Flavor Physics with ATLAS
Status and Perspectives

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on behalf of the ATLAS collaboration

Flavor Physics and CP Violation 2010
May 25-29, 2010
Torino - Italy

B-Physics time-line program

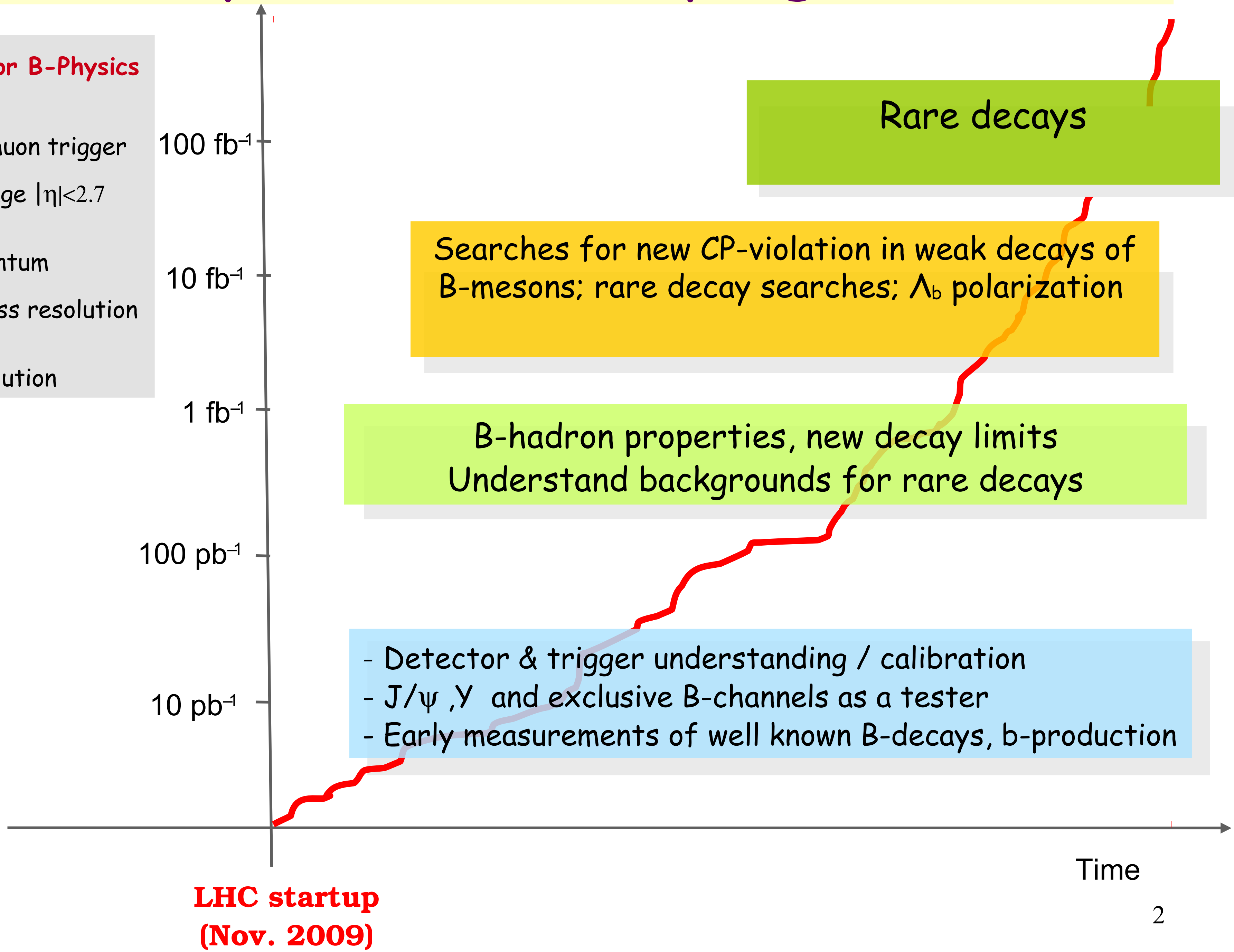
Key elements for B-Physics searches:

Efficient low pt muon trigger

Good muon coverage $|\eta|<2.7$

Good track momentum resolution and mass resolution

Good vertex resolution

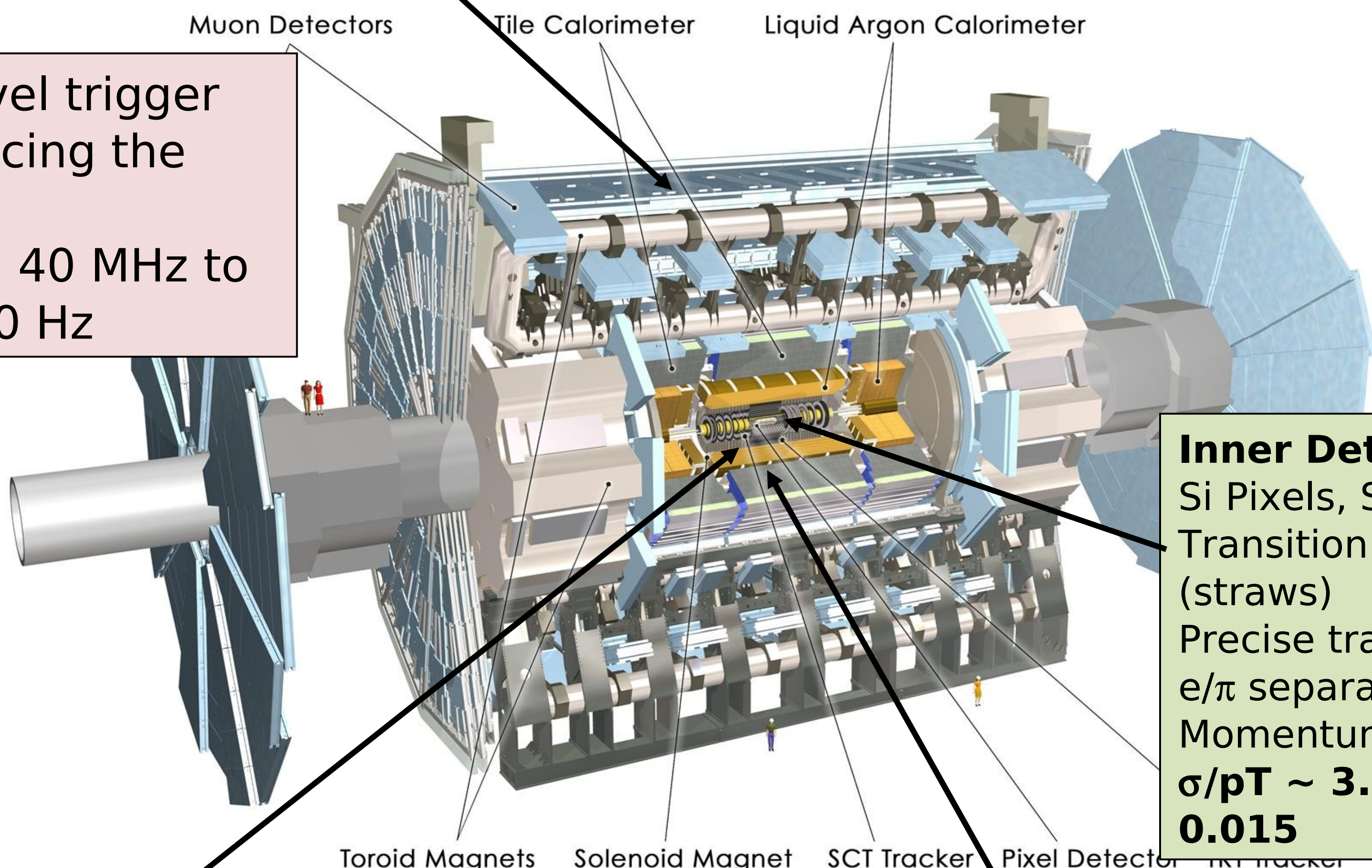


The Atlas Detector

Muon Spectrometer ($|\eta|<2.7$) : air-core toroids with gas-based muon chambers
Muon trigger and measurement with **momentum resolution < 10% up to E_μ ~ 1 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
3000 km of cables

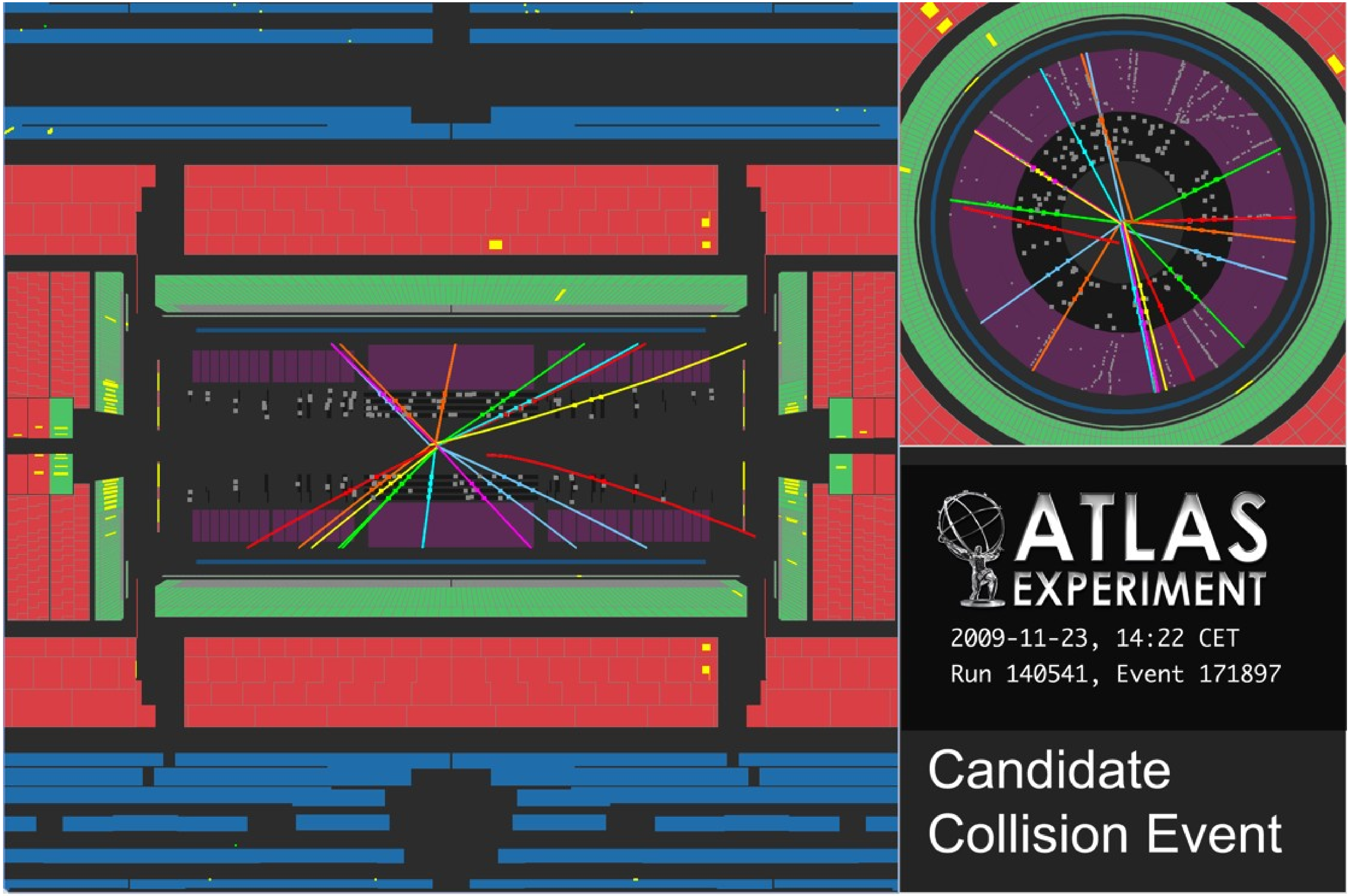


Inner Detector ($|\eta|<2.5$, B=2T):
Si Pixels, Si strips,
Transition Radiation detector (straws)
Precise tracking and vertexing,
e/π separation
Momentum resolution:
$\sigma/p_T \sim 3.8\times10^{-4}\ p_T\ (\mathrm{GeV}) \oplus 0.015$

EM calorimeter: Pb-LAr Accordion
e/γ trigger, identification and measurement
E-resolution: $\sigma/E \sim 10\%/\sqrt{E}$

