Nordic Workshop on the LHC and Beyond

- 12.06.2008 -

ATLAS Solenoid Field

Measured field, validation & plans

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On behalf of the Solenoid Field Map team

Measured Field

Solenoid Magnet

The Solenoid Magnet

Solenoid Magnet

Solenoid characteristics (ATL-S-EN-0002)

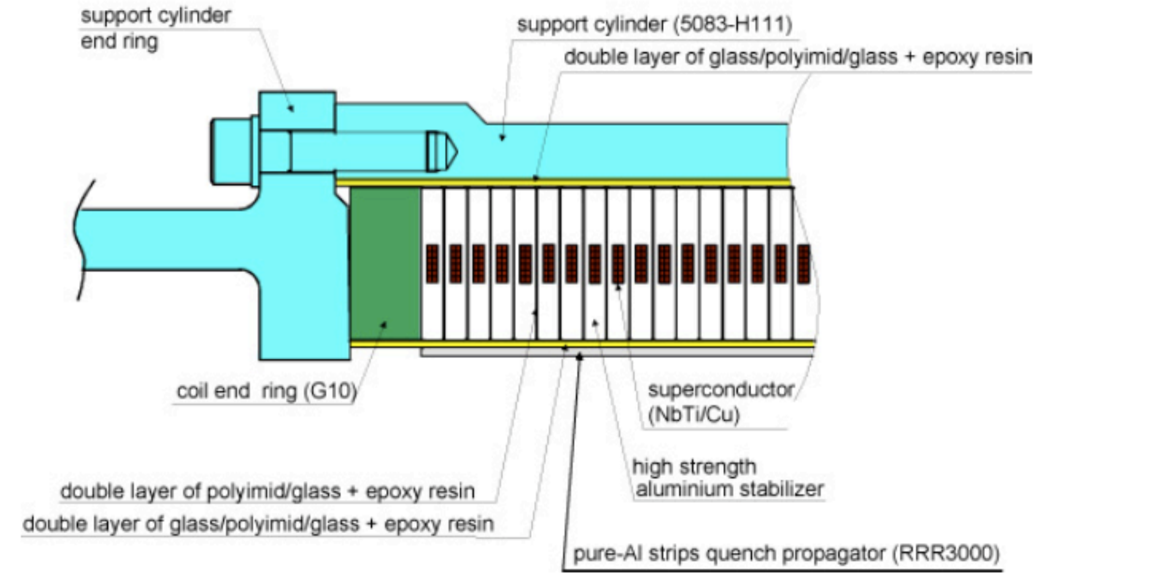
- 4 coils welded together, in total 1154 electrical turns
- 3 joint welds where the current passes through two wires instead of one and two end welds
- Length = 5.3 m, radius 1.25 m
- Return cable along the vessel surface (C to A) at 11.25°

