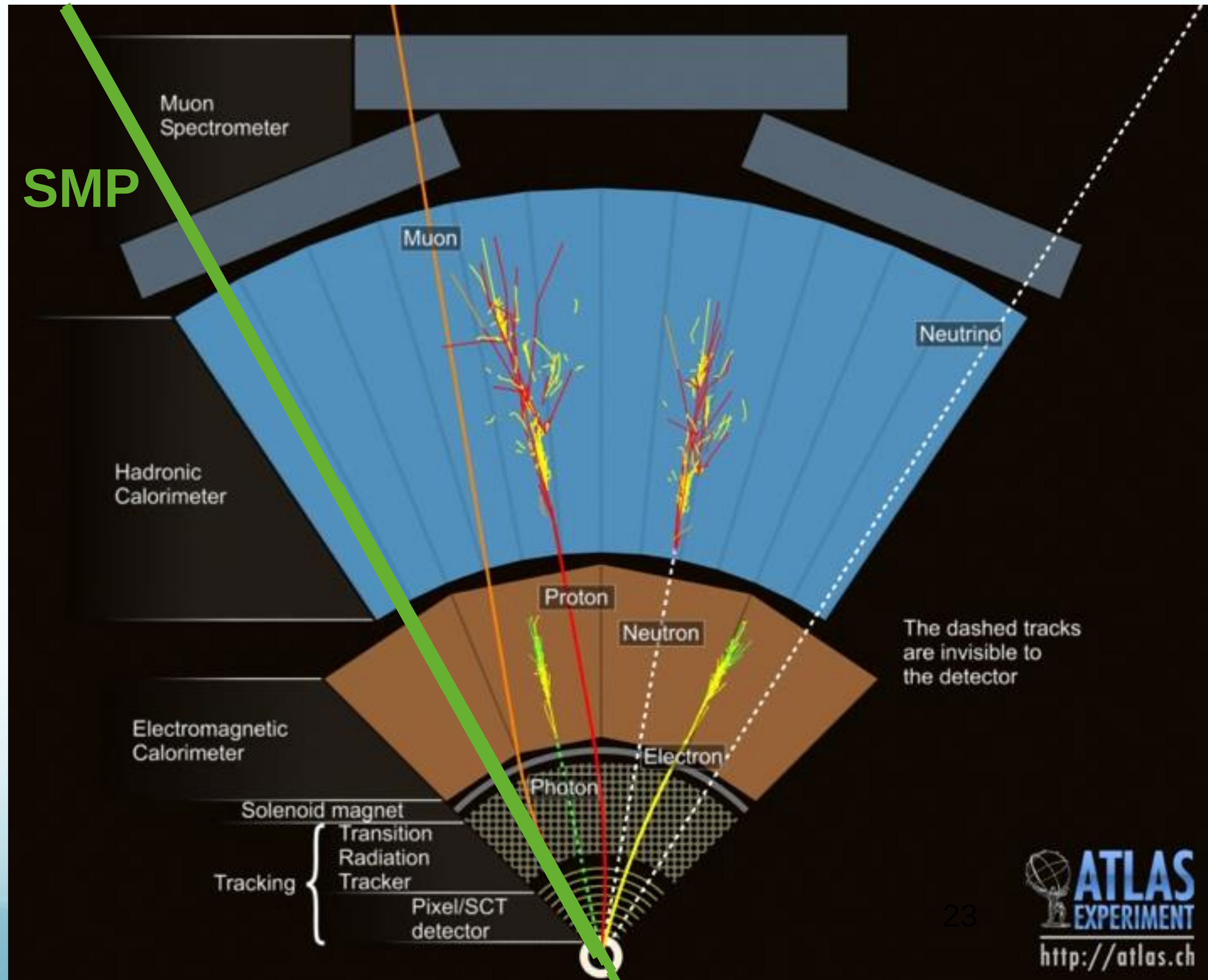
Preliminary

Heavy Stable Charged Particles (SMPs)



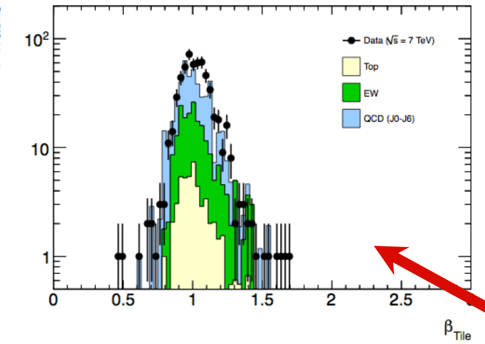
Stable heavy particles in detector

- [redacted] **ID+MS**
  [redacted]ns,
  [redacted]s)
- [redacted] **MS only**
  [redacted]ns)
- [redacted] **D only**
  [redacted]s,
  [redacted] *with*
  [redacted]*times*)