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

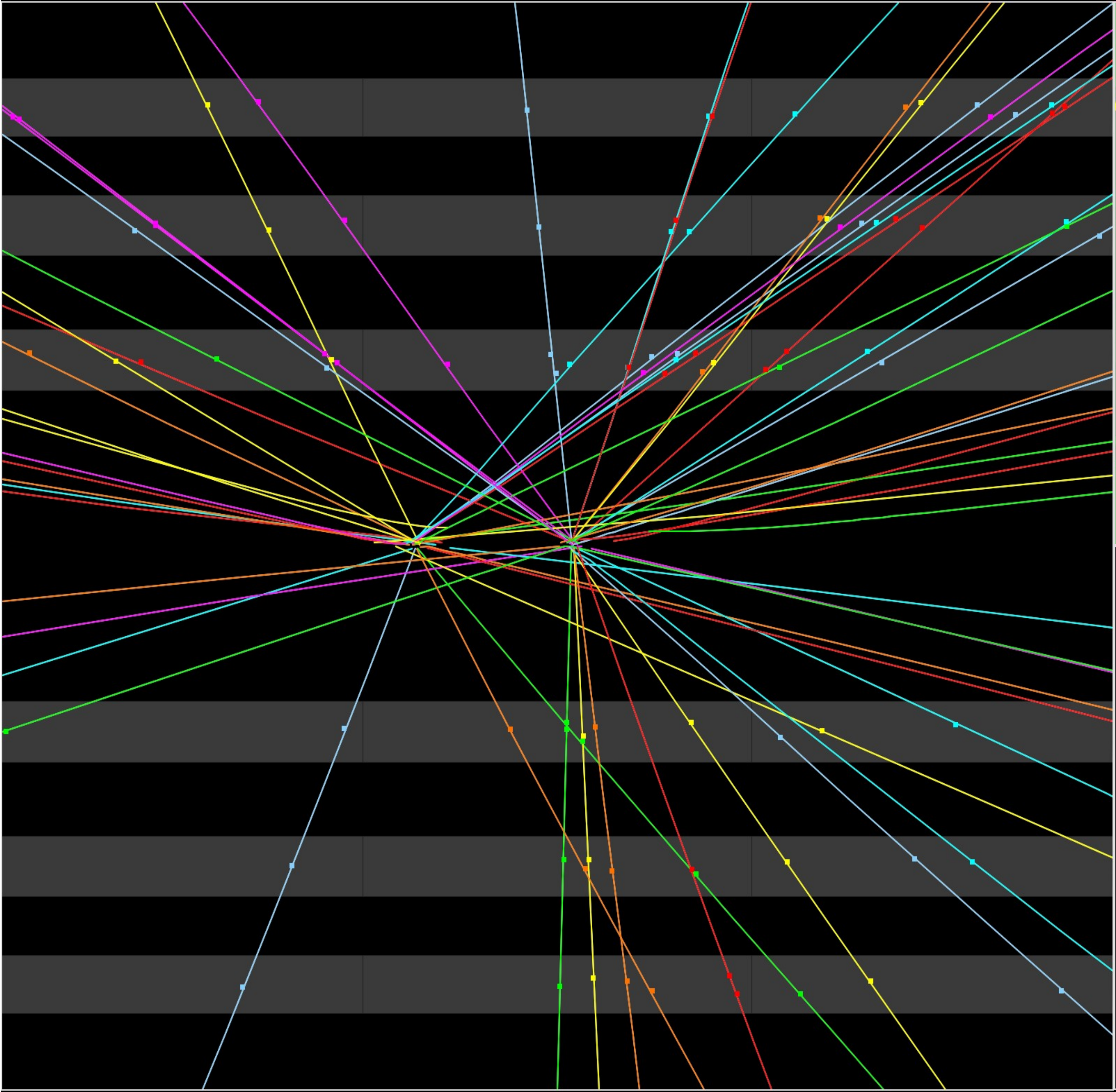
First observed collision candidate at 900 GeV, Nov 23 2009

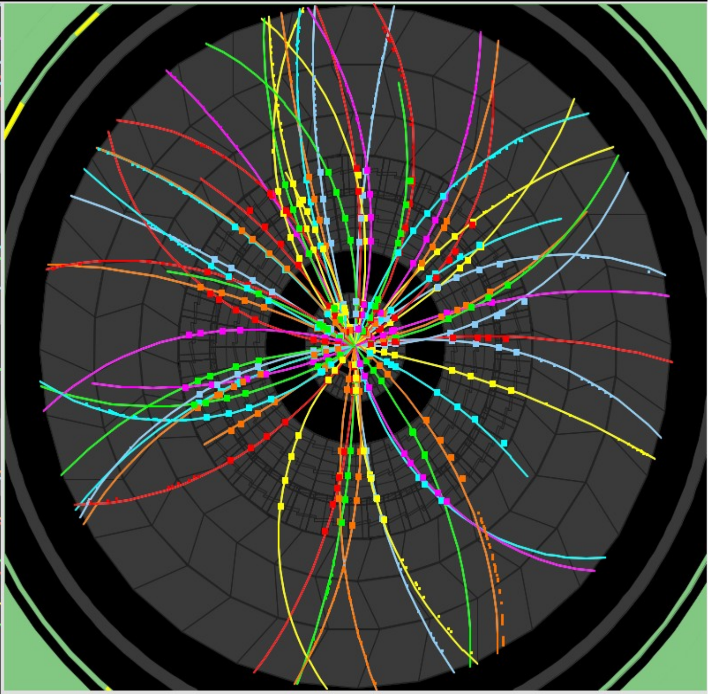


http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

Note: Solenoid off and Si detectors off or at reduced voltage (no stable beam)

Collision Event at 7 TeV with 2 Pile Up Vertices





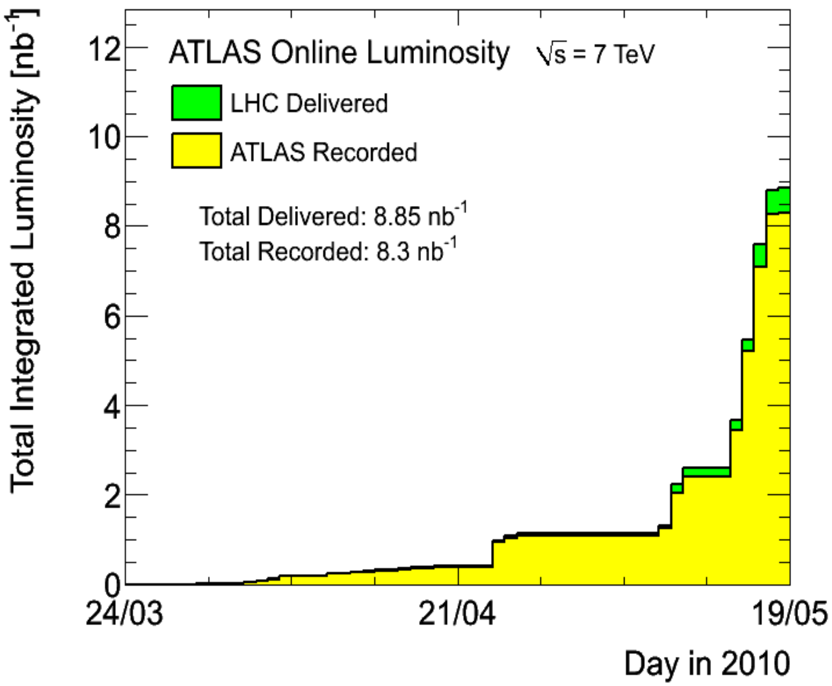
ATLAS EXPERIMENT

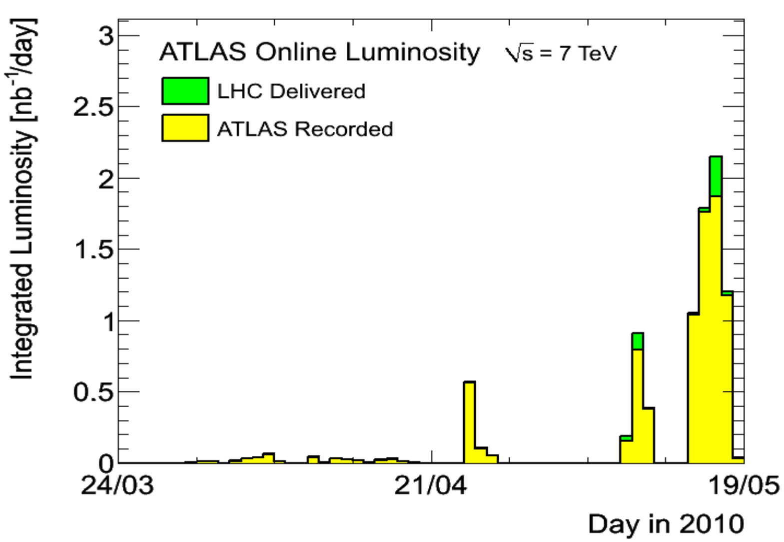
Run Number: 152166, Event Number: 467774