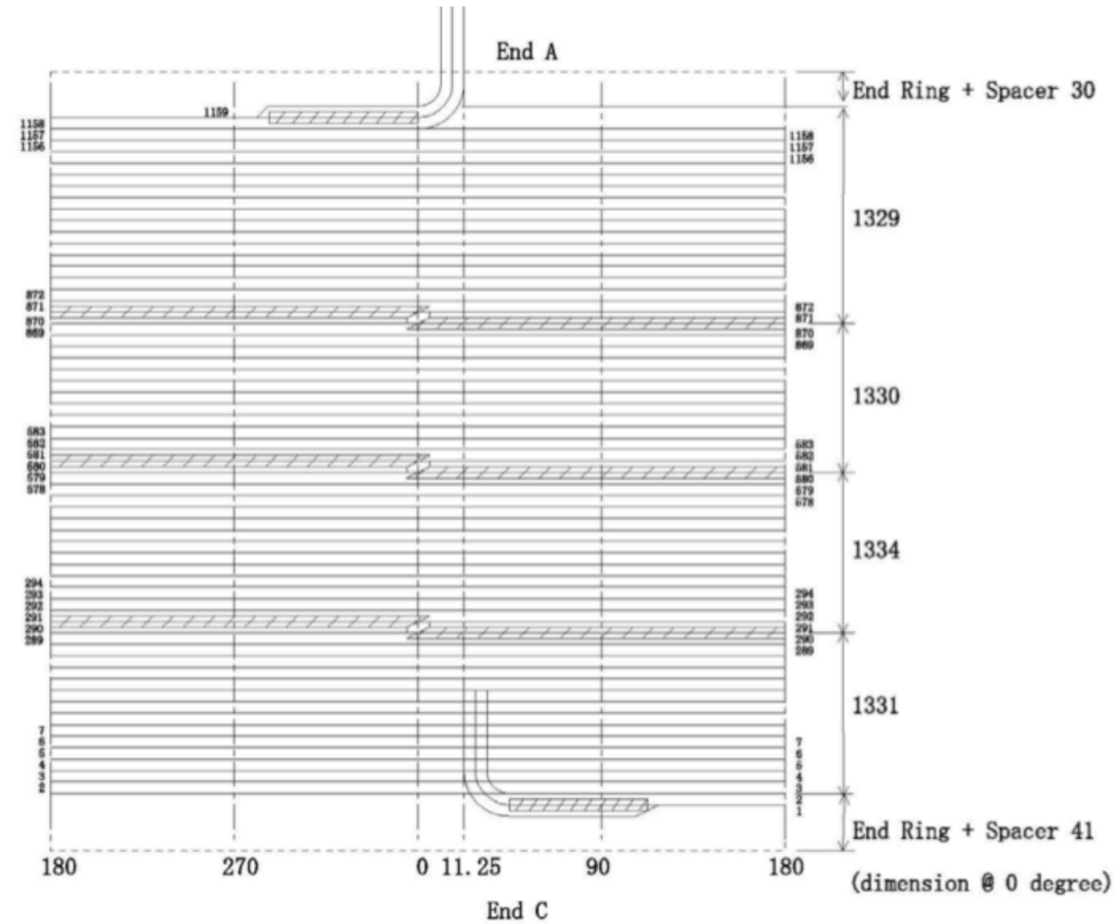
Solenoid current

- Monitored with a DCCT with current stability of **0.1 A** (at nominal field 7730 A the reading was 7729.995 A)

Solenoid field

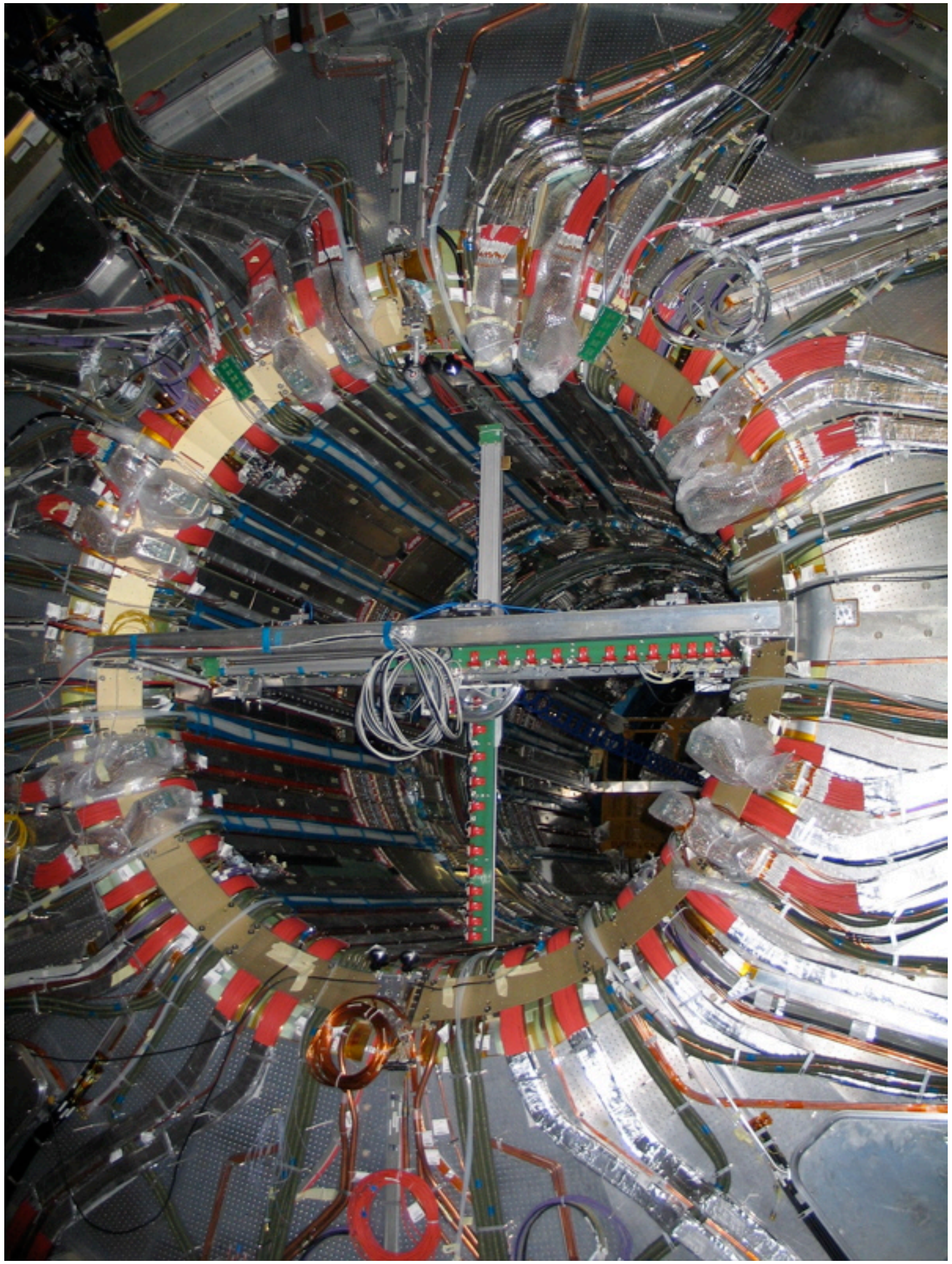
- Provides a **2 T field at 7730 A** at the solenoid centre
- The resulting field instability as measured with the NMR system is **< 0.03 Gauss**

