B-physics In ATLAS
An overview

Sagi Ben-Ami.
Technion- Israel institute of Technology.
On behalf of the ATLAS B-physics group.

B-Physics in ATLAS

- ATLAS has a diverse B-physics program :

1. Measurements of weak rare B-hadron decays, CP-violation.

   $\left(B_s^0 \rightarrow \mu^+\mu^-\ ,\ B_s \rightarrow J/\Psi\phi,\ \Lambda_b \rightarrow \Lambda\mu^+\mu^-\ , etc.\right)$

2. Measuring production cross sections of beauty, charm hadrons and onia ⟶ QCD models for the LHC.
3. B-mesons and B-baryons properties ⟶ knowledge of spectroscopic and dynamical aspects of B-physics.

⟶ Complementary information regarding NP

- Four periods:

1. 10-100 pb^{-1}: understanding detector properties,measuring production cross sections… $B^+ \rightarrow J/\psi K^+ \ldots$	2. 0.2-1 fb^{-1} : B-hadron properties, new decay limits par example. $B_s^0 \rightarrow \mu^+\mu^-$ 1^{st} limit	3. 10-30 fb^{-1} : production and decay properties of B-hadrons. $B_s^0 \rightarrow \mu^+\mu^-$, B_s^0 system, etc.	4. 100 fb^{-1} each year. Rare decays.

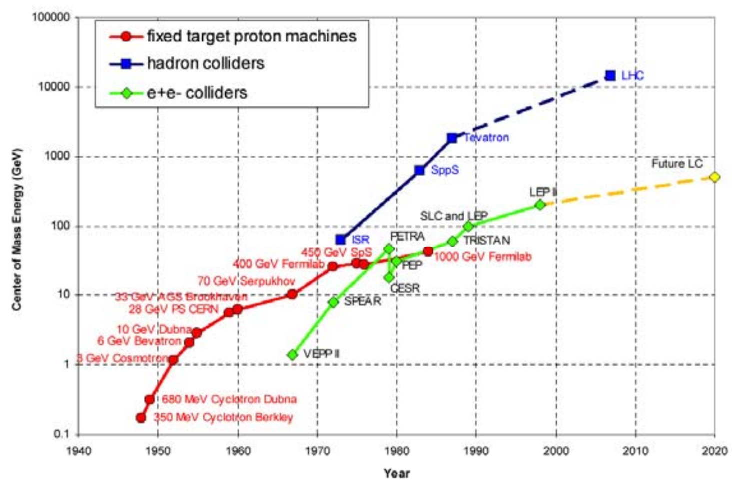
ATLAS advantages:

- When compared to B-factories:

1. Study the rare B_s^0 decays and Λ_b.
2. Rare decays with extremely small Br.
3. Differential distributions for rare dimuonic decays.

- When compared to the Tevatron:

1. The LHC will produce 50 times more $b\bar{b}$ events.

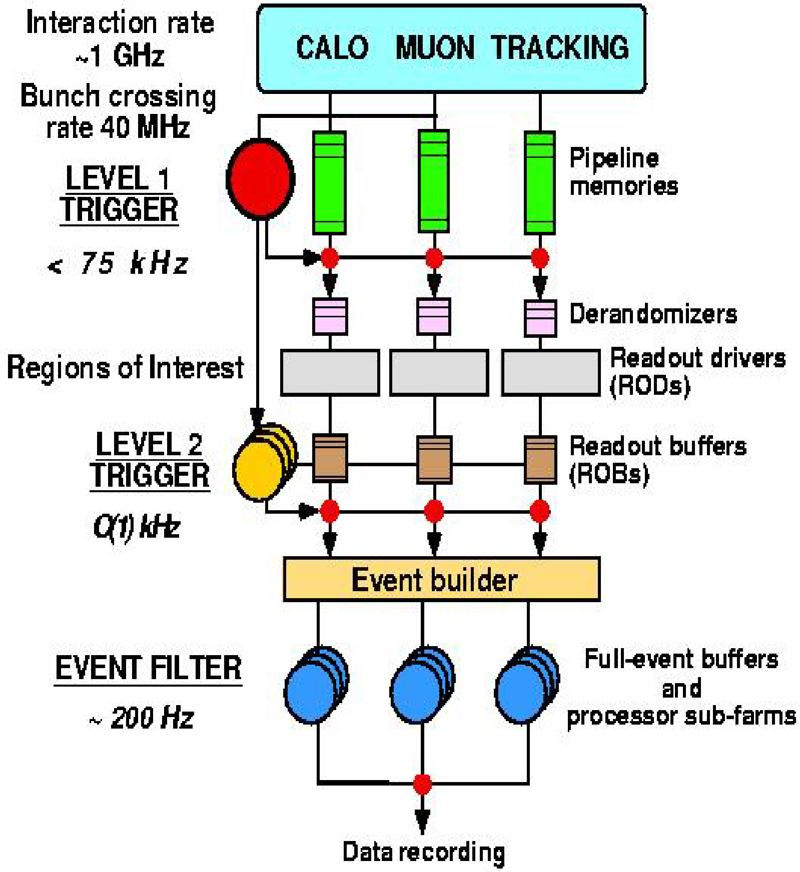


- When compared to the LHCb:

1. Capability of working in a much higher luminosity.
2. Capability of working with pileup events.
3. Less affected by K and π decays in flight.

Atlas Trigger

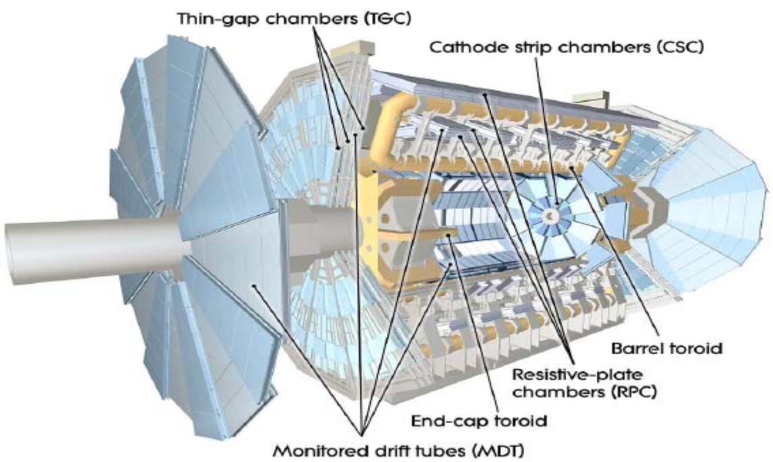
- ATLAS will be working in an unprecedented luminosity of 10^{34} $cm^{-2}s^{-1}$.
- Challenge: Extract signals from among the large QCD background.
- We need to keep an acceptable trigger rate, while keeping high trigger efficiency to study low-p_T physics.
- ATLAS use a three level trigger which will reduce the trigger rate to 100Hz, with an event size of 1.3Mbyte.



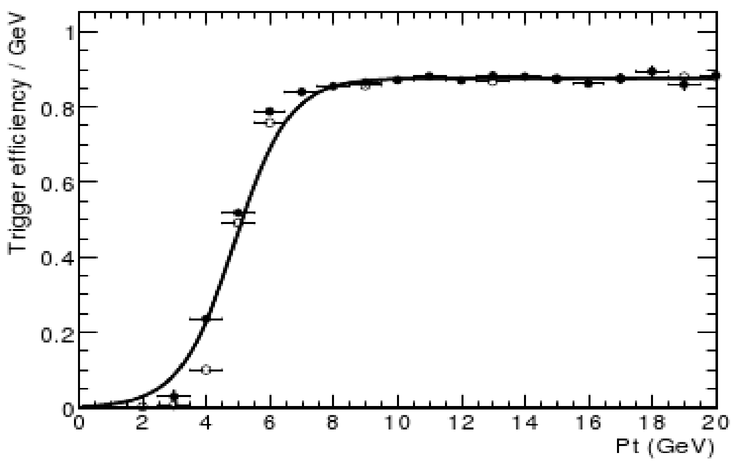
Level1 Muonic trigger

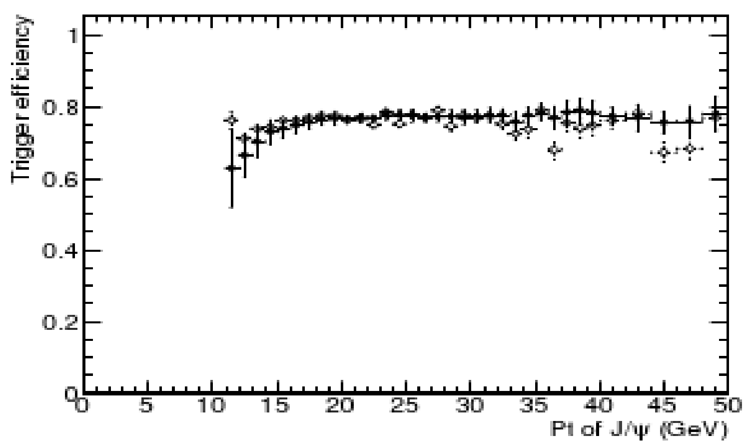
- Dedicated fast detector:

1. TGC and RPC for muonic trigger.
2. EM-calo trigger.



- Decision in 25ns, (latency 2.5μs) ⟶ reducing the rate to 75kHz.
- Challenge: measure the efficiency of the of the event selection.
- Tag-and-probeTM: di-muon decay allows us to probe the trigger efficiency.