Date: 2010-03-30 13:31:46 CEST

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

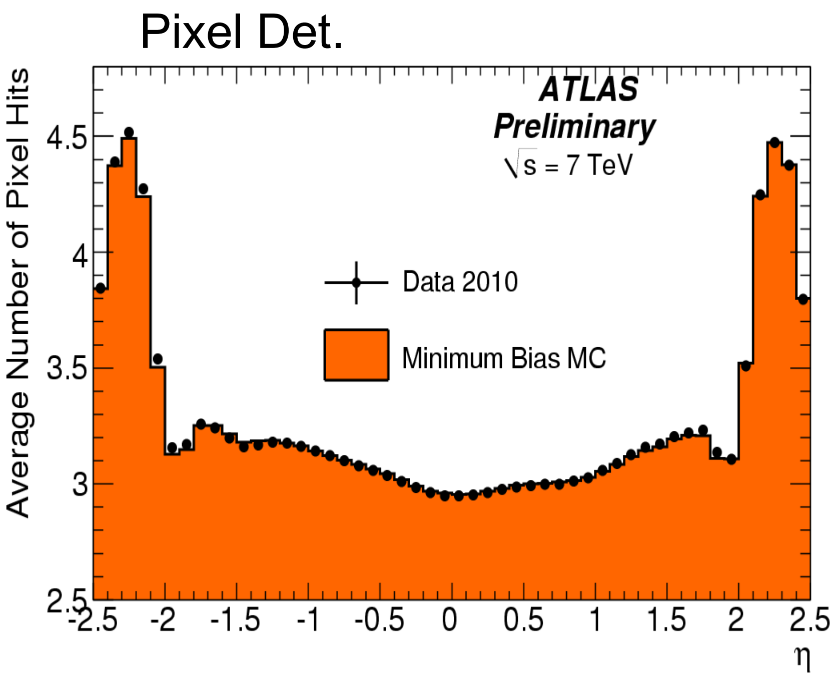
Overall Statistics for 7 TeV Collisions

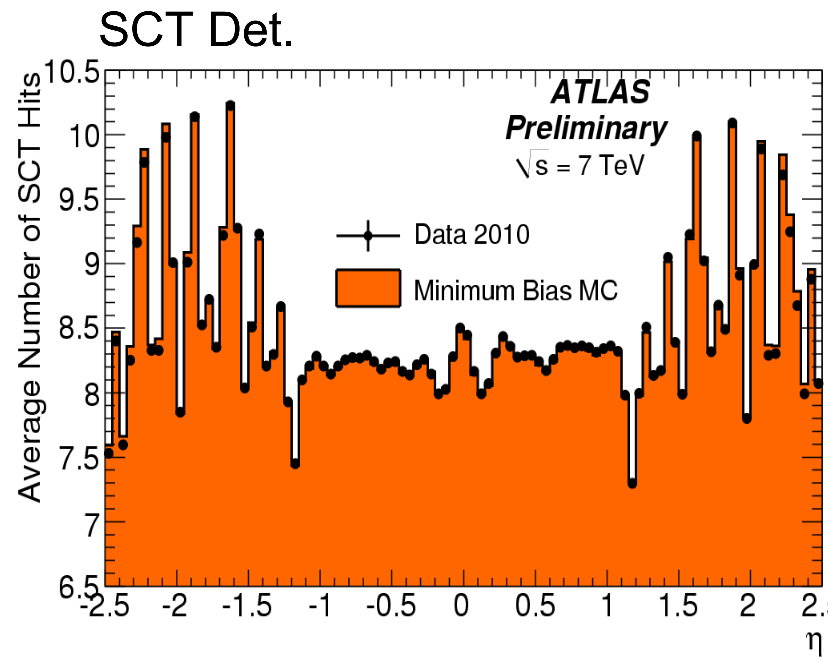




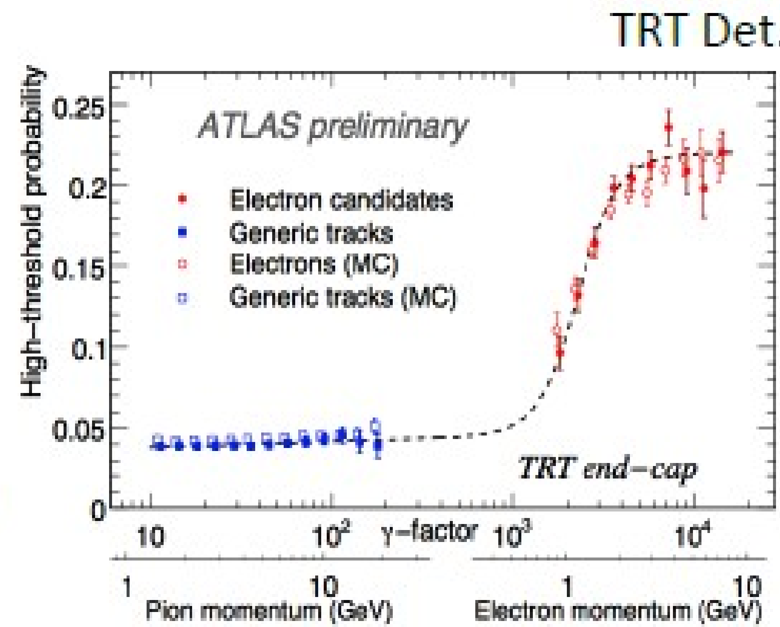
- Consider period from 30-March till 19 May (31 runs)
- Instantaneous luminosity L derived from:
  - MBTS (trigger scintillators at ±3.5m from IP) double-side coincidence trigger rate
  - LAr offline event selection (coincidence of in-time end-cap energy deposits)
  - Measurement from dedicated LUCID forward detectors, at ±17m from IP
  - Present overall L scale uncertainty ~20% from systematic uncertainties (MC cross-section)
- Total luminosity about 8.3 nb-1
- 94 % of luminosity delivered with Stable Beams was recorded by ATLAS

Tracking : Data/Simulation Agreement



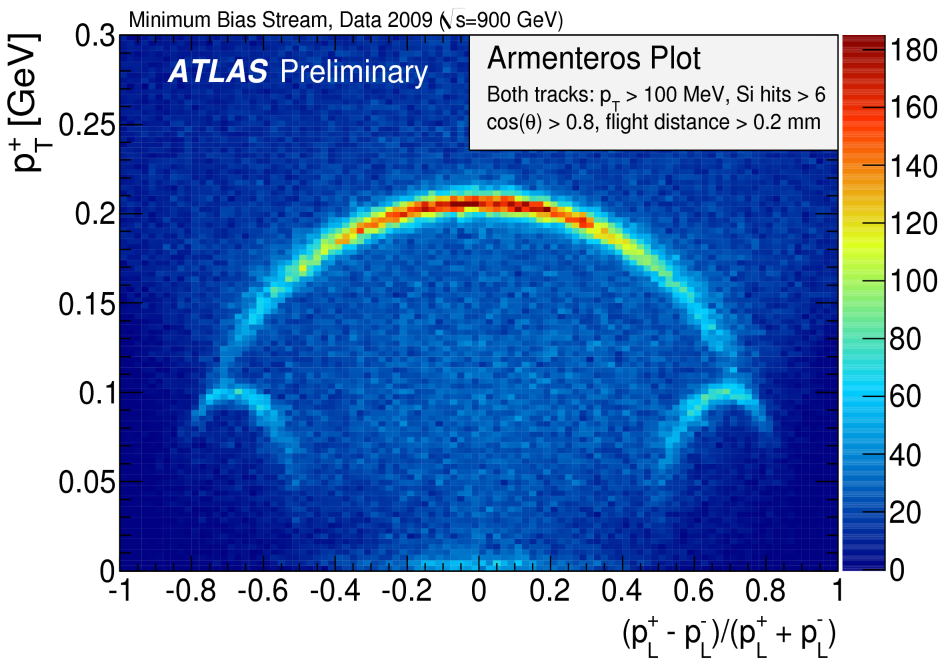


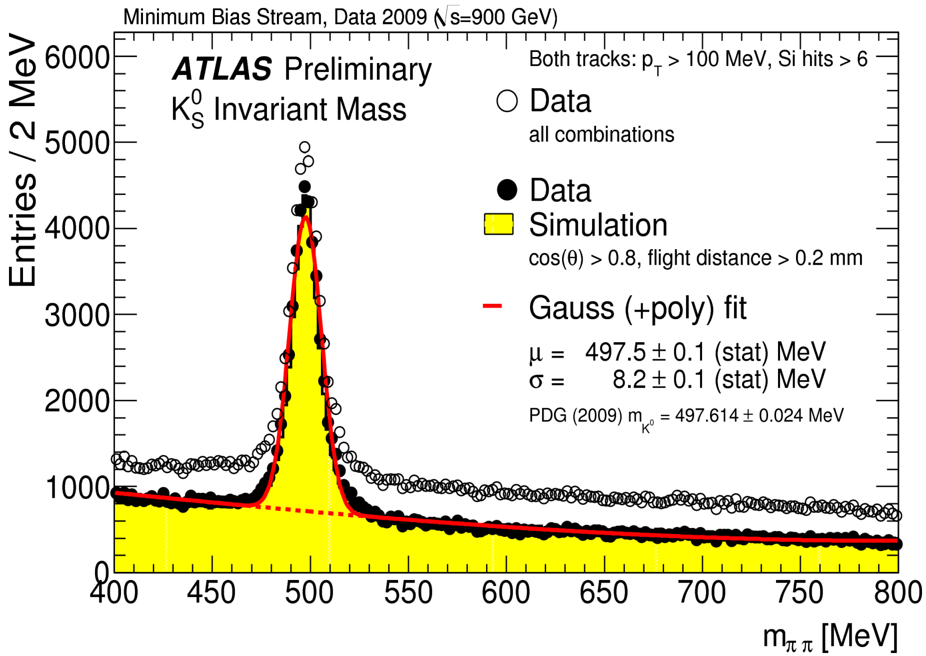
- Detailed studies comparing data/MC
- dedicated care that Monte Carlo samples reflect conditions during data taking (*beam spot position, inactive modules, noisy channels)*
- In general, there is an excellent agreement between data and Monte Carlo

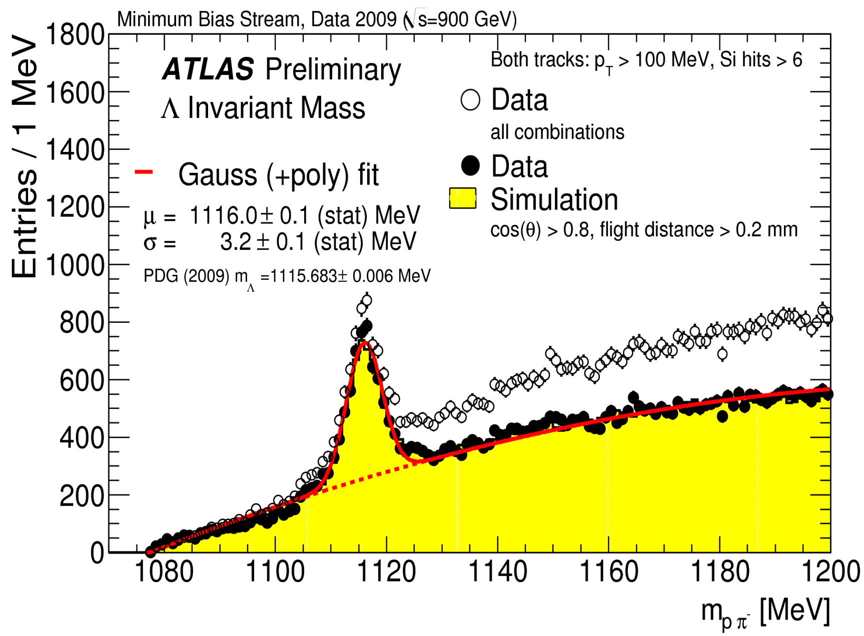


Mass Peaks in Minimum Bias Data

- Weak decay reconstruction provides a stringent test of tracking performance
  - reconstructed Ks and Λ masses close to PDG value
  - width of the invariant mass peaks well reproduced by Monte Carlo

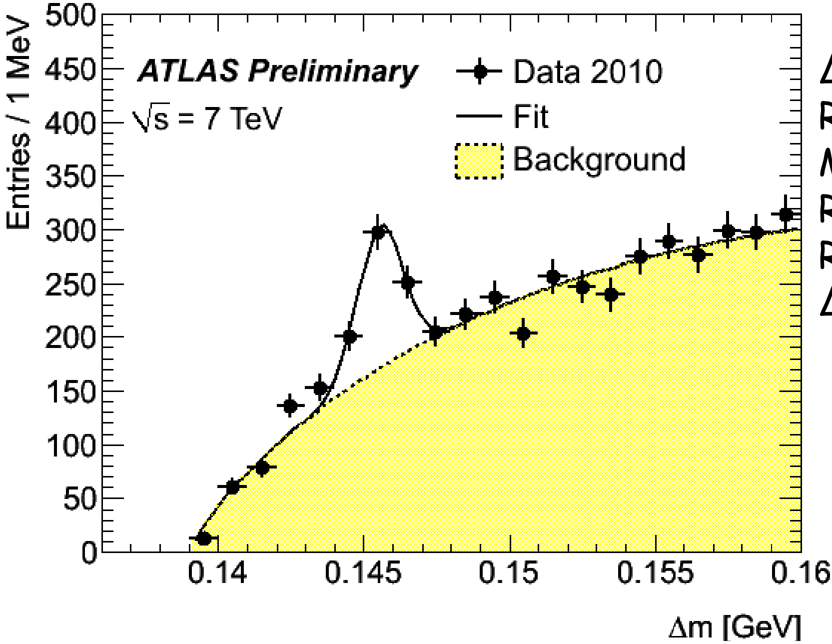




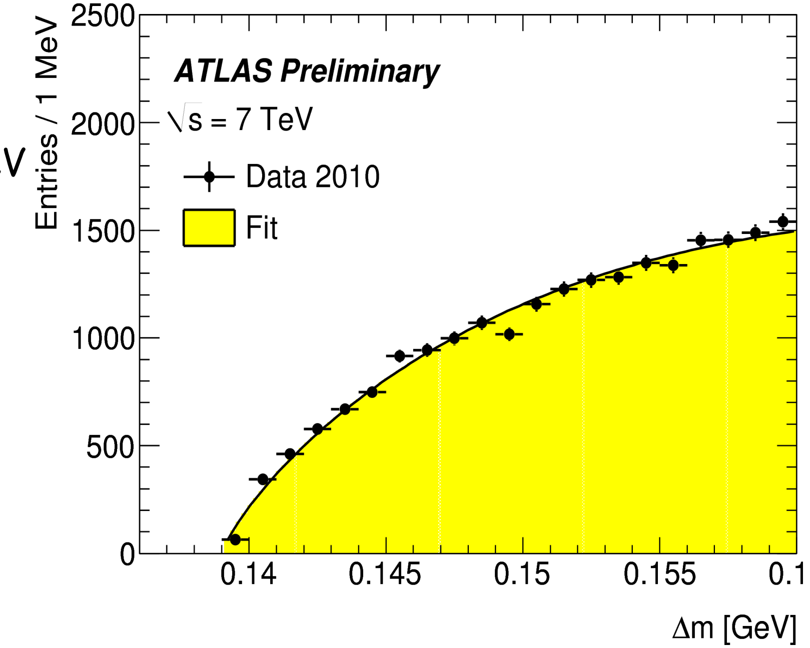


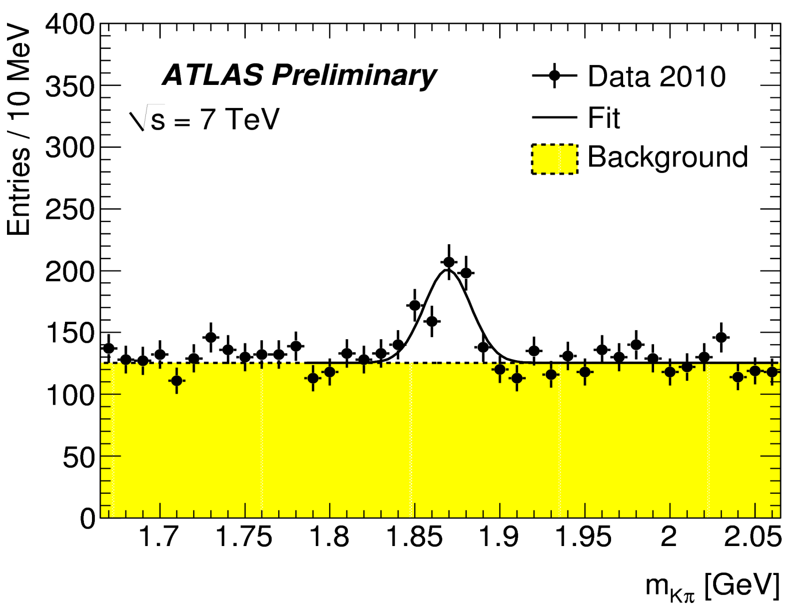
Observation of D*->Dπ at 7 TeV

Masses and Widths agree well with MC expectations (integrated Luminosity~ 200 μb-1)