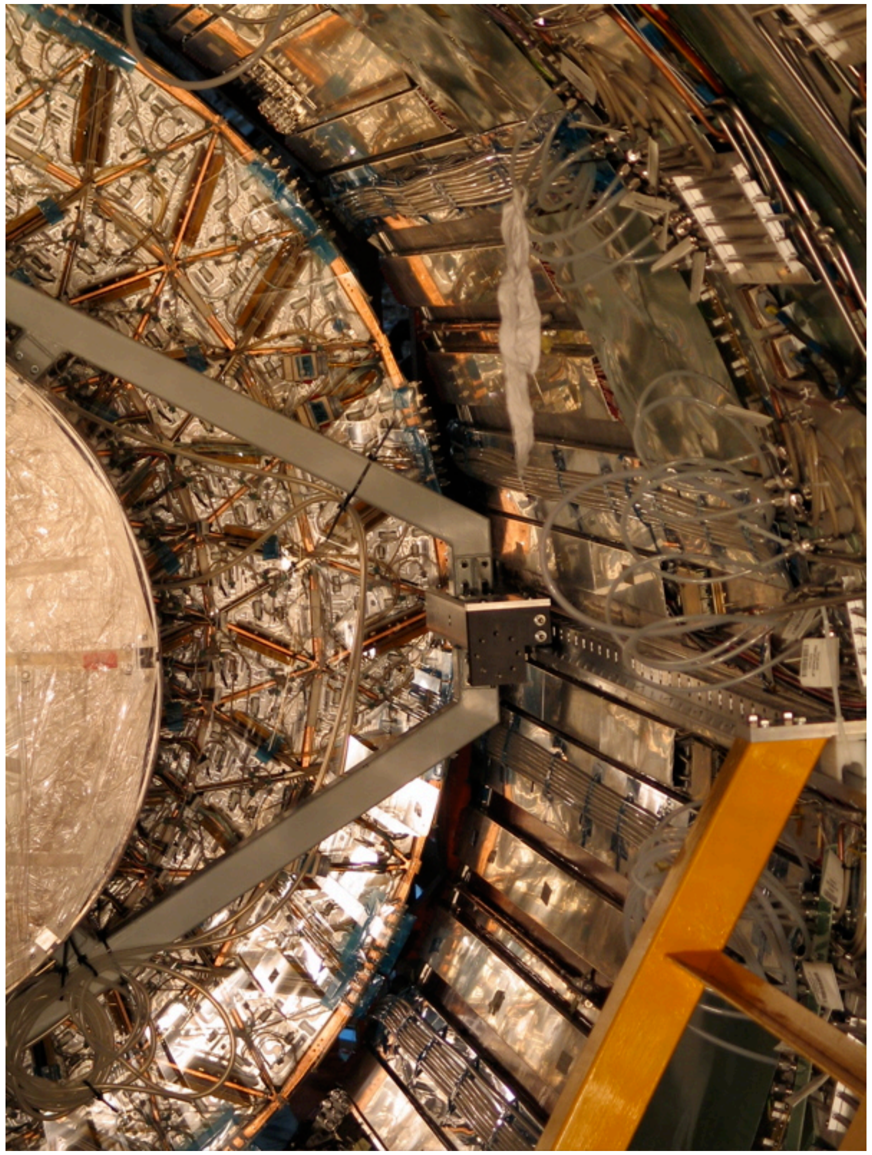




⇒ ***Solenoid current and thus magnetic field is very stable !***

Solenoid Magnet





The field mapping campaign

Using a pneumatic system for the first time

Expected field and Simulations