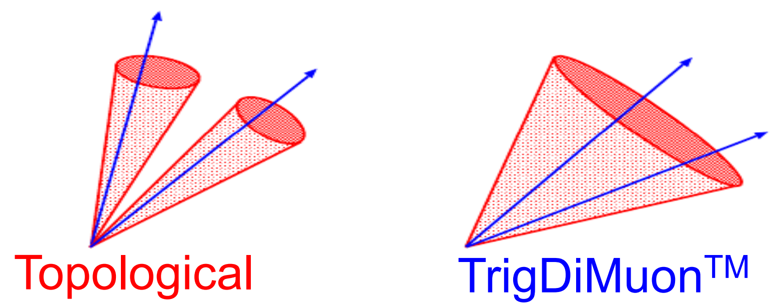


⟶ ATLAS has six different p_T thresholds @LVL1.

The trigger is ready for first collisions.

Muon Trigger – Level 2

- LVL2 trigger: Based on fast software, rate reduced to 1-2KHz, out of which 5-10% goes to permanent storage.
- ATLAS has two Level-2 di-muon trigger Algorithms:



- Start from a di-muon trigger at level-1 which produce RoIs.
  → Topological.
  Mainly for high luminosity.

- Start with a single muon trigger and search for two muons in a wider RoI. Search for tracks from the ID out to the MS.
  → TrigDiMuon™.
  Mainly for low luminosity.

Threshold (Luminosity)	Chain starting from	TrigDiMuon			Topological		
		Efficiency (%)	J/ψ rate (Hz)	Total rate (Hz)	Efficiency (%)	J/ψ rate (Hz)	Total rate (Hz)
4 GeV (10^{31})	level−1	71	1.17	3.1	51	0.8	24
	muFast	70	1.15	2.7	43	0.7	-
	muComb	69	1.14	2.4	33	0.5	0.6
6 GeV (10^{33})	level−1	74	43	151	56	32.5	357.5
	muFast	66	38	114	25	14.5	-
	muComb	59	34	109	15	8.7	9.3

- At low p_T triggering we prepared algorithms to remove muons from K and π.

→ Instead of cutting out all low p_T muons we use topology of event to remove muons from K and π :

1. Extrapolation of the MS tracks back to the ID and looking for a discrepancy between the two tracks.
2. K and π muons decaying between the pixel and the SCT can be rejected by applying a cut on the χ^2 of the inner detector fit.

Sample	muFast rate (Hz)	muComb rate (Hz)	muComb + π/k cuts rate (Hz)
π/k	5050 ± 760	3530 ± 380	2860 ± 410
b	5550 ± 600	4900 ± 400	4550 ± 430
c	6900 ± 700	5390 ± 420	5050 ± 450

6GeV Thresholds @ 10^{33} luminosity

→ Rejection 46% of Bg, loosing only 12.5% of signal.

Study of rare decay: $B_s^0 \to \mu^+\mu^-$

- SM lowest order contributions from box and penguin diagrams.
- SM predictions are tiny: meson has positive C-parity, helicity suppression.

$$Br(B_s^0 \to \mu^+\mu^-) = (3.86 \pm 0.15) \times \frac{\tau_{B_s^0}}{1.527\,ps} \frac{|V_{ts}^* V_{tb}|^2}{1.7\times 10^{-3}} \frac{f_{B_s}}{240 MeV} \times 10^{-9}$$

$$Br(B_d^0 \to \mu^+\mu^-) = (1.06 \pm 0.04) \times \frac{\tau_{B_d^0}}{1.527\,ps} \frac{|V_{td}^* V_{tb}|^2}{6.7\times 10^{-5}} \frac{f_{B_s}}{240 MeV} \times 10^{-10}$$

- May be enhanced by several order of magnitudes due to new loop diagrams: SUSY, Higgs doublet, extra gauge bosons, etc. $(\,MSSM \sim \tan^6(\beta)\,)$
- CDF Limit: $Br(B_s^0 \to \mu^+\mu^-) < 5.8\times 10^{-8} \quad (95\%\,CL)$