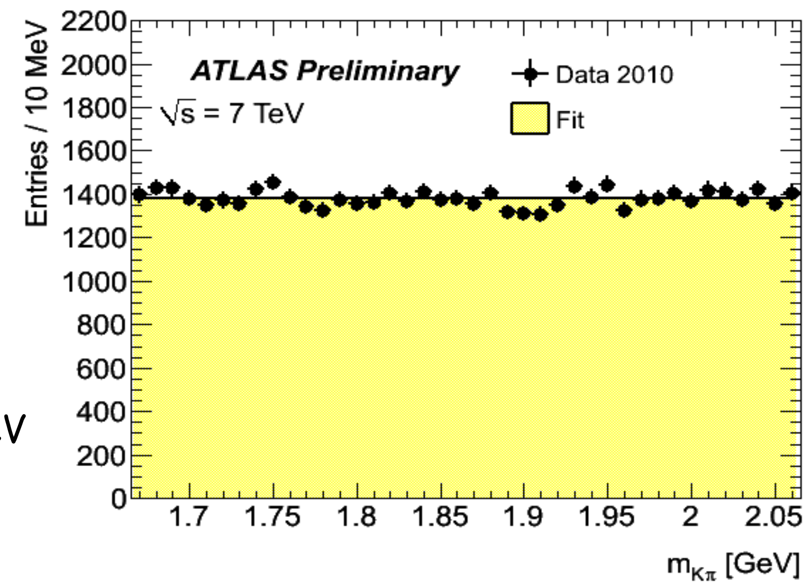


Δ(M(Kππ) -M(Kπ)):
Require:
M(Kπ) = 1865±20 MeV
Right = sideband
Results:
ΔM = 145.6±0.1 MeV



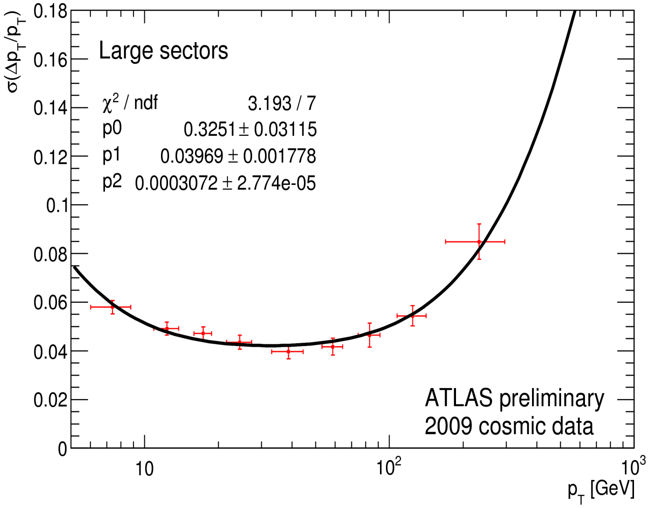


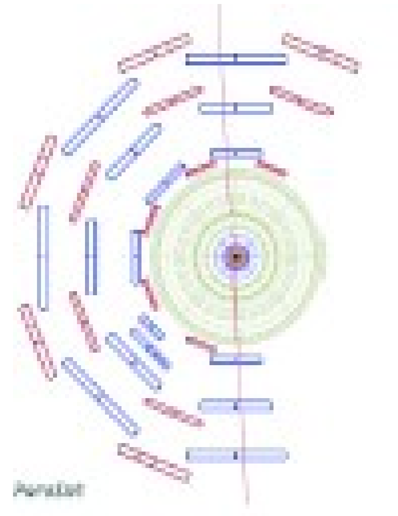
M(Kπ):
Require:
ΔM = 145.4±1.5 MeV
Right = sideband
Results:
M(Kπ) = 1869.2±2.4 MeV

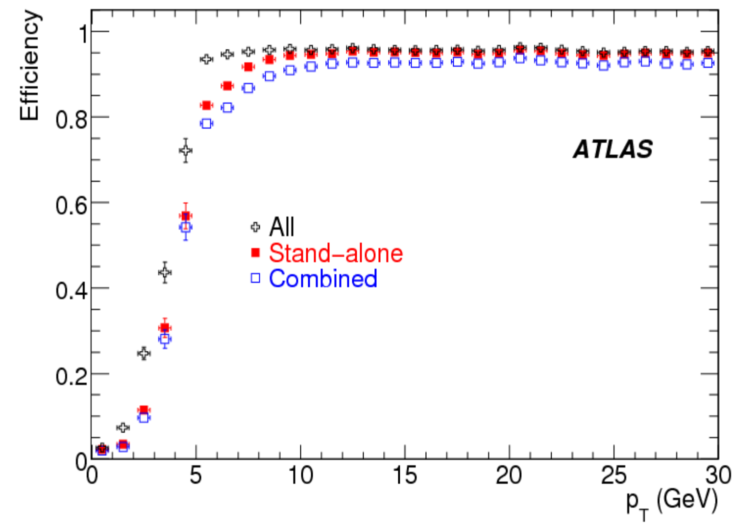


Muon Spectrometer Results

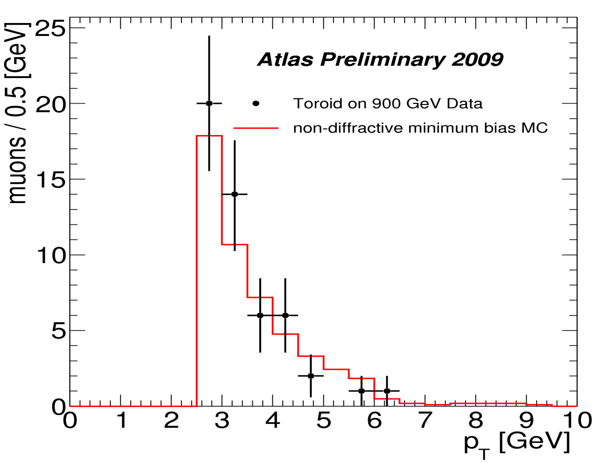
- Cosmics : a lot of studies made with cosmic rays allow to evaluate the level of readiness of our Spectrometer

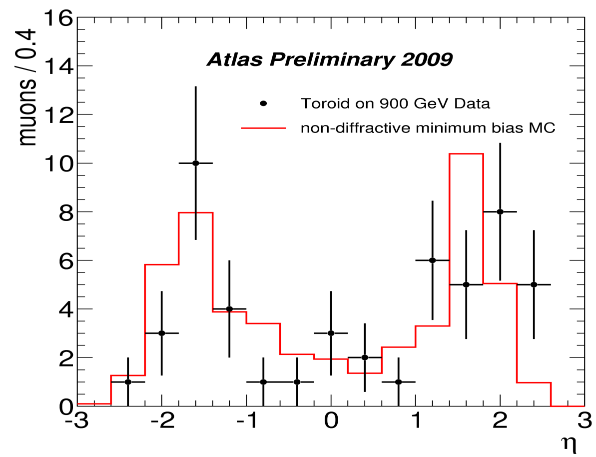






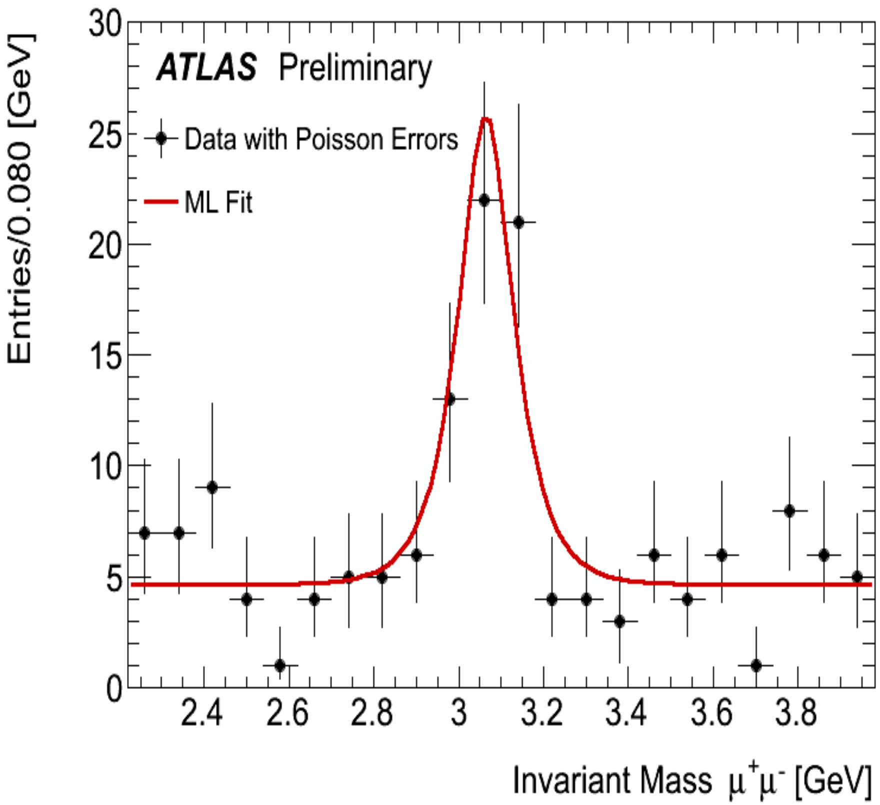
- 900 GeV data : Statistics limited, dominantly in the forward region
- Data and Monte Carlo are consistent with available statistics (P>4 GeV, pT>2.5 GeV, $|\eta|$<2.5)

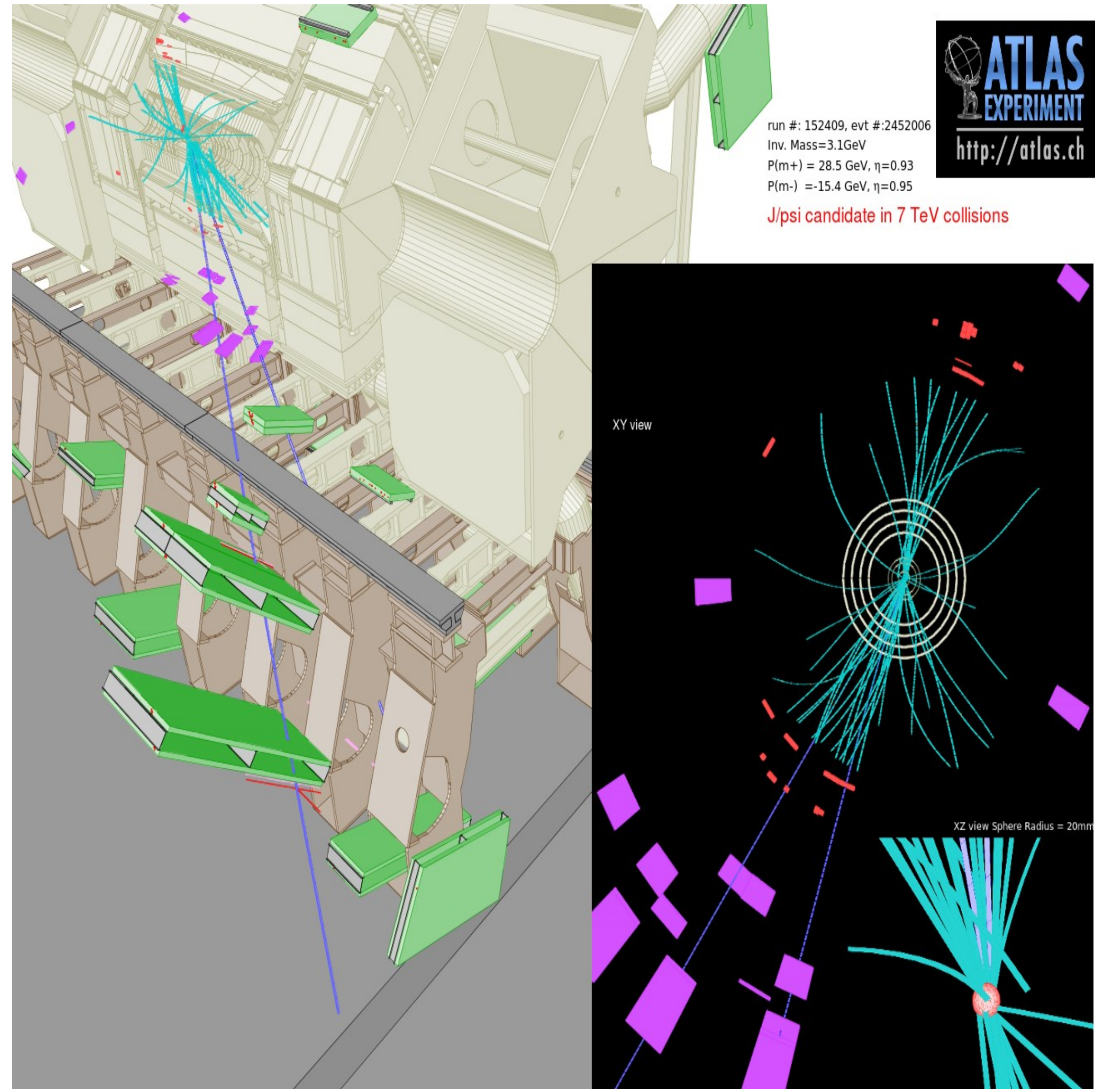




Observation of J/ψ->μμ at 7 TeV

Data for integrated luminosity ~ 320 μb-1





Gaussian-mean mass: 3.06±0.02 GeV
Resolution: 0.08±0.02 GeV
Number of signal events: 49±12
Number of background events: 28±4
Signal and background are computed in a mass range: 2.82-3.30 GeV(3σ around the peak).