Field compositions

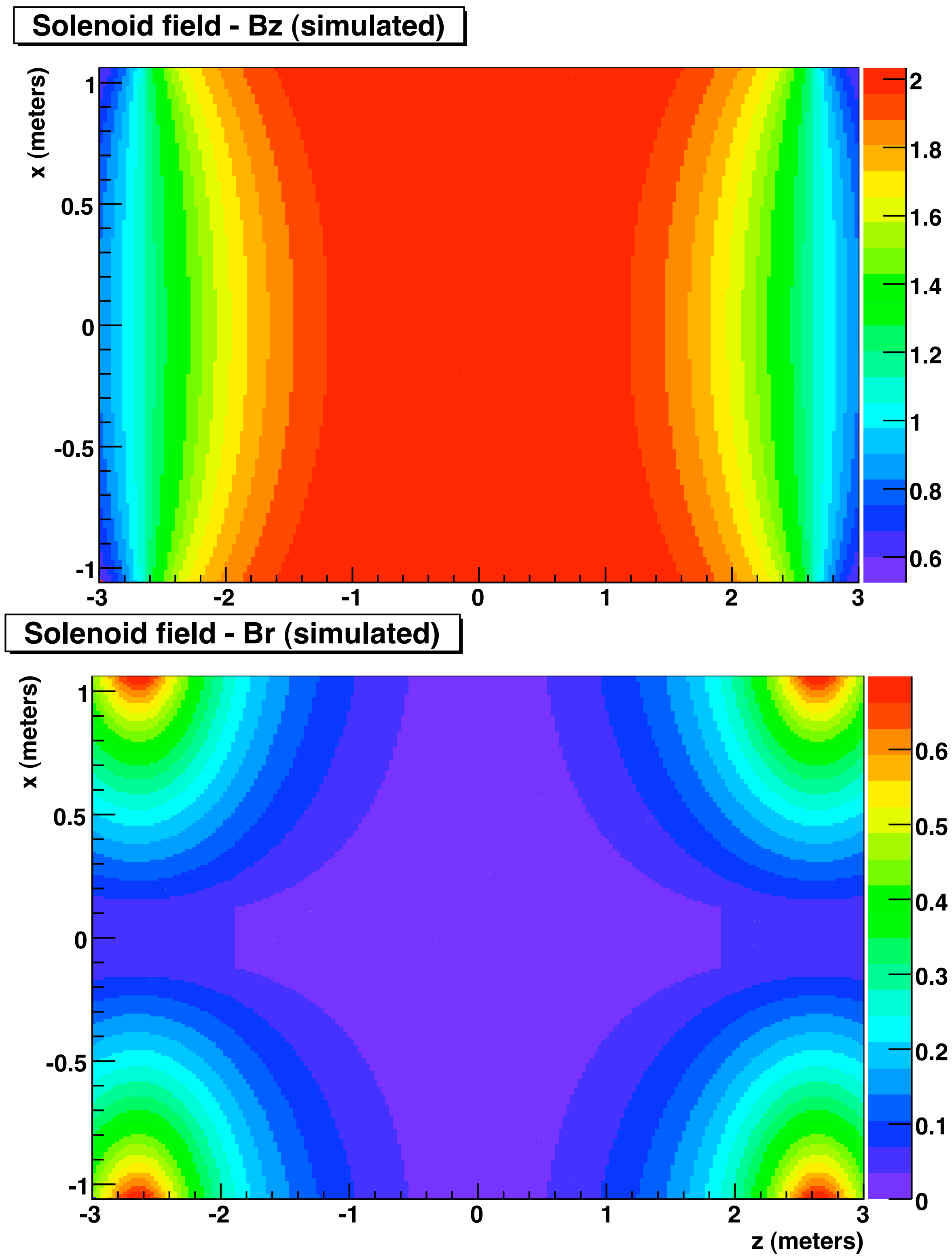
- 95.5 % of the field is due to the current in the coil
- 4.5 % is due to the magnetised iron.
- There is as well a small, calculated to be negligible, effect from the toroid field