The method

- The signal will be normalized to $B^+ \to J/\psi(\mu^+\mu^-)K^+$:

$$Br(B_s^0 \to \mu^+\mu^-) = \frac{N_{B_s}}{\alpha_{B_s}\epsilon_{Bs}} \cdot \frac{\alpha_{B^+}\epsilon_{B^+}}{N_{B^+}} \cdot \frac{f_u}{f_s} Br(B^+ \to J/\psi K^+) Br(J/\psi \to \mu^+\mu^-)$$

- Triggering on $B_s \to \mu\mu$
  - LVL2: Required mass of combined opposite charge muon tracks less than 7GeV.
    - LVL2: Muons should be fitted to a common vertex.

$$Ef\,(L1*L2) = 0.52 \qquad Ef\,(EF\ w.r.t\ L2) = 0.88 \qquad Ef\,(Overall) = 0.46$$

- Startup strategy
  - Tuning of selection and Bg estimation procedure with $1fb^{-1}$ of integrated luminosity.
  - Irreducible contributions will be determined on the base of study of hadron/muon misidentification probability.
  - Study of reference channel in order to check MC description.

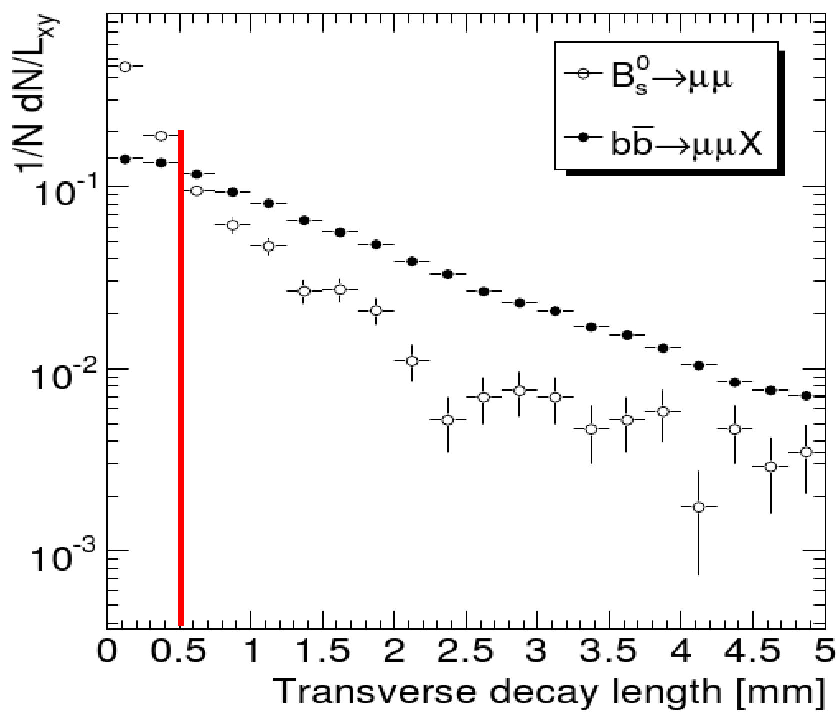
•Offline cuts:

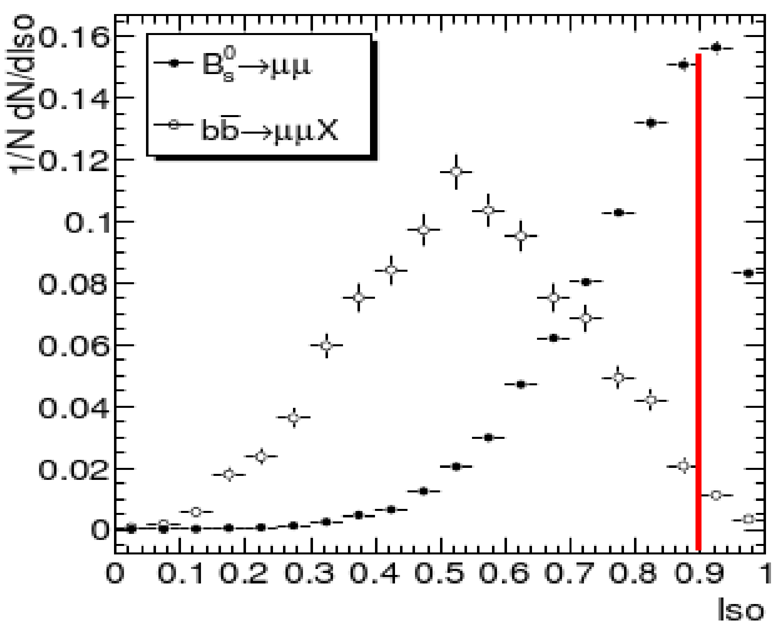
-Transverse decay length of candidates.