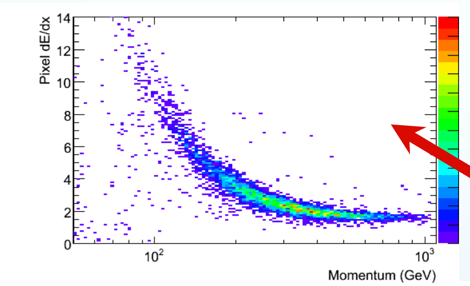


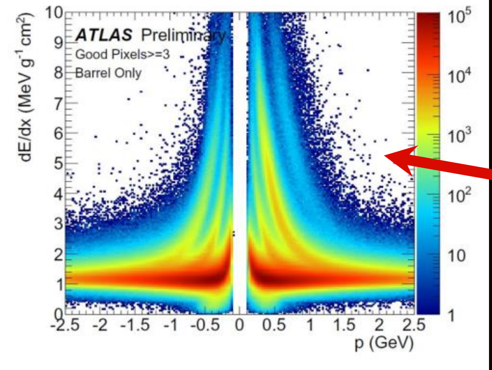
Stable heavy particles in detector

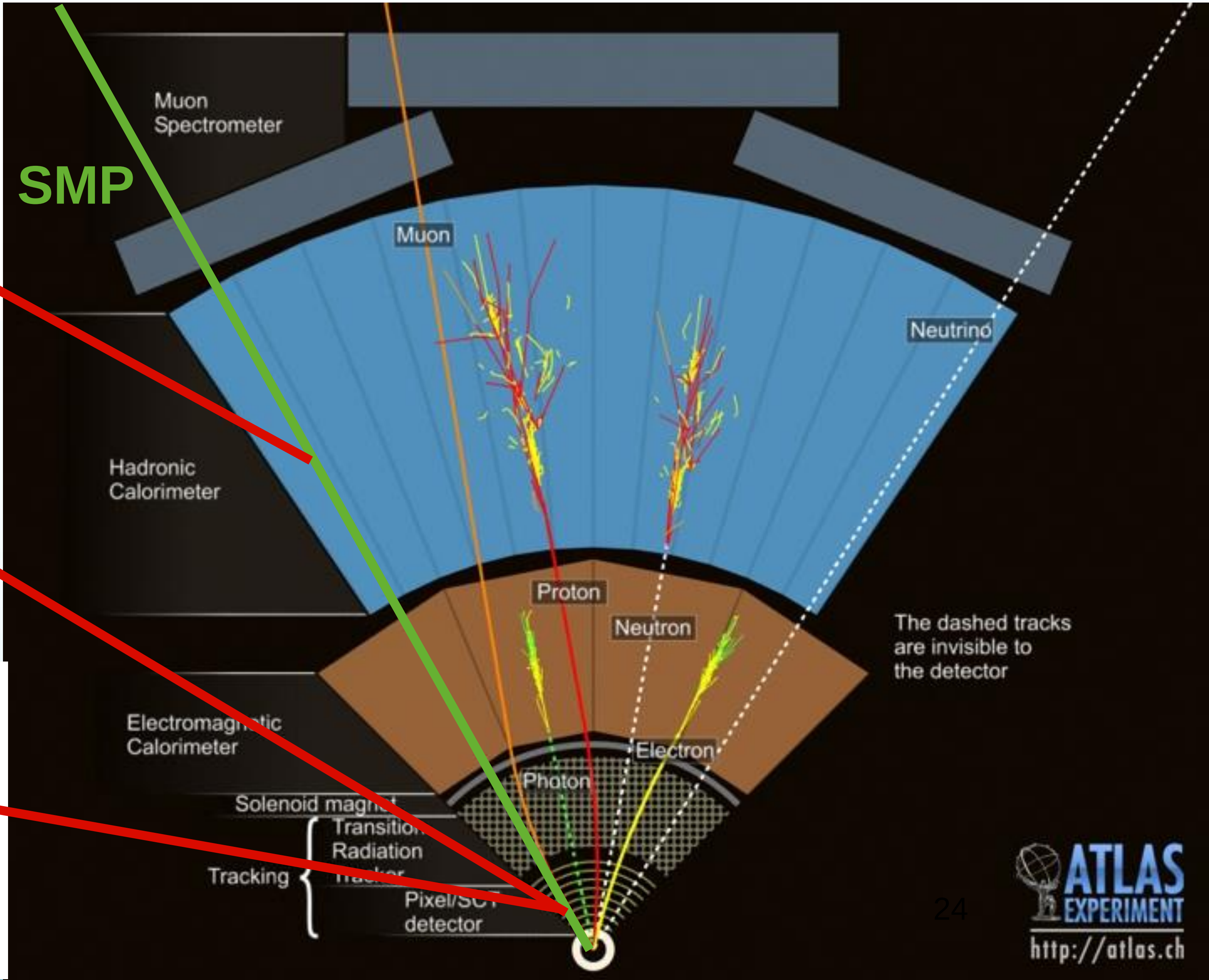
Tile (or LAr):