Perspectives

Selected B-Results with 14 TeV Simulation

1) B-Trigger Strategy
2) Onia Production and Plarization
3) B^{+}->$J/\psi K^{+}$
4) B_{s}->$J/\psi\ \phi$ and B_{d}->$J/\psi\ K^{*}_{0}$
5) $B_{s}\rightarrow\mu\mu$

B-Trigger Strategy

➔ **Low p_T single / two muons**

- Control samples, only at very low luminosity

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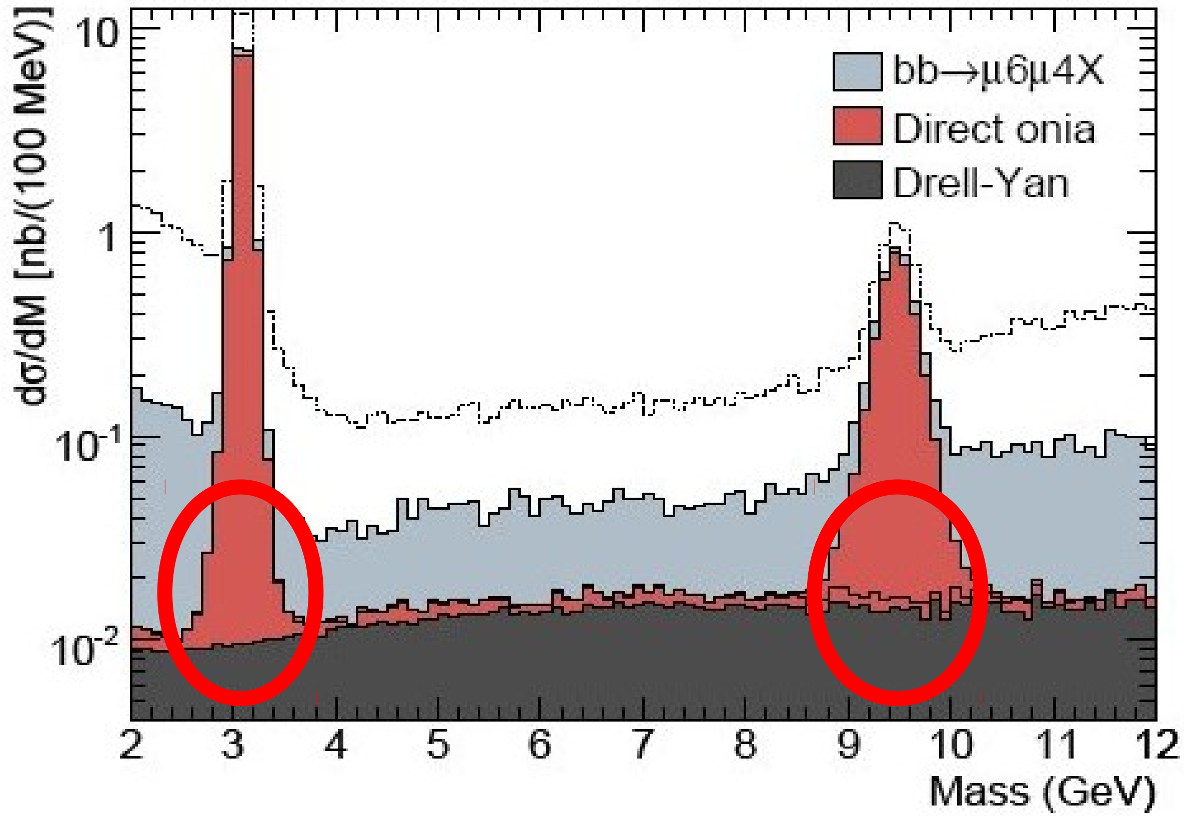
➔ Di-muon (common vertex) in the final state, invariant mass ranges:
  - J/ψ and other heavy quarkonia (Υ) decaying to $\mu\mu$



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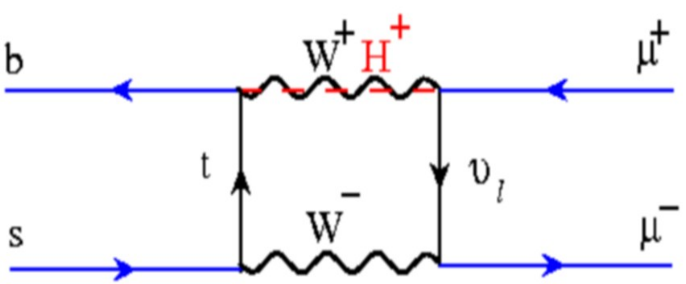

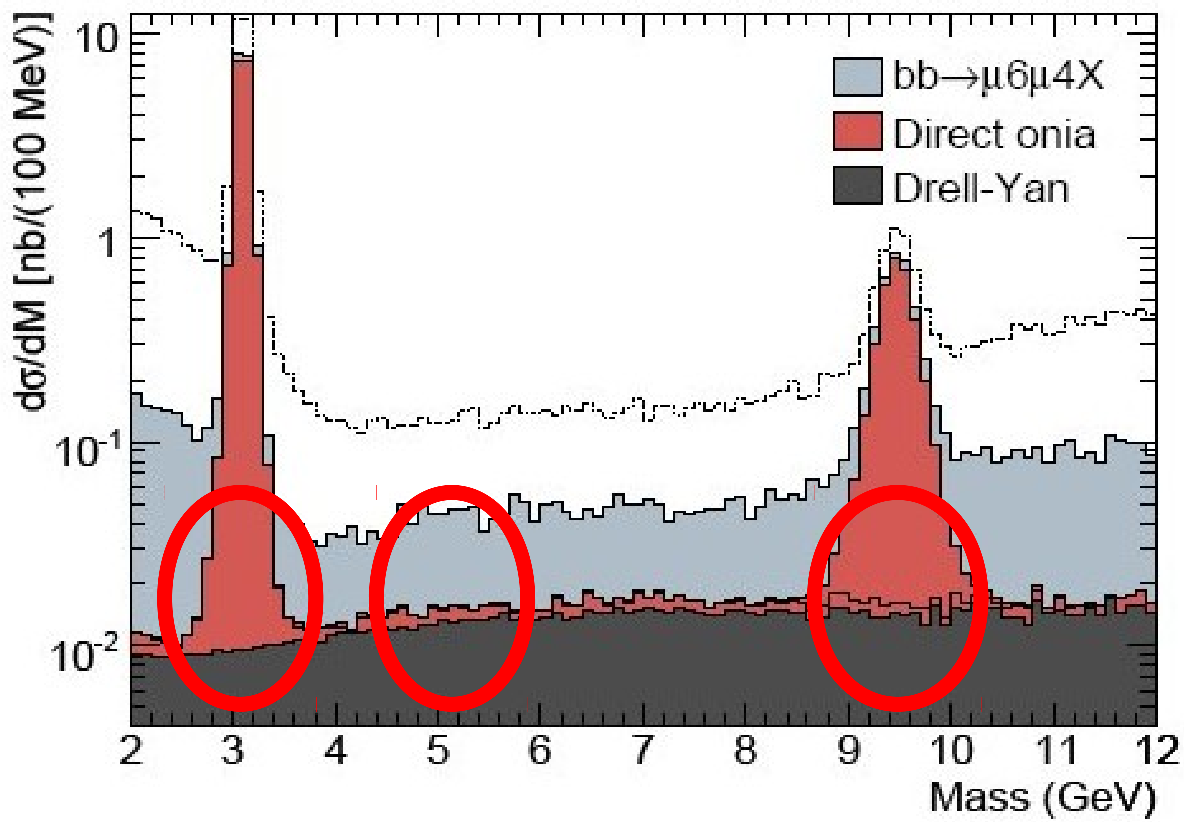

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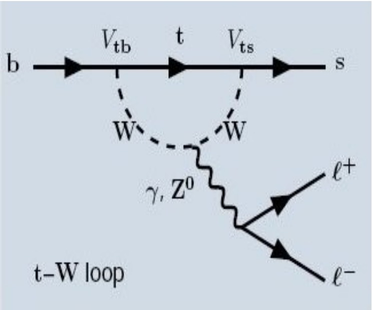