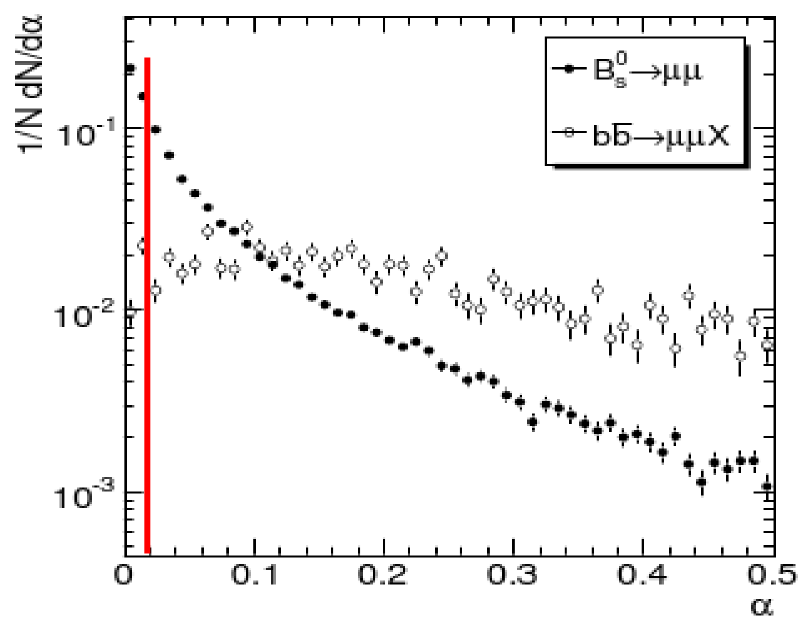
-Pointing angle between flight direction and DV direction.

-Track isolation.

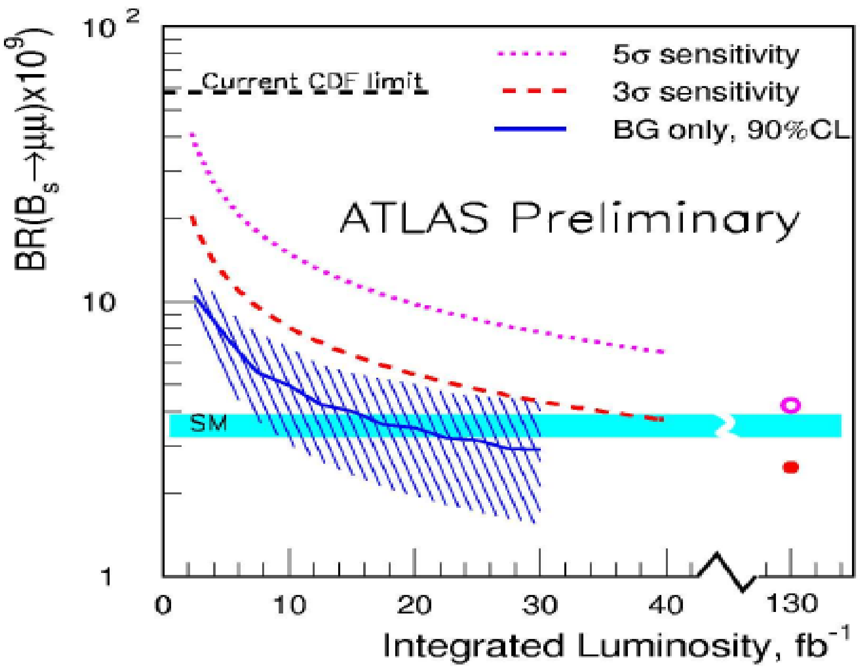
-Asymmetric mass window.