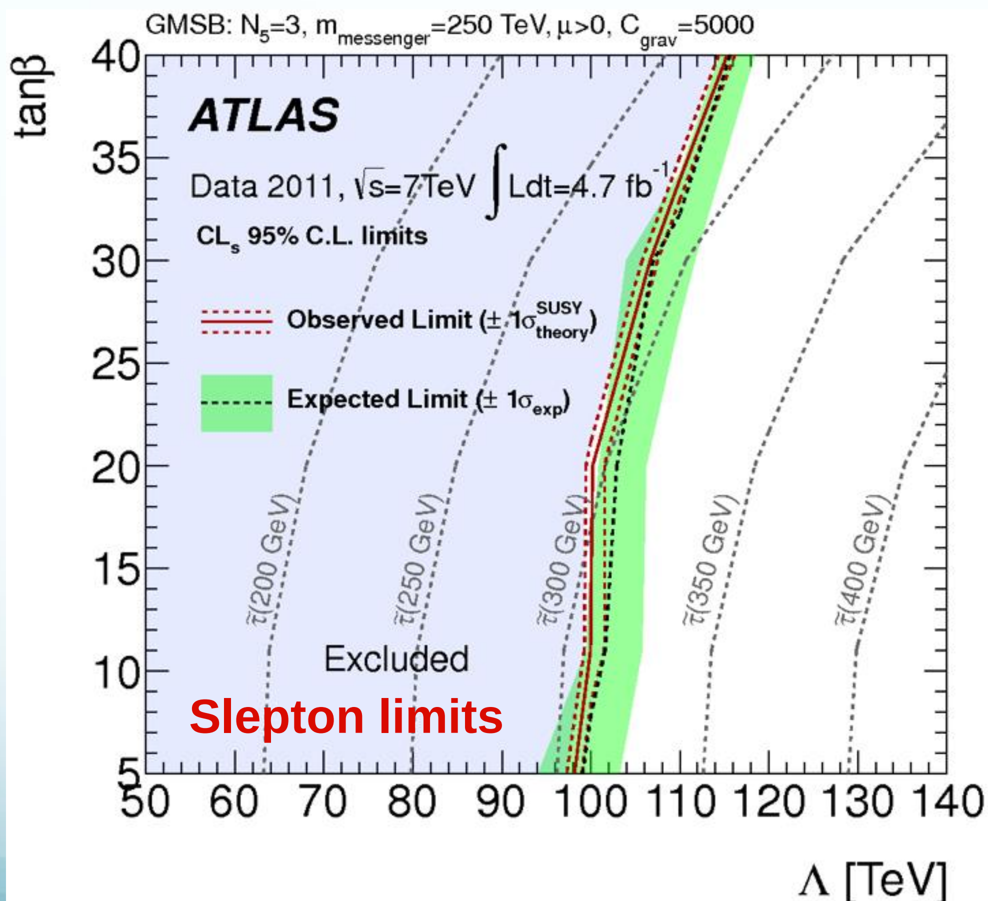
Pixel:

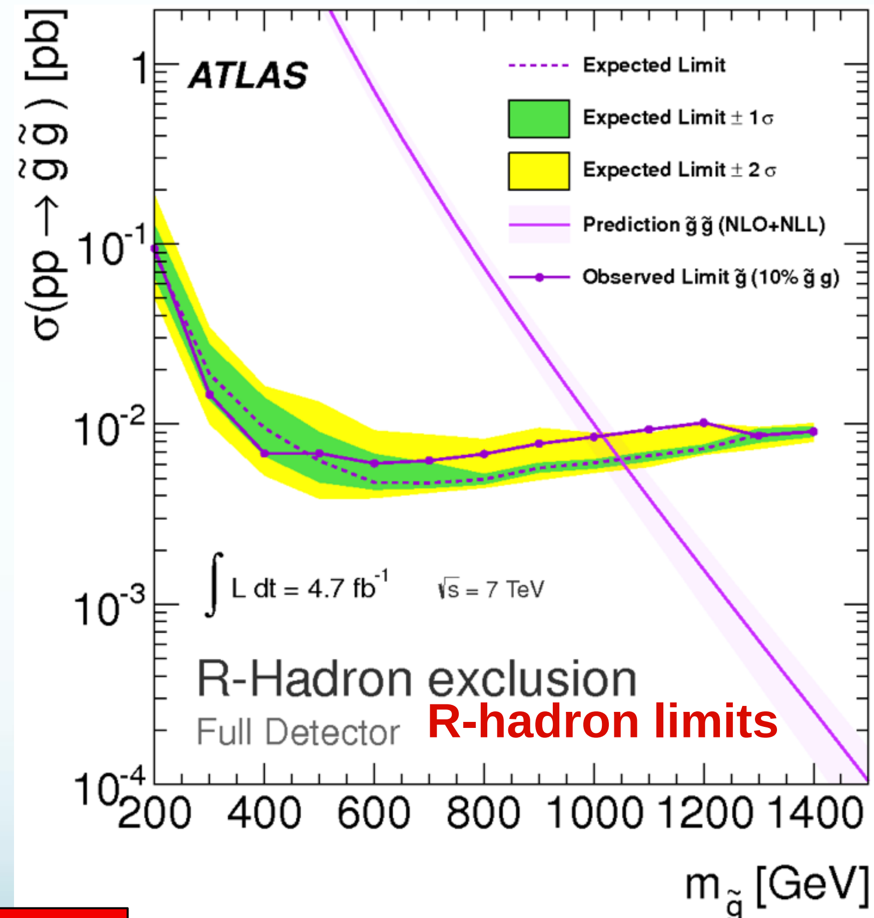






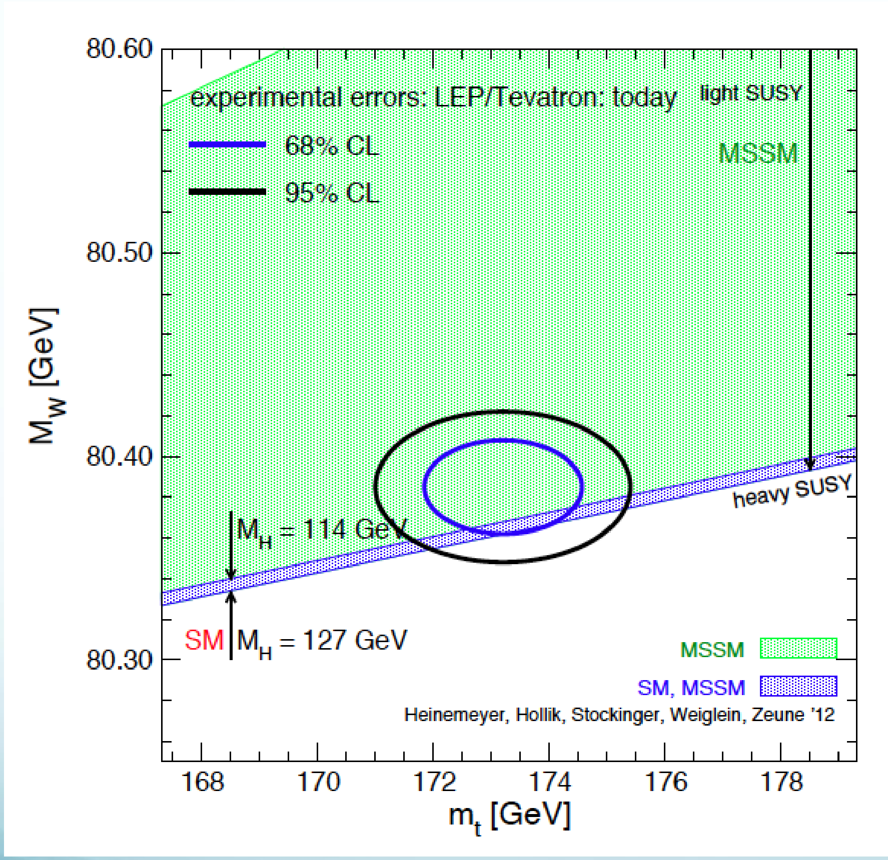
SMPs results





[redacted] 986 (940) GeV
[redacted]: 683 and 612 GeV
[redacted] 278 GeV

Indirect searches for new physics



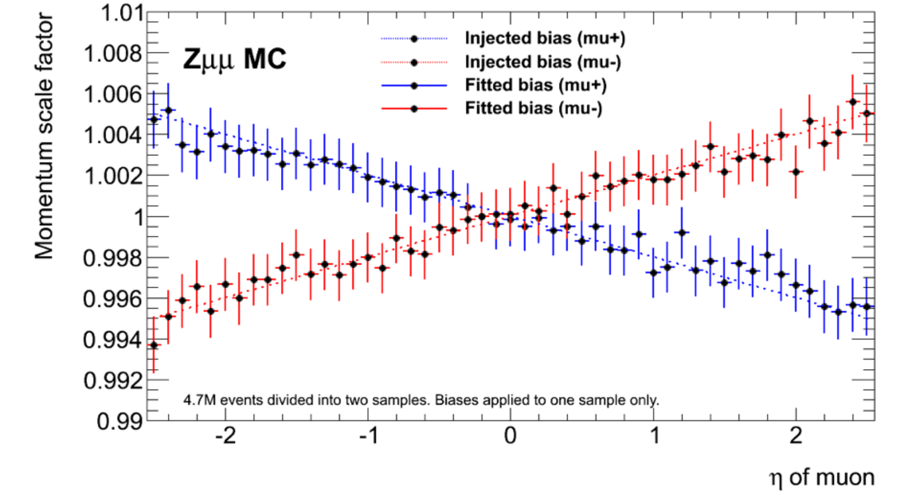
"The W mass is probably the most powerful indirect probe for new physics" (T.Petersen)

Current world average is $m(W)$ = **80385 ± 15 MeV**, dominated by Tevatron results.

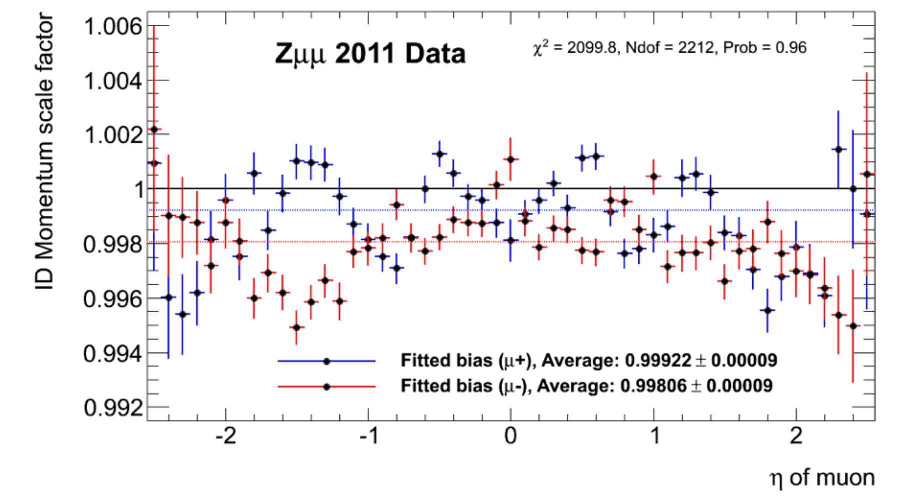
Dominating uncertainties: **lepton scale** and **PDFs**, **both improvable at LHC**!

W mass

Closure test on MC:



Result on data:



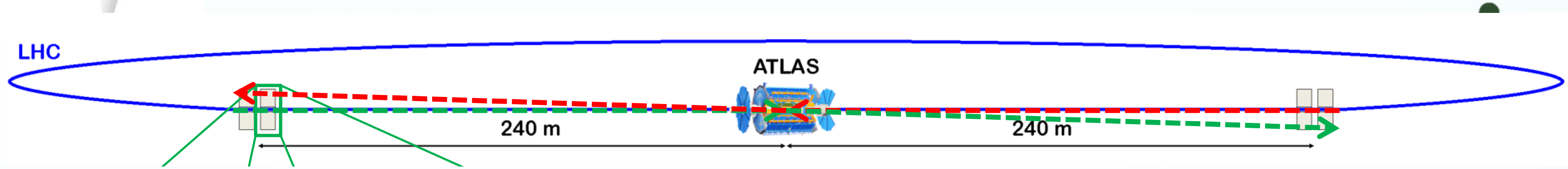
At LHC using Z-peak in new differential methods we can get muon momentum scale uncertainty to 7 MeV using 20% of data.