Overall field shape

- Bz peaks at ~ 2 T, Br peaks at 0.8 T, Bf > 0 but close to 0 when corrections are applied
- Non uniform field at the end of coil, Bz component drops off and the Br component rises sharply at z = 2.65 m
- We expected also a non uniform field at the weld regions and or the return current at 78.75° (11.25°)

B field = Biot-Savart + TileCal
2 T = 1.92 T + 0.08 T

Sensitive to shift and tilt



Simulated field maps

Solenoid Field - Results of measurements

Field precision needed

- Integrated B-Field needs to be known with a precision of 0.05 % (10 Gauss in the 2 T field)

Measured field (JINST 3 P04003)

- Fit function (satisfying Maxwell's equations) matches data within **rms < 0.4 mT**
- Systematic error on the track sagitta due to field uncertainty between **0.02% and 0.12%**

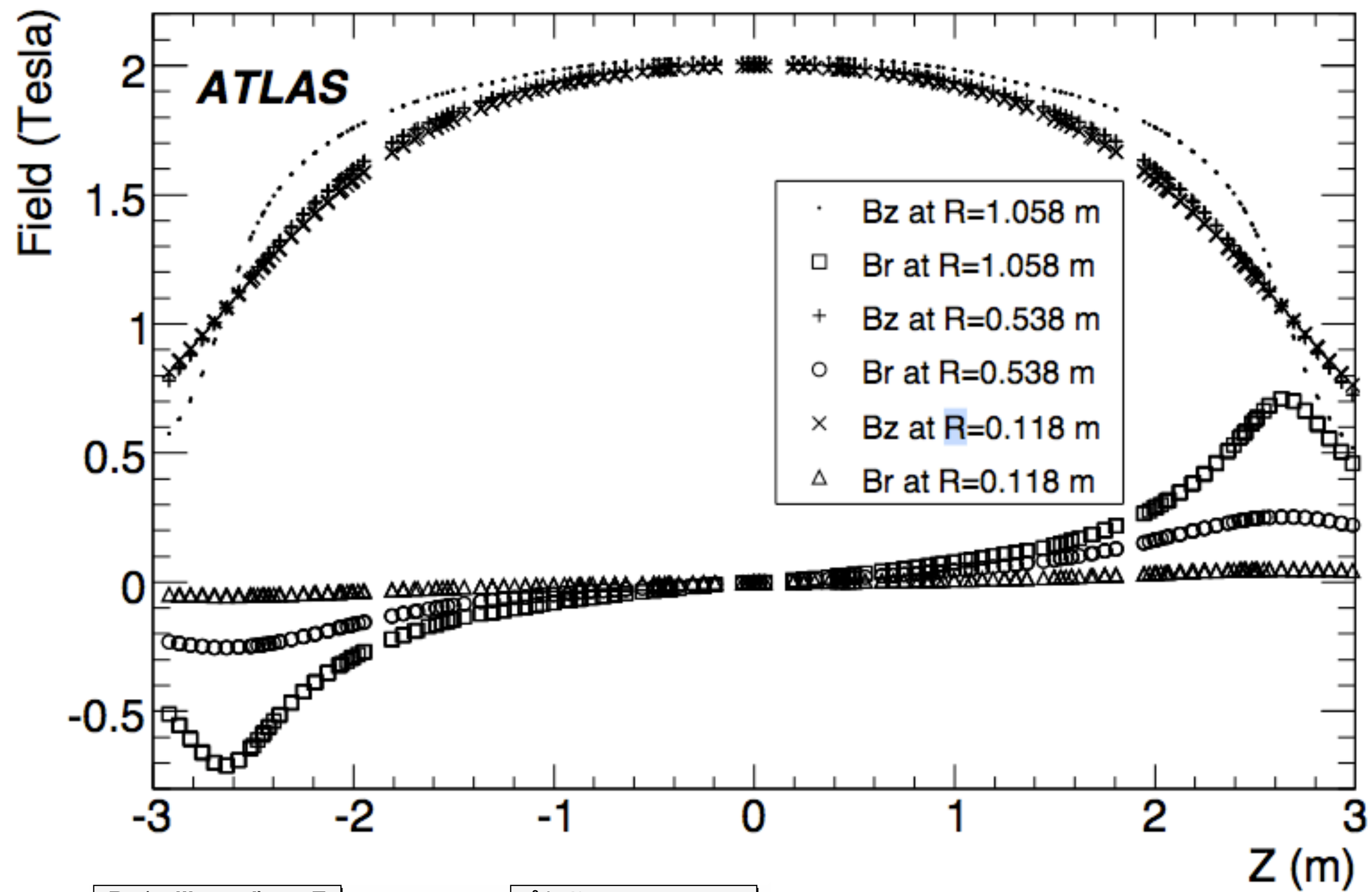
Survey information

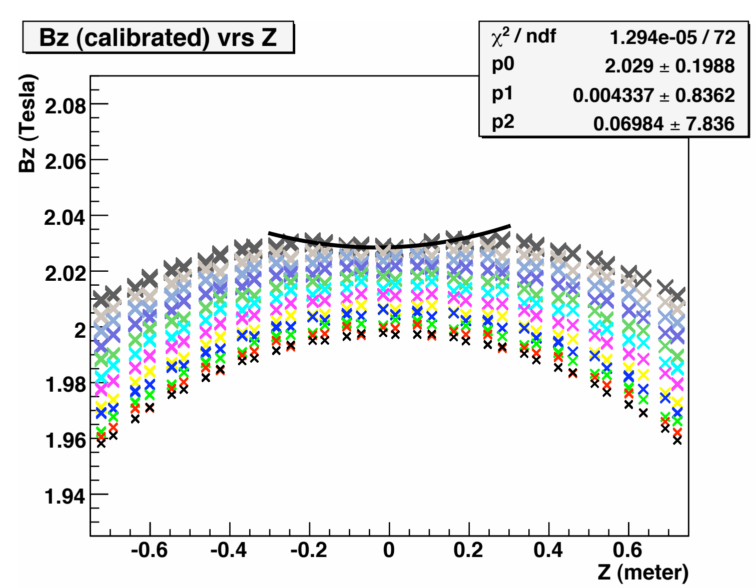
- Expected offsets for the solenoid centre from the field measurements are :

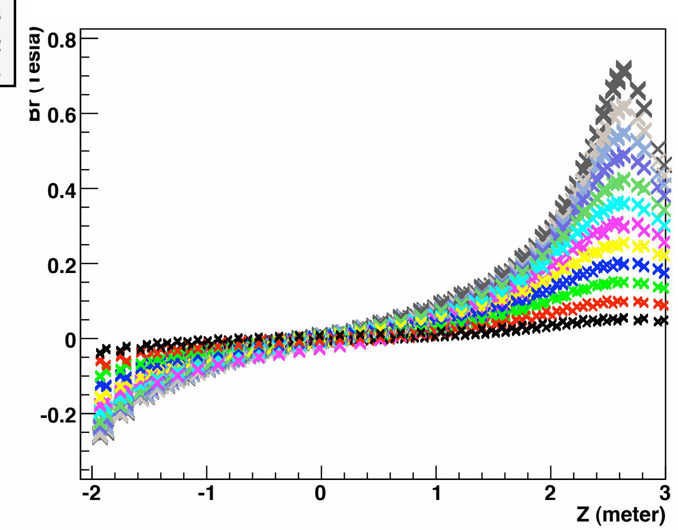
  x = -0.3 ± 0.4 mm

  y = -2.2 ± 0.4 mm

  z = -0.1 ± 2.3 mm







Measured field maps

⇒ ***Solenoid field measurement and fit function are very precise !***

Solenoid fit functions

Geometrical fit model