Results



- With 2 fb^{-1} : $Br<10^{-8}$
- 3σ evidence : 3 years@10^{33}
- 5σ evidence : First year@10^{34}

Discr. variable	$B_s^0 \to \mu\mu$	$bb \to \mu\mu X$		$B_s^0 \to K\pi$	$B_s^0 \to K\mu\nu$
$Iso > 0.9$	0.24	$(2.6 \pm 0.3) \cdot 10^{-2}$		n/a	n/a
$L_{xy} > 0.5mm$	0.26	$(1.4 \pm 0.1) \cdot 10^{-2}$	$(1.0 \pm 0.7) \cdot 10^{-3}$		
$\alpha < 0.017rad$	0.23	$(8.5 \pm 0.2) \cdot 10^{-3}$			
Mass in $[-\sigma, 2\sigma]$	0.76	0.079			
TOTAL	0.04	$0.24 \cdot 10^{-6}$	$(2.0 \pm 1.4) \cdot 10^{-6}$		
Events	5.7		14^{+13}_{-10}	0.015	0

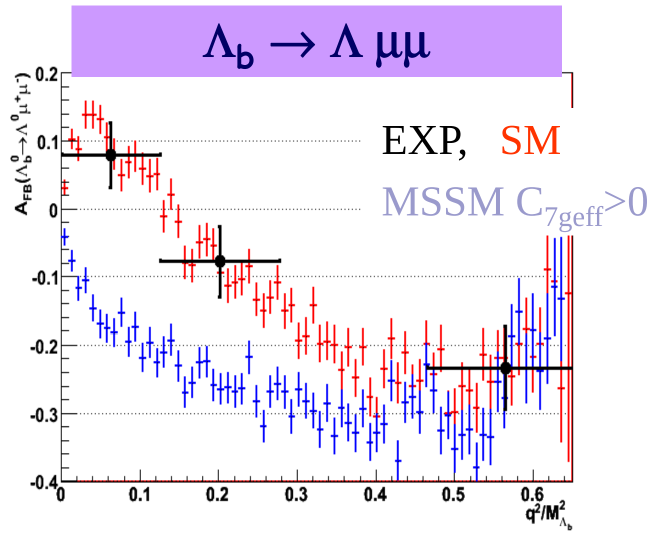
Table given for 10fb^1

ATLAS potential for Exclusive semi-muonic rare decays $b \rightarrow d,s\mu\mu$

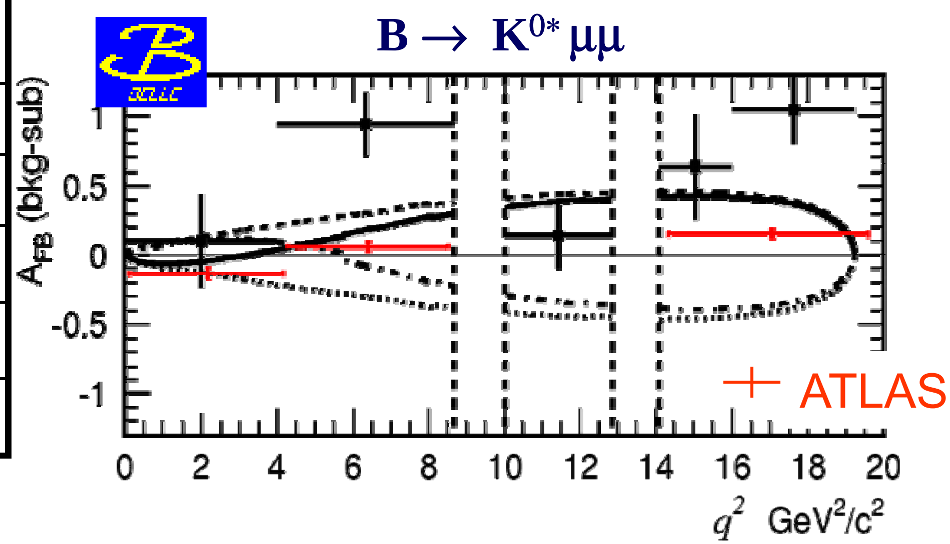
- **Variety of exclusive channels**

Di-muon trigger acceptance will allow us to work at high luminosities of 10^{34} cm^{-2}s^{-1}.

Dedicated talk by Cristina Adorsio on Wednesday



30 fb^{-1}	δA_{FB} (1-6)GeV^2	Signal events
$B \rightarrow K^{0*}\mu\mu$	4.8%	2500
$B_s \rightarrow \phi\ \mu\mu$	6%	900
$B^+ \rightarrow K^{+*}\mu\mu$	5.2%	2300
$B^+ \rightarrow K^+\mu\mu$	3.%	4000
$\Lambda_b \rightarrow \Lambda\ \mu\mu$	6%	800



Atlas potential in CPV in $B_s \rightarrow J/\psi\Phi$

Method:

- Simultanious maximum likelihood fit for parameters: phi_s, Γs, ΔΓs, A⊥,A∥, δ1,δ2.
- Experimental inputs: 3 angles, proper decay time, flavour tag; background fraction and composition.
- Independent measurement of Δms in flavour explicit channel.