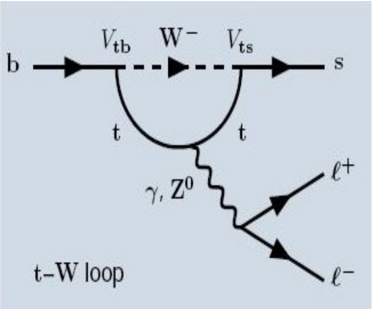

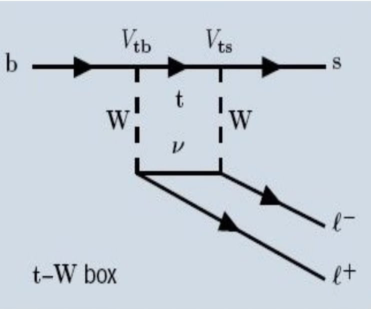

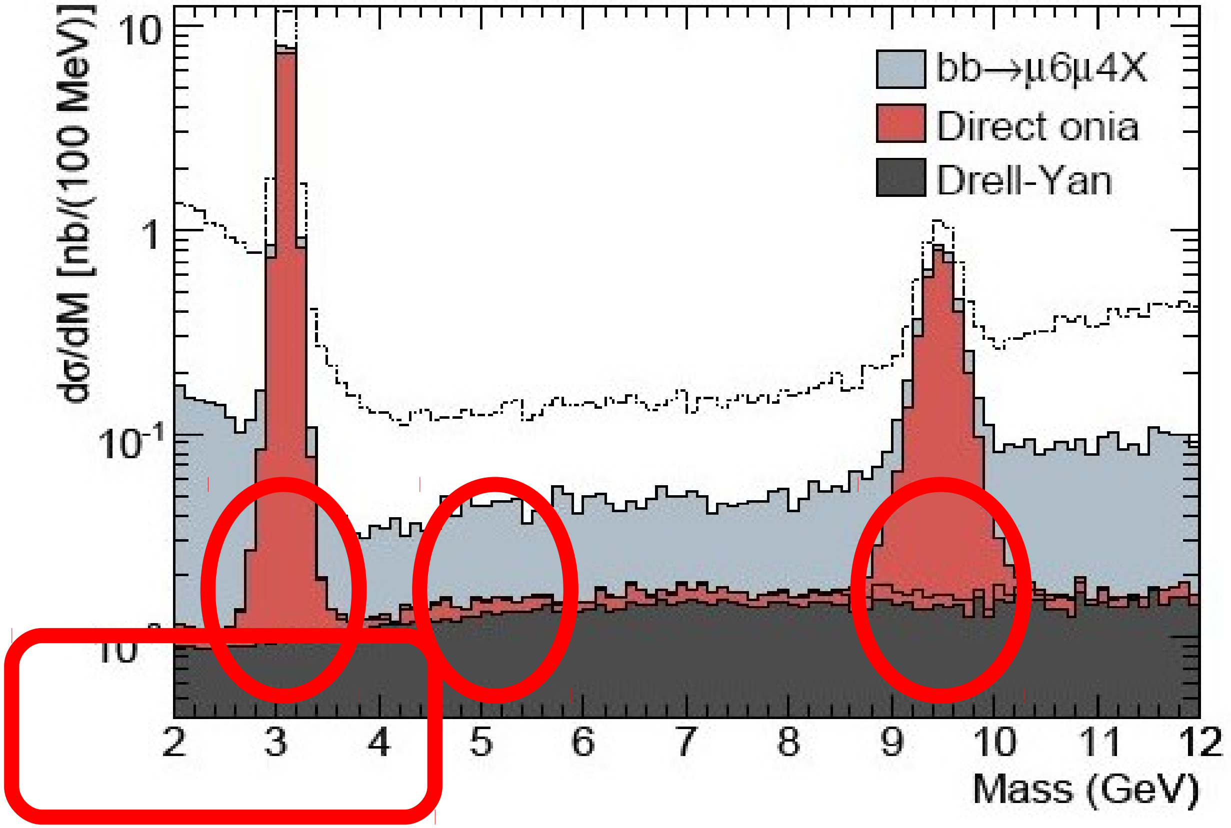

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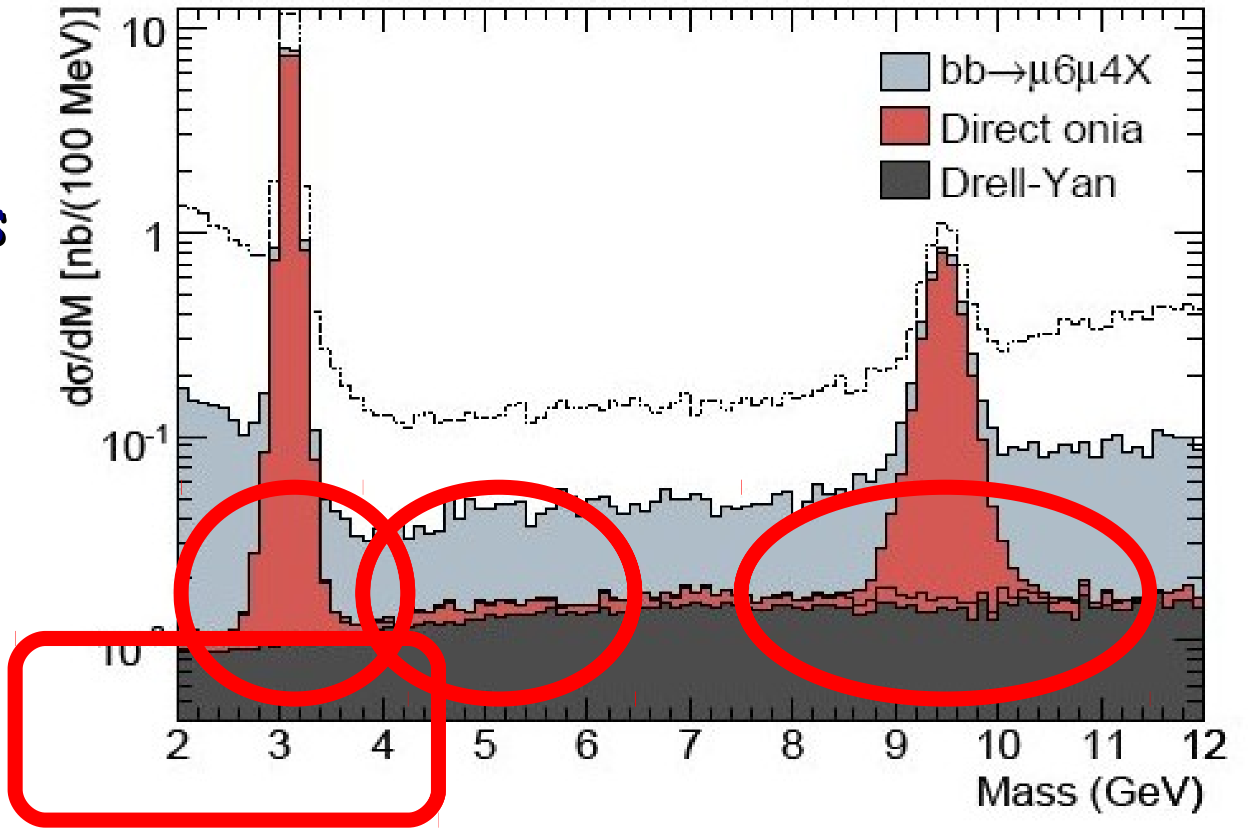

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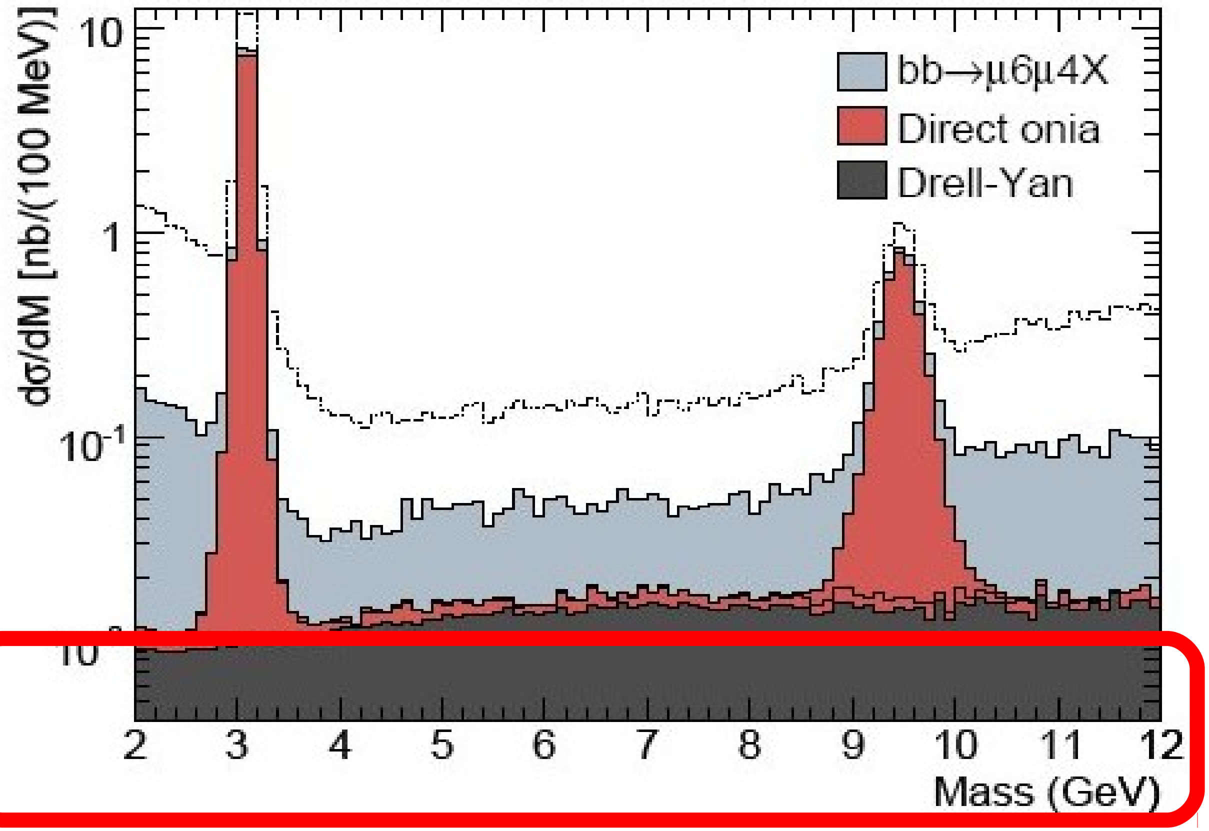
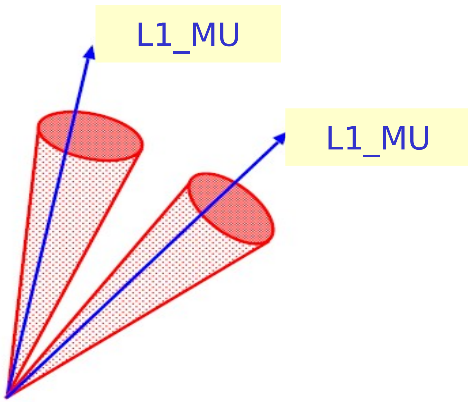
  - Very rare $B \rightarrow \mu\mu$
  - Semileptonic rare $B \rightarrow X_s\mu\mu$
  - Need to cover sidebands around the signal peak
  - Control measurements di-muon low-mass (bb, cc, contributions)

  ➔ Trigger for mass range $M(\mu\mu) <\sim 13$ GeV



B-Trigger Strategy

Di-muon Trigger



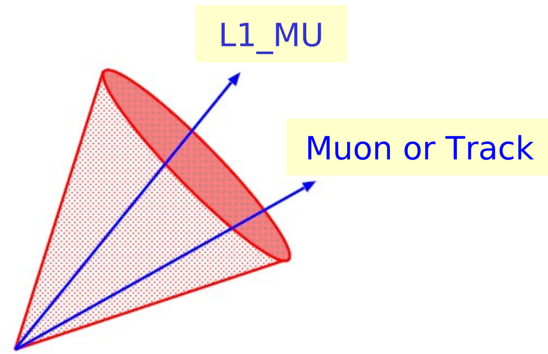
Two L1 muons

confirm muon at L2

Tracking in small RoI

Mass & vertex cuts

Single μ Trigger



One L1 muon

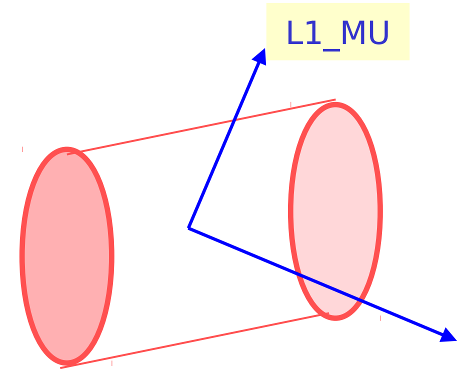
confirm muon at L2

Tracking in one large

RoI,search for the 2[rd] muon

Mass & vertex cuts

FullScan Trigger



One L1 muon

confirm muon at L2

Tracking in entire detector,

search for the 2[rd] muon

Mass & vertex cuts

The lowest level 1 muon trigger threshold are 4 GeV, 6 GeV

- Single L1 muon triggers:
  - Use lowest muon pT threshold and FullScan(time consuming) to give highest efficiency at startup
- L1 di-muon triggers:
  - Use lowest muon pT threshold (MU4)
  - Reduce the background and will be needed at higher luminosity.