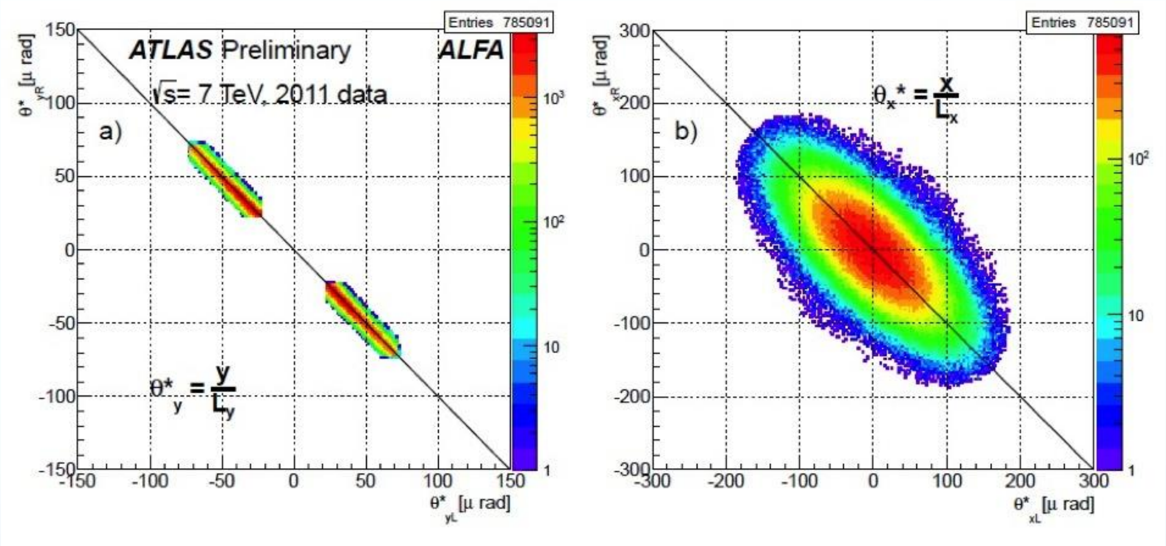
The LHC use of Z-peak for calibration gives further cancellations in PDF errors through correlations between W & Z (PDF variations moving mW also move mZ!).

ATLAS target m(W) precision: Below 10 MeV

[Eur.Phys.J. C57 (2008) 627-651]

Luminosity





Forward Proton Tagger ALFA : Roman pots with scintillating fiber trackers (30 μm). Trigger & operations joint Copenhagen-CERN project.

Elastic scattering at low t -> inelastic-> luminosity (using Totem the total cross section)

Combine ALFA with ATLAS to study diffraction

Run 2 and beyond

LHC timeline

centre for particle physics Discovery

2009 — LHC start up, $\sqrt{s}$ = 900 GeV

2010, 2011, 2012 — $\sqrt{s}$ = 7-8 TeV , L = 6 to $8 \cdot 10^{33}$ $cm^{-2}s^{-1}$, bunch spacing **50 ns** — ~25 fb^{-1}

2013, 2014 — LS1 — Go to design energy, nominal luminosity

2015, 2016, 2017 — $\sqrt{s}$ = 13-14 TeV, L = $1 \cdot 10^{34}$ $cm^{-2}s^{-1}$, bunch spacing **25 ns** **(likely to be more)** — ~50 fb^{-1}

2018 — LS2 — Injector & LHC Phase I upgrade to full design luminosity

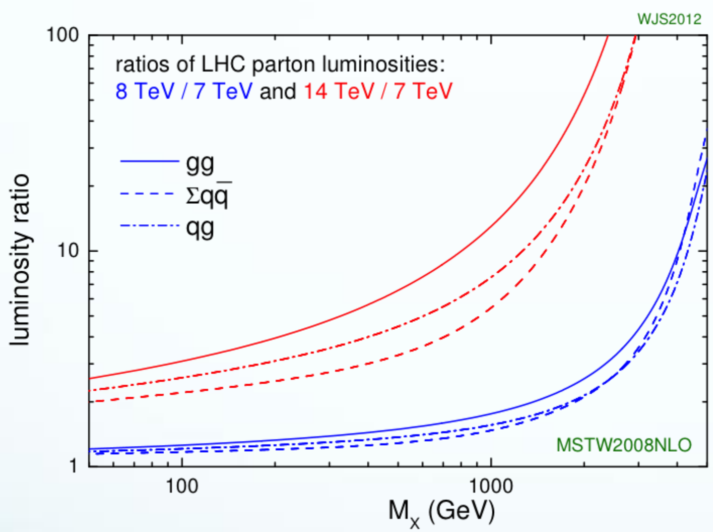
2019, 2020, 2021 — $\sqrt{s}$ = 14 TeV, L = $2 \cdot 10^{34}$ $cm^{-2}s^{-1}$, bunch spacing **25 ns** **(likely to be more)** — ~300 fb^{-1}