- Detailed model of the solenoid conductor geometry and integrating the Biot-Savart law using the known current
- The magnetised iron (e.g. TileCal, shielding disks) are parametrised using 4 free parameters of Fourier-Bessel series

General fit model

- Describes any field obeying Maxwell's equations
- Uses only the field measurements ont he surface of a bounding cylinder including its ends
- Bz fitted as a Fourier series
- The Bz field at the cylinder ends are fitted as a series as a series of Bessel functions

Map	B_Z (G)		B_R (G)		B_φ (G)		$\delta S/S$ ($\times 10^{-4}$)	
	rms	extreme	rms	extreme	rms	extreme	rms	extreme
5000	2.27	-25.1	1.84	-30.1	1.85	+11.5	1.70	+6.2
5000h	3.68	-31.0	3.12	-28.3	2.75	+12.7	2.40	+9.9
7000	4.97	-37.5	4.49	-33.5	3.64	+15.9	1.51	+7.2
7730a	4.34	-37.1	3.52	-33.8	2.90	+15.2	1.29	+6.5
7730b	3.47	-32.3	3.74	-54.1	3.85	+17.0	1.58	+8.4
7850	3.55	-32.6	3.85	-48.8	3.85	-17.2	1.69	+9.0

from P. S. Miyagawa - Final result from general fit model

Validation & Plans

Athena Implementation

Solenoid field

- Realistic model of the coil based on the measured field map points
- $|z| < 2.820$ m, $r < 1.075$ m
- Precision of the order of **0.4 mT**
- Worth noting change of centre field value in athena from 1.96 to 2 T