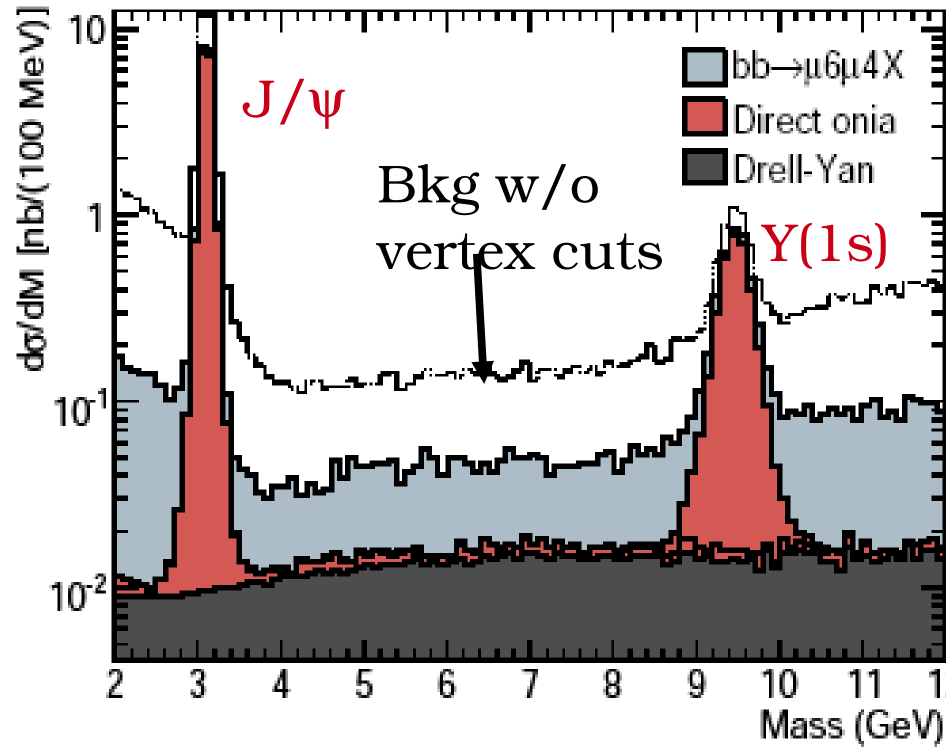
Onia Production

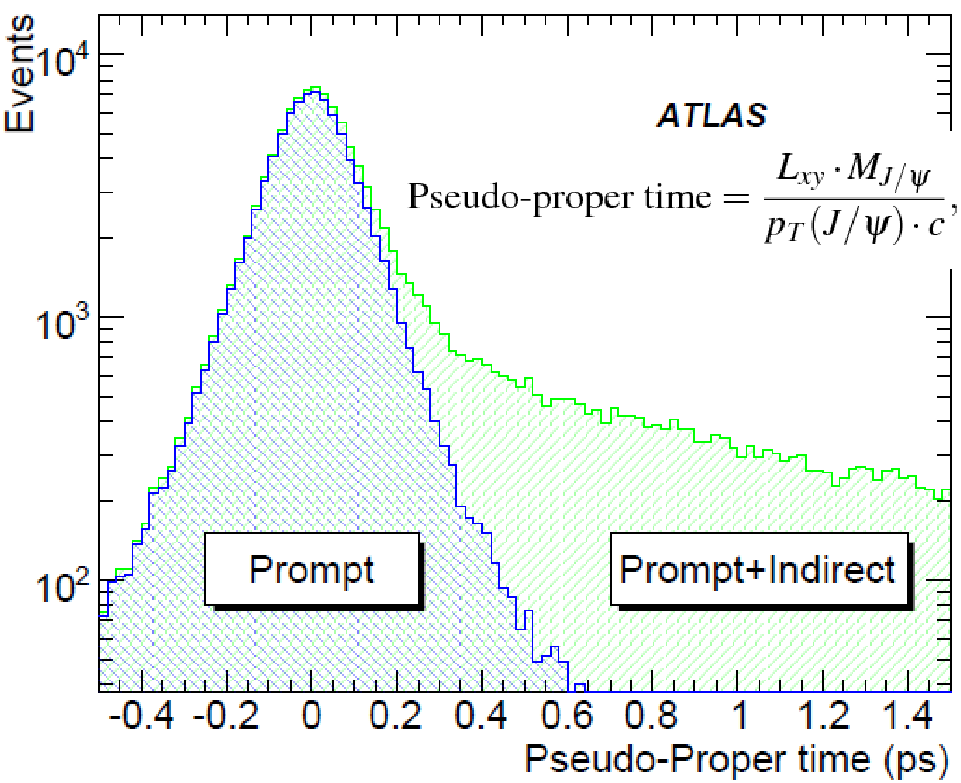
- Seeded by Level1 Di-μ trigger

μ tracks are fitted to a common vertex
For J/ψ, pseudo-proper time < 0.2 ps
(background suppression)

- Expected statistics : 15.000 J/ψ and 2000 ϒ per 1 pb^{-1} using di-μtrigger (pT(μ1,2) > 4 GeV)

S/B = 60 (J/ψ), 10 (ϒ)



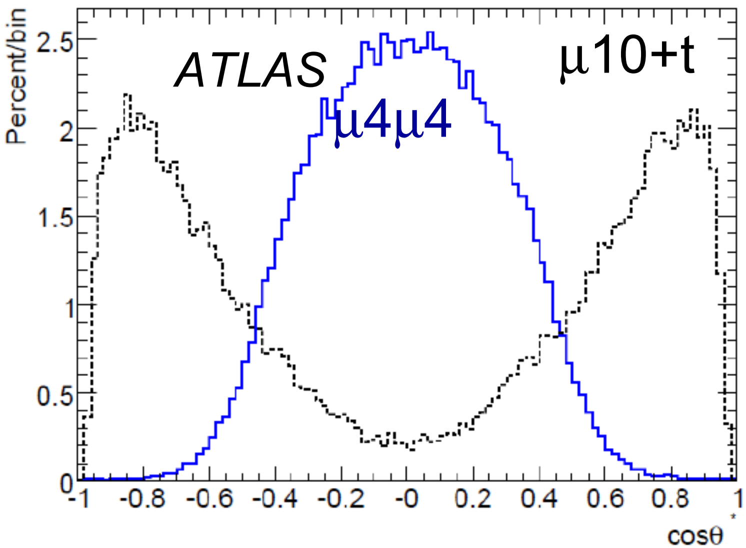


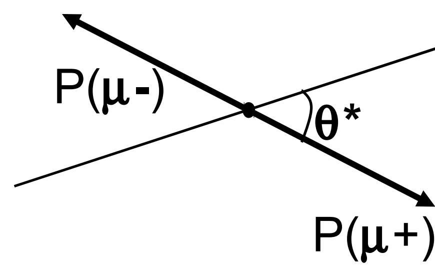
- Measurement of prompt J/ψ to indirect cross-section relies on separation (and understanding of separation) of these two processes

- With 1pb^{-1}, the ratio R= σ(bb → J/ψ)/σ(pp → J/ψ) can be measured as a function of pT, η with a statistical precision of 10%.

Onia Cross Section and Polarization

- In Atlas, measurement of high-p_T polarization will allow to distinguish production models
- In order to have a full cosθ* coverage, combine di-muon and single-μ trigger measurements





$$\frac{dN}{d\cos\theta} \propto 1 + \alpha \cos^2\theta$$

Precision on polarization of J/ψ about 0.02-0.05 after 10 pb−1 and cross-section measurement precision in bins of p_T of the order of 1% (dependent on the polarisation)

Sample	p_T, GeV	9 – 12	12 – 13	13 – 15	15 – 17	17 – 21	> 21
J/ψ, $\alpha_{gen} = 0$	α	0.156 ±0.166	−0.006 ±0.032	0.004 ±0.029	−0.003 ±0.037	−0.039 ±0.038	0.019 ±0.057
	σ, nb	87.45 ±4.35	9.85 ±0.09	11.02 ±0.09	5.29 ±0.05	4.15 ±0.04	2.52 ±0.04
J/ψ, $\alpha_{gen} = +1$	α	1.268 ±0.290	0.998 ±0.049	1.008 ±0.044	0.9964 ±0.054	0.9320 ±0.056	1.0217 ±0.088
	σ, nb	117.96 ±6.51	13.14 ±0.12	14.71 ±0.12	7.06 ±0.07	5.52 ±0.05	3.36 ±0.05
J/ψ, $\alpha_{gen} = -1$	α	−0.978 ±0.027	−1.003 ±0.010	−1.000 ±0.010	−1.001 ±0.013	−1.007 ±0.014	−0.996 ±0.018
	σ, nb	56.74 ±2.58	6.58 ±0.06	7.34 ±0.06	3.53 ±0.04	2.78 ±0.03	1.68 ±0.02
Υ, $\alpha_{gen} = 0$	α	−0.42 ±0.17	−0.38 ±0.22	−0.20 ±0.20	0.08 ±0.22	−0.15 ±0.18	0.47 ±0.22
	σ, nb	2.523 ±0.127	0.444 ±0.027	0.584 ±0.029	0.330 ±0.016	0.329 ±0.015	0.284 ±0.012

J/ψ polarisation

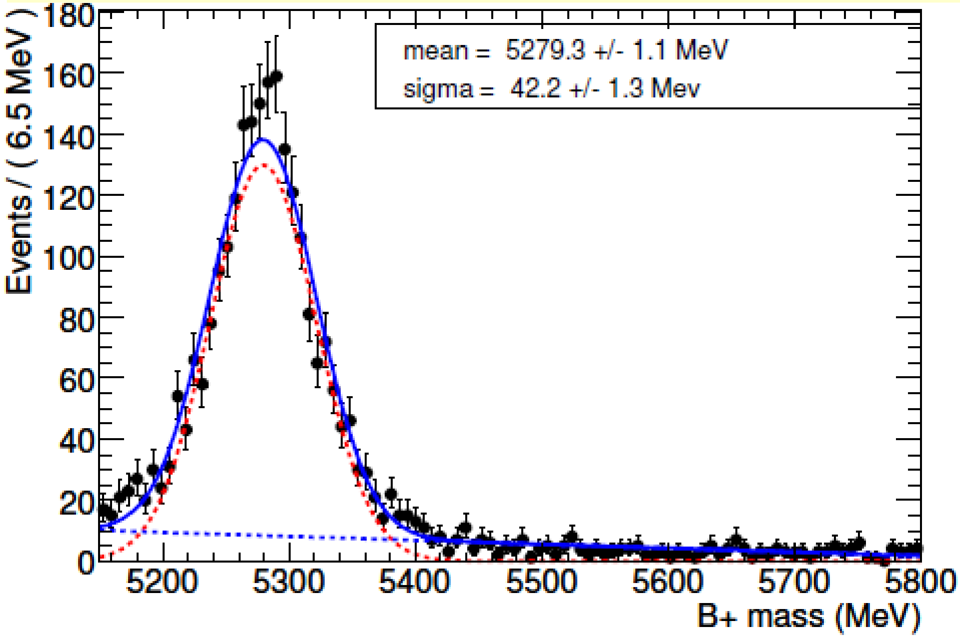
J/ψ cross-section

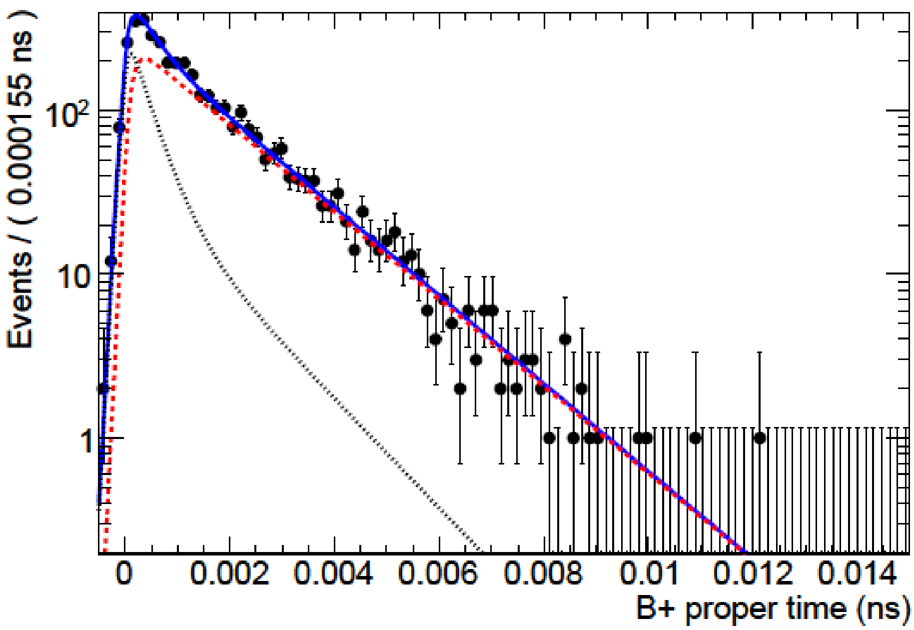
Results at extrema of polarisation states

ϒ polarisation

ϒ cross-section

$B^+ \to J/\psi(\mu\mu)\ K^+$





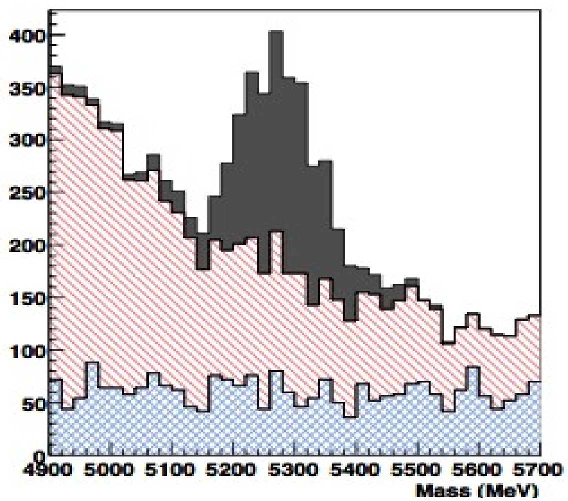
- Reference channel for the search for rare B-decays
- Using di-muon trigger (pt>4,pt>6 GeV), expect ~1600 events for 10 pb-1
  - Cross section (stat) (total)
  - Total to ~3 % ~15 %
  - dσ/dpT to ~10 % ~16-20 %
  - Signal lifetime to ~ 2.5 % (stat only)