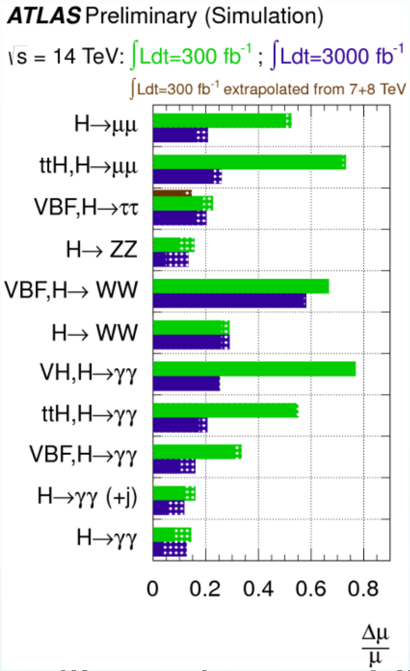
2022 — LS3 — HL-LHC Phase-2 upgrade, crab cavities?, IR

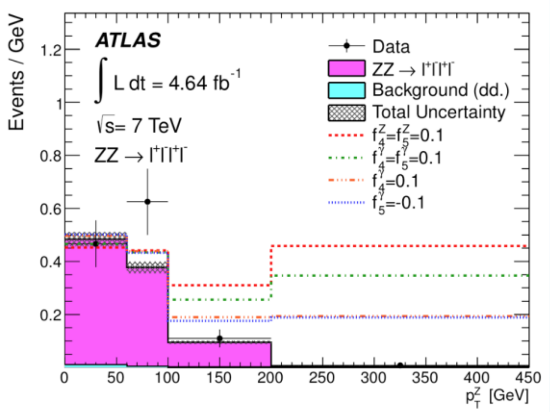
2023 – 2030? — $\sqrt{s}$ = 14 TeV, L = $5 \cdot 10^{34}$ $cm^{-2}s^{-1}$, bunch spacing **25 ns** **Plan for 50% more** — ~3000 fb^{-1}

NBI Plans for Physics searches 14 TeV

TGC : 8->14 TeV x 4
higher lumi x2







Fantastic opportunity to enlarge the reach for new physics searches e.g. SMPs

Still need to establish
discovery in tau tau Higgs decay channel.
Access low rate Higgs decays
and measure properties precisely.

NBI contribution to ATLAS upgrade

Long Shutdown 1:

1. Improve L1 trigger readout rate to 100kHz
2. Improve speed of calorimeter HLT algorithms, assess need of a L4 trigger
3. Upgrade the ALFA electronics to run with 2015 ATLAS trigger

Long Shutdown 2 :

1. New muon small wheels with more trigger granularity and trigger track vector information
2. Forward physics detection station at 220m for new diffractive physics - AFP (full 3D edgeless and timing detectors)

Summary

2010-2012 have been amazing three years!

Hard work but exciting and satisfying!

In Run1 the ATLAS NBI group has :

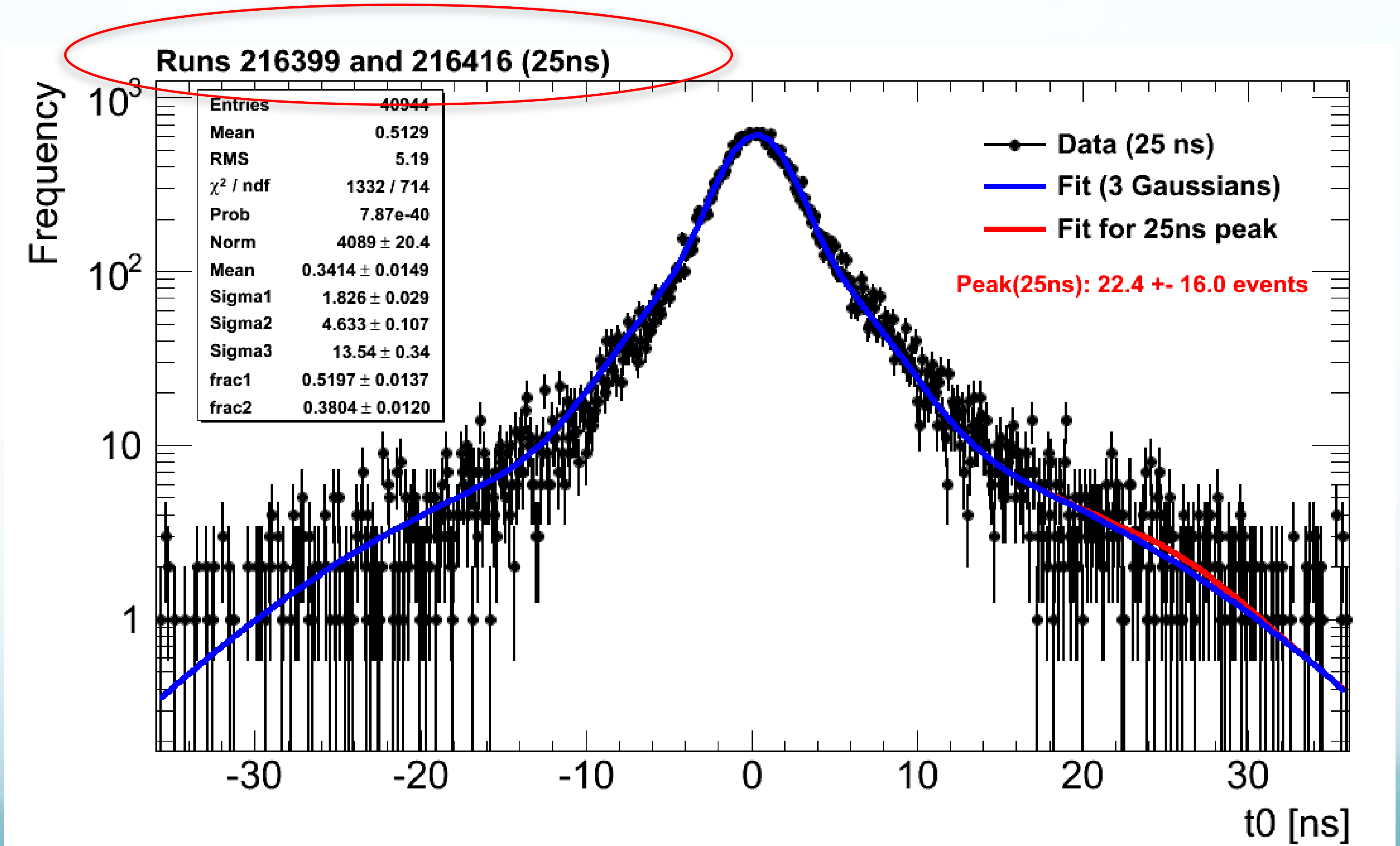
- contributed significantly to ensuring good physics results could be extracted from the LHC pp data : trigger, tracking, particle identification, luminosity.
- Had fun using the data to find the Higgs, look for new physics, and in general try to answer the important open questions in particle physics.