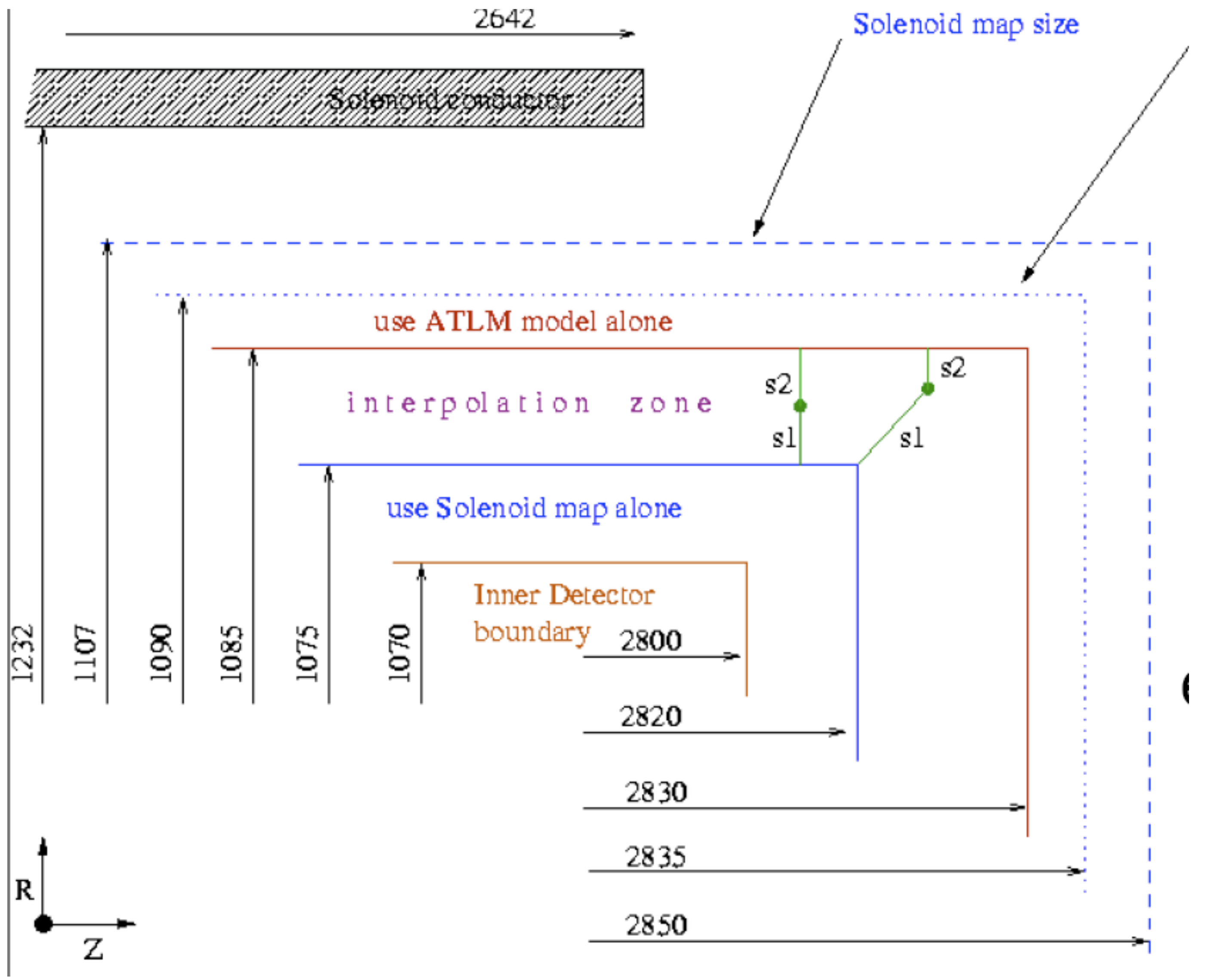
ATLM model

- Realistic toroid field and iron contribution models → depends on tilt and shift of the solenoid
- $|z| > 2.830$ m, $r > 1.085$ m

Interpolation region

- Weighted mixture where the weights are proportional to the shortest distance to the boundaries
- Precision of the order of **1 mT**

Region permitting shift (8mm) and tilt (2 mrad)



$$B^{interp} = (B^{map} * s2 + B^{ATLM} * s1) / (s1+s2)$$

from S. Snow

⇒ Successful implementation of the measurements in Athena !