Error on	ATLAS
Years / Luminosity	**30 fb-1**
ϕ_s	0.067
ΔΓs	13%
Γs	1%
$A_\parallel$	0.9%
$A_\perp$	3%
Δm_s (ps-1)	Fixed 17.77 +- 0.12
δ1	Fixed B_d-J/y K*
δ2	"

sensitivity after 30 fb^{-1}:

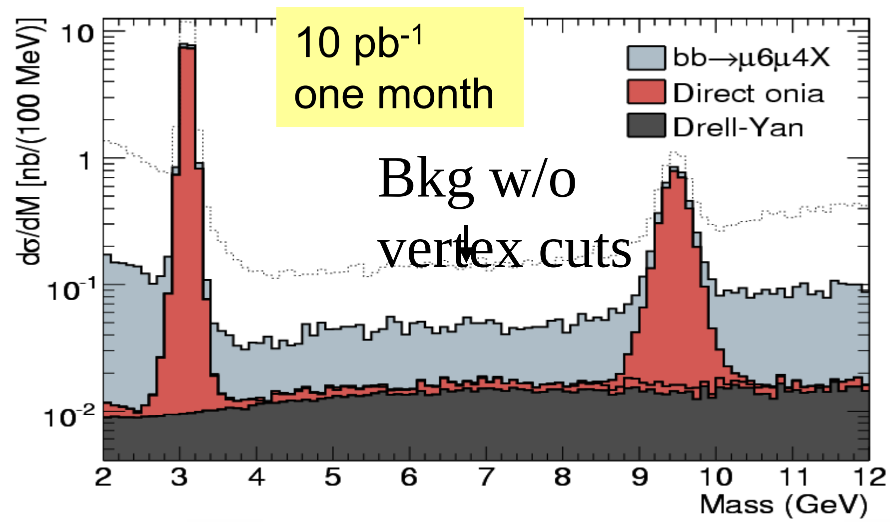
(3years) $\delta(\phi_s) = 0.067$

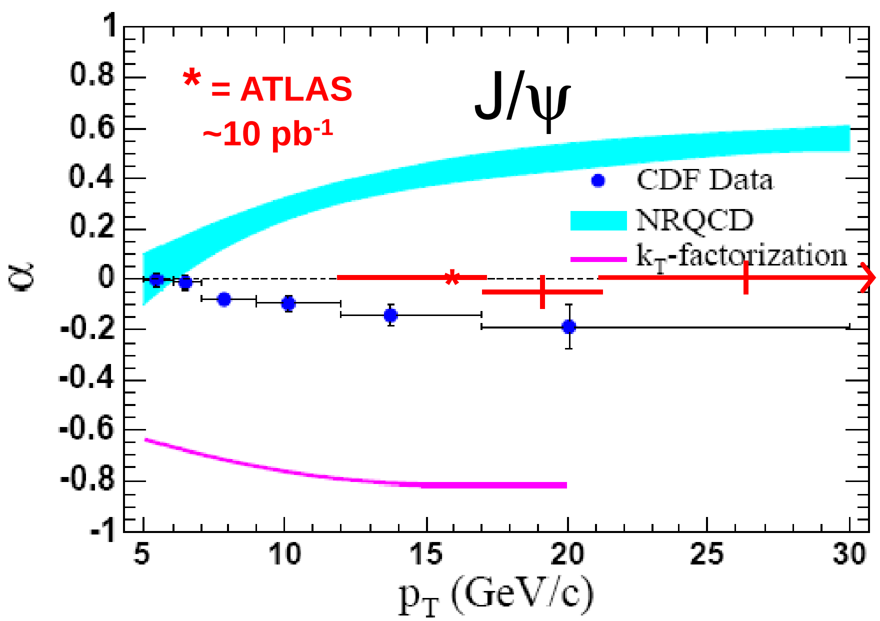
→ can be evidence of NP

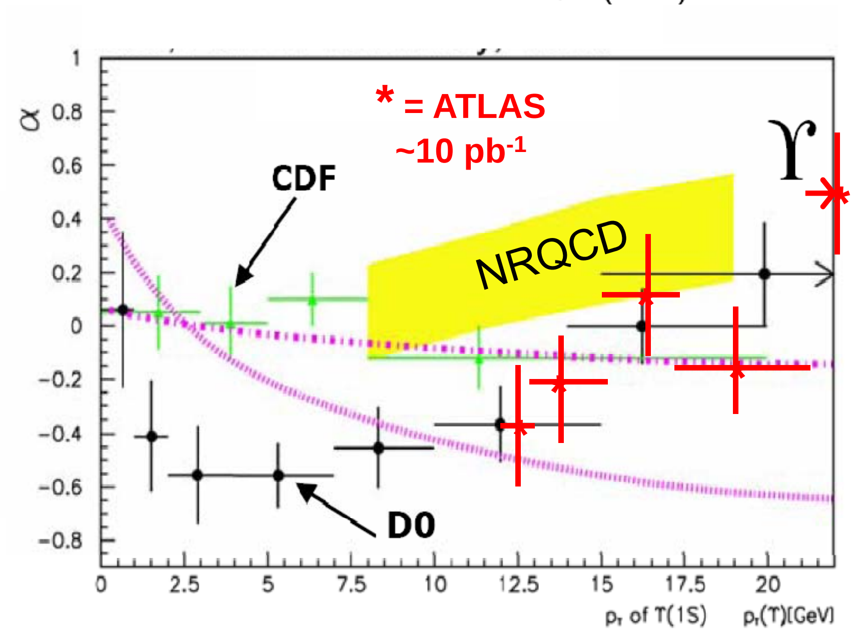
More details at dedicated talk in this workshop. (O.Leroy)

Selected examples of B measurements at very early stage. (<100 pb^{-1})

ATLAS measurements of Onia cross section and polarization







$B_s^0 \to J/\psi\phi \quad and \quad B^0 \to J/\psi K^{*0}$

- Very early measurement with exclusive B-decays: serve to test ATLAS detector performance.
- Already at $10pb^{-1}$ (1-2 month) – B masses and lifetime measurements by reconstructing exclusive decays. Serve to test detector performance understanding.

- Method:

Use soft cuts ⟶ no secondary vertex displacement cuts.

- What we give:

Background from prompt J/ψ decays will be enhanced.

- What we get:

avoid bias from misalignment and vertexing algorithms.

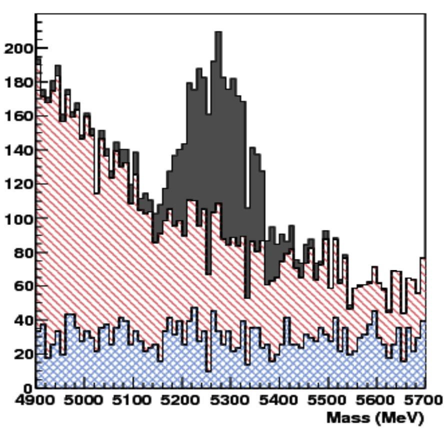
⟶ Still will be able to measure lifetime with precision needed to test alignments.

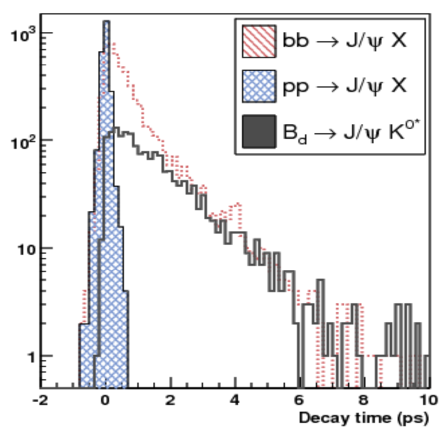
- Method: simultaneous determination of B mass and lifetime by maximum likelihood.

	Selected candidates expected with 10 pb^{-1}
Signal $B_d^0 \to J/\psi K^{0*}$	1024
$pp \to J/\psi X$ background	1419
$b\bar{b} \to J/\psi X$ background	3970

- 11 parameter fit to mass and proper decay time.

$$L = \prod_{i=1}^{N}\left[\frac{n_{sig}}{N}\times p_{sig}(t_i, m_i) + \frac{n_{bck1}}{N}\times p_{bkg1}(t_i, m_i) + \frac{1-n_{sig}-n_{bck1}}{N}\times p_{bkg2}(t_i, m_i)\right]$$





Result for 10 pb^{-1} :

Life time precision of 10% will allow serve to test detector performance understanding

Other channels:

$B^+ \to J/\psi K^+$ 6% with 10 pb^{-1}

$B_s \to J/\psi \Phi$ 10% with 100 pb^{-1}