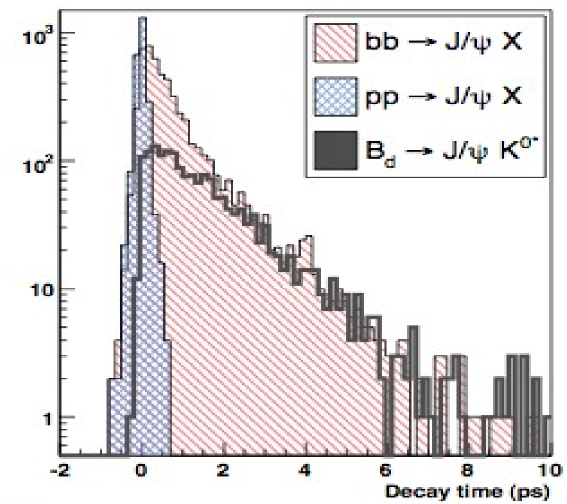
p_T range [GeV]	$p_T \in [10,18]$	$p_T \in [18,26]$	$p_T \in [26,34]$	$p_T \in [34,42]$	$p_T \in [10,\inf]$
stat. + $\mathscr{A}$ [%]	7.7	6.9	10.5	13.9	4.3
total [%]	16.1	15.8	17.6	19.8	14.8

B_s->J/ψ(μμ)φ and B_d->J/ψ(μμ)K^*_0

- The channel Bs→J/ψφ is a promising indirect route to New Physics
  - "Weak mixing phase" φs has been calculated in the SM and is very small (-0.0368±0.0018) but may be enhanced by BSM processes
- The topologically identical Bd→J/ψK0* (15x greater statistics) is the primary background and is also essential as a control channel (test of lifetime measurement and tagging calibration)
- Simultaneous fit to mass and decay time can be used to extract signal mass and lifetime from data in the channel $B_d \to J/\psi K_0^*$ with $10 pb^{-1}$

- In early data, loose cuts will be used (No vertex displacement cut)
- After 10 pb^{-1} the precision on the B_d lifetime will be 10% and similar precision for the B_s mean lifetime will be available after 150 pb^{-1}





Parameter	$B_d \to J/\psi K^{0*}$ after 10 pb^{-1}		$B_s \to J/\psi\phi$ after 150 pb^{-1}	
	Simulated value	Fit result + st error	Simulated value	Fit result + st error
Mean lifetime ,ps^{-1}	0.651	0.73 ± 0.07	0.683	0.743 ± 0.051
Mean mass m, GeV	5.279	5.284 ± 0.006	5.343	5.359 ± 0.006
Lifetime resolution σ, ps		0.132 ± 0.004		0.152 ± 0.001
Mass resolution $σ_B$, GeV		0.054 ± 0.006		0.061 ± 0.006
n_{sig} /N	0.16	0.155 ± 0.006	0.018	0.031 ± 0.005
n_{bckl} /N	0.062	0.595 ± 0.017	0.397	0.379 ± 0.006

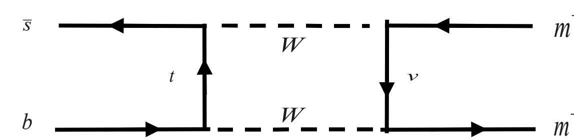
ATLAS flavour tagging performance

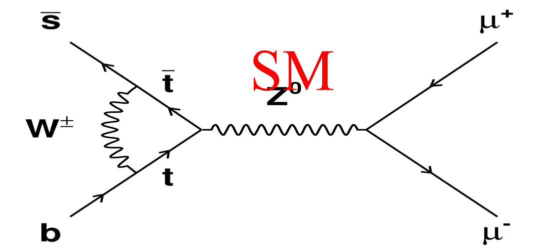
- After about 1 fb^{-1}, it will be possible to extract interesting parameters from the $B_s \to J/\psi\phi$ decays
  - FLAVOUR TAGGING (attempting to determine whether the decay is from a B_s or an anti-B_s) is an essential part of this decay. $B_s \to J/\psi\phi$ is not self-tagging
  - In ATLAS, the best flavour tagging performance for $B_s \to J/\psi\phi$ is obtained using the jet charge tagging algorithm, which is a "same side" tag
  - Utilize correlations between the original quark flavour and momenta, and the charge and momenta of the fragmentation products (jet charge tagging)
- Calibration of the jet-charge tag will be done with the self-tagging reference channel $B_d \to J/\psi K^{0*}$, and will validate Monte Carlo models for fragmentation
  - Validated Monte Carlo will be used to determine the tagger quality for $B_s \to J/\psi\phi$

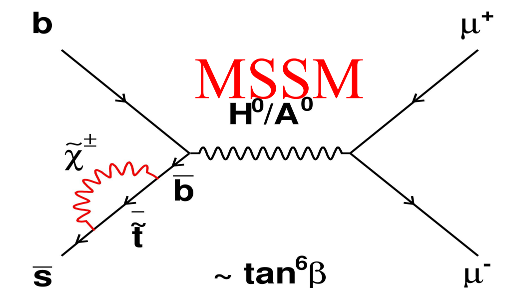
Tuned jet charge tagger performance		
Parameter	**$B_d \to J/\psi K^{0*}$**	**$B_s \to J/\psi\phi$**
Luminosity	150 pb^{-1}	1.5 fb^{-1}
Tag Efficiency	0.870 ± 0.003	0.625 ± 0.005
Wrong tag fraction	0.380 ± 0.004	0.374 ± 0.005
Dilution	0.240 ± 0.009	0.251 ± 0.010
Quality	0.050 ± 0.004	0.039 ± 0.003

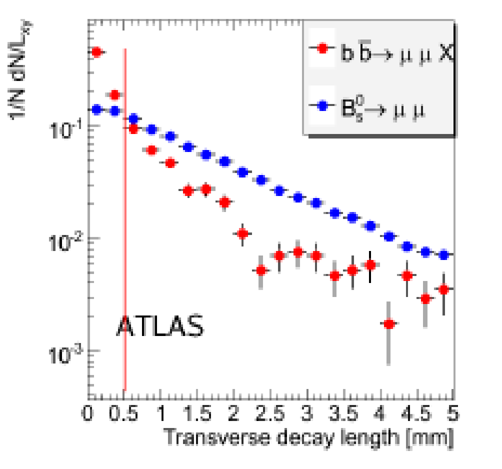
ATLAS performance for $B_s \to \mu\mu$

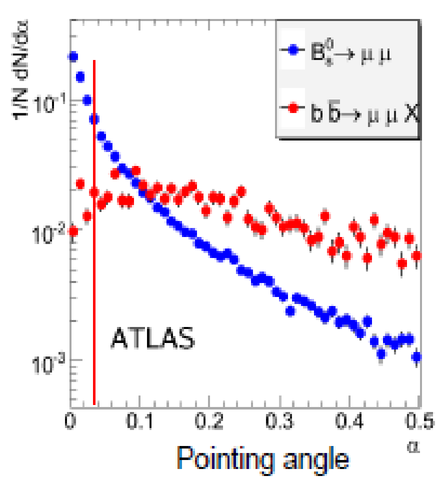
- $B_s \to \mu^+\mu^-$ is highly suppressed in SM (box, penguin diagr.)
  - BR SM($B_s \to \mu\mu$)=(3.42 ± 0.52) × 10–9
  - Best exp. limit BR CDF($B_s \to \mu\mu$)<5.8x10-8 (95%CL)
- Sensitive to New Physics (new particles in the loop)
- Main challenge is to control the background, the Atlas strategy is:
  - Trigger on events with $B_s \to \mu^+\mu^-$ candidates using dedicated trigger algorithms
  - Discriminating variables:
    - decay flight length (significance)
    - pointing angle between di-muon momentum and vector from primary vertex to di-muon vertex
    - isolation (no hadronic activity around Bs flight direction)
    - mass window around m(Bs)

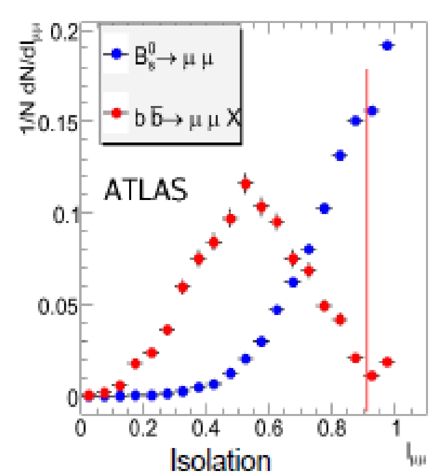




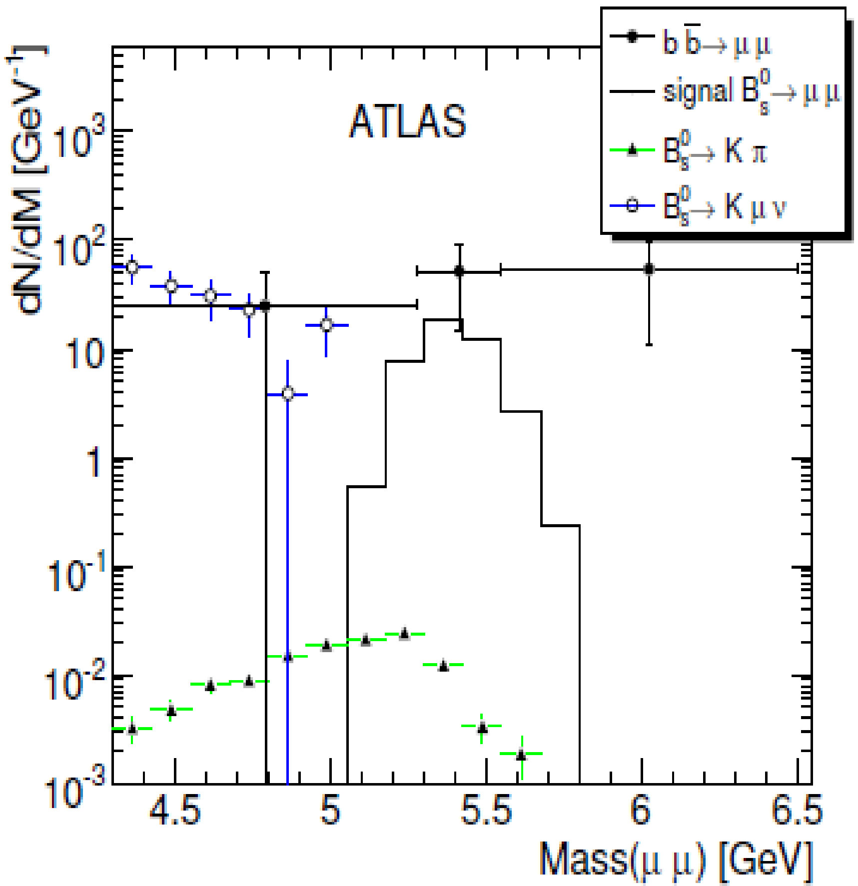








ATLAS performance for $B_s \to \mu\mu$



- After 1 fb^{-1} ATLAS will have collected $O(10^6)$ dimuons in the invariant mass range 4-7 GeV
  - This will allow tuning of cuts and potentially training of multivariate procedures
- Use $B^+ \to J/\psi(\mu\mu)K^+$ as a reference channel (similar to CDF & D0)
- Branching Ratio will be estimated by normalization to the $B^+ \to J/\psi(\mu\mu)K^+$ events
- After 10 fb^{-1} (1 year @ 10^{33}) we expect (SM):

Expected #ev after kinemat. preselec.	150	7000000
	$B_s \to \mu\mu$ efficiency	$bb \to \mu\mu X$ efficiency
Isolation>0.9	0.24	$(2.6\pm0.3)\times10^{-2}$
L_{xy} > 0.5 mm	0.26	$(1\pm0.3)\times10^{-3}$ *)
α < 0.017 rad	0.23	
$M=M_{Bs}{}^{+140}_{-70\,\mathrm{MeV}}$	0.76	0.079
Events/10fb^{-1}	5,7	14^{+13}_{-10}

The ATLAS $B_s \to \mu\mu$ program will continue throughout the lifetime of the detector

Summary

- ATLAS detector is performing remarkably well as commissioning for physics advances in the month since first 7 TeV collisions:
  - Tracking studies very advanced, including detailed understanding of material, and first physics results. Precise comparisons of data and MC in many domains, signals for meson/baryon resonances and charm
  - First significant number of collision muons have led to $J/\psi \to \mu\mu$ observation, and muon spectrometer is performing very well
- An efficient, fast and clean di-muon trigger scheme will allow ATLAS to collect large numbers of B-hadron decays involving $\mu\mu$ final states, throughout the lifetime of the experiment
- Early B-Physics data will provide valuable information on the detector performance, but will also allow calibration studies in support of New Physics searches.