We are now ready to pull up our sleaves and help getting ready for the next exciting step: 2015 Run 2 period.

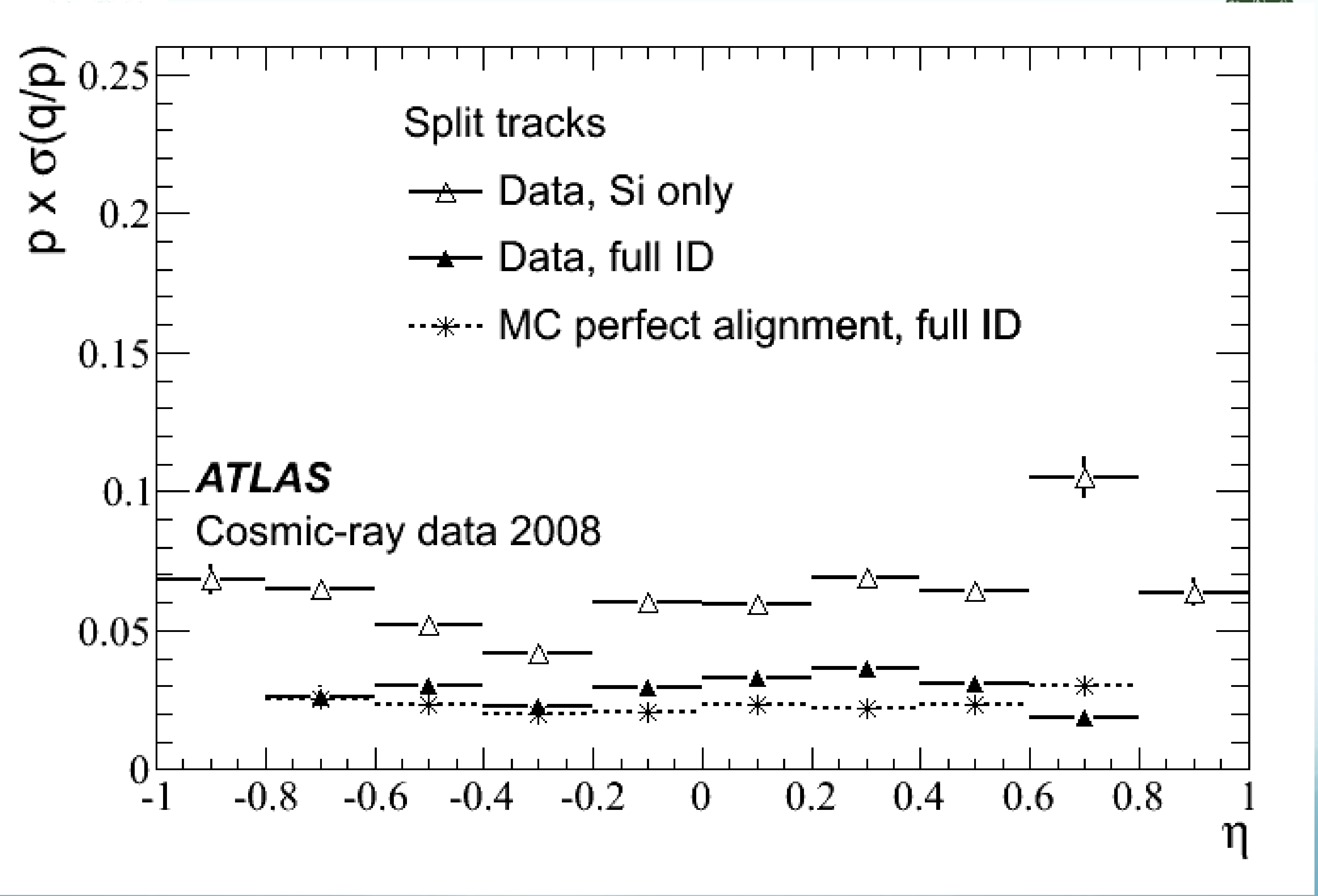
CERN and ATLAS is the place to be for the next many years ! That's where we get answers to our fundamental questions about Nature

backup

SMPs results: how is the future?



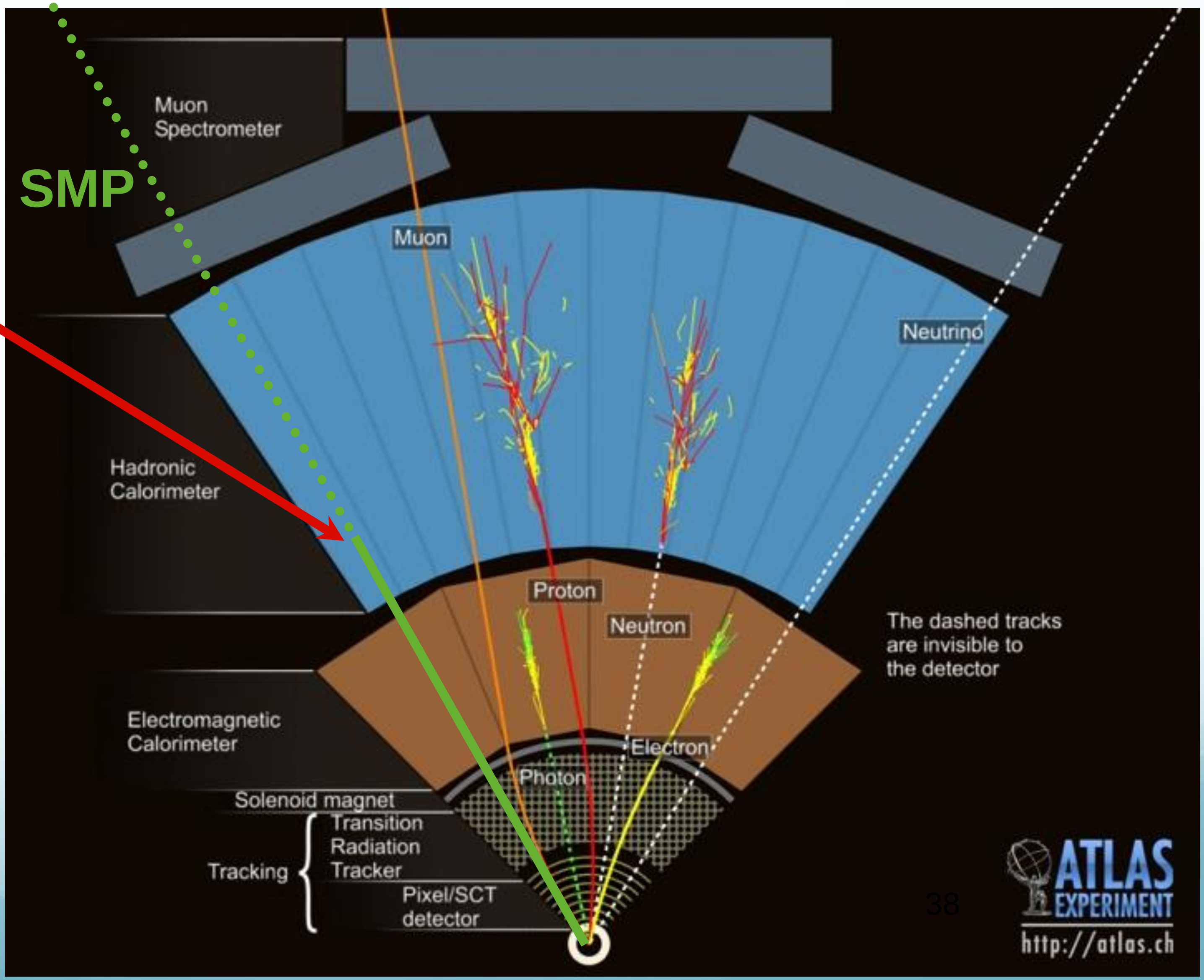
No significant out-of-time background is seen with this data...

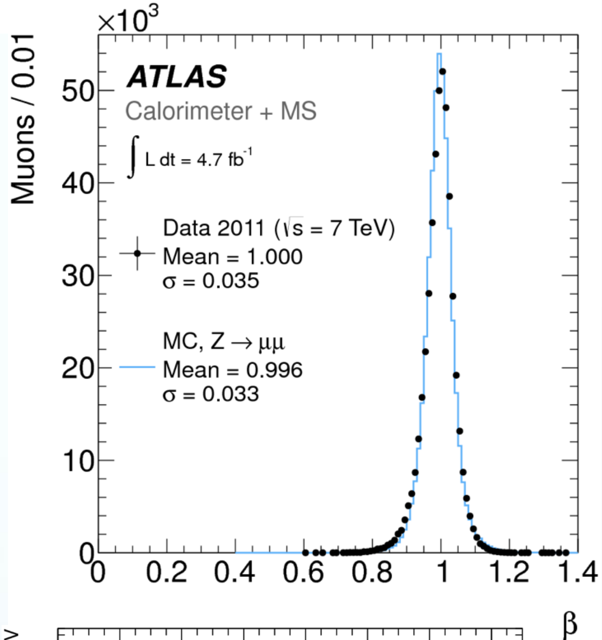


Split tracks
Data, Si only
Data, full ID
MC perfect alignment, full ID
ATLAS
Cosmic-ray data 2008
p x σ(q/p)
0.25
0.2
0.15
0.1
0.05
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
η

Stable heavy particles in detector

Stable charged R-hadron, becoming neutral in hadronic interaction!





Three measurements

p, **β** and **βγ**

through relation

$\mathbf{m = p/\beta\gamma}$

combines to two masses

$\mathbf{m_\beta}$ and $\mathbf{m_{\beta\gamma}}$

to our signal region (SR):