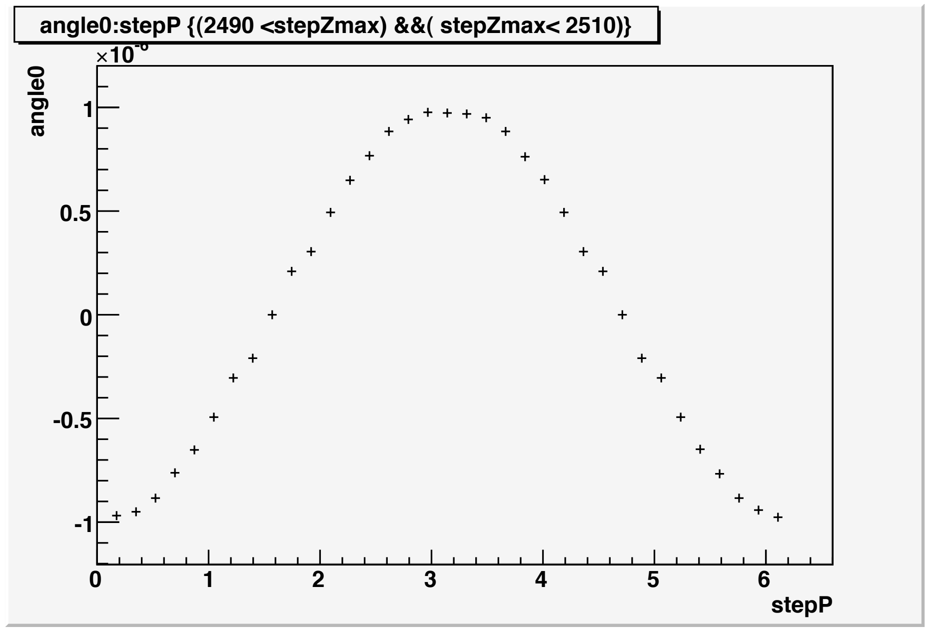
Current plans

Goals:

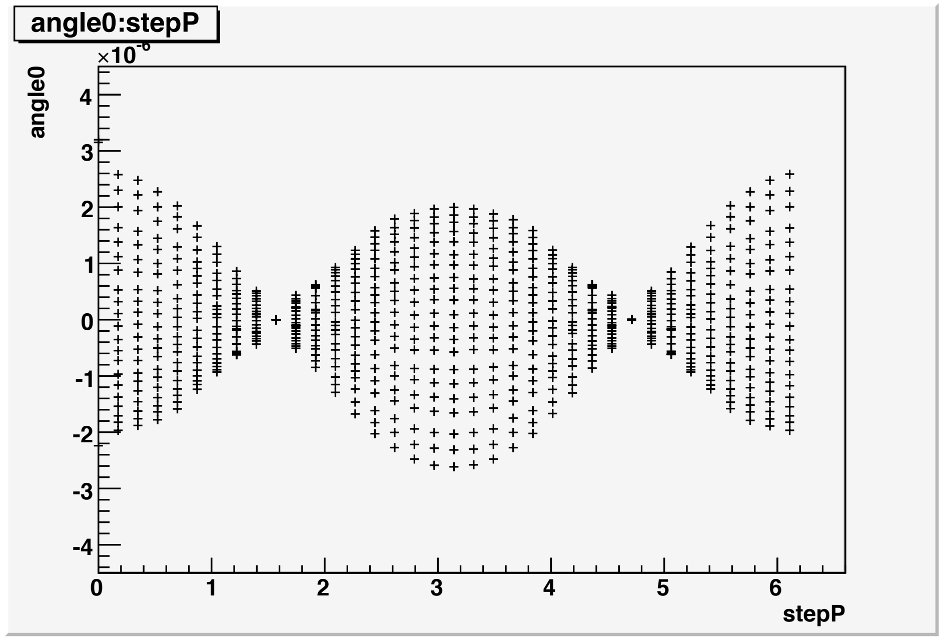
- Simple validation tools already exist at level of Athena compilation - basically verifying the shift and tilt of the field
- Can we establish more advanced tools using particles to be able to determine the performance of the measured field even better ?
  - To improve precision in the **interpolation regions**
  - Learn more about the impact of shifts and tilt of the field and its effect on the **iron contribution**
  - Would like to find the **field axis** with respect to the TileCal

Magnetic field effects

- Any effects are expected to be very small !
- Particles checked need to go through the same area of the detector to be influenced by the same magnetic field
- Statistics is probably an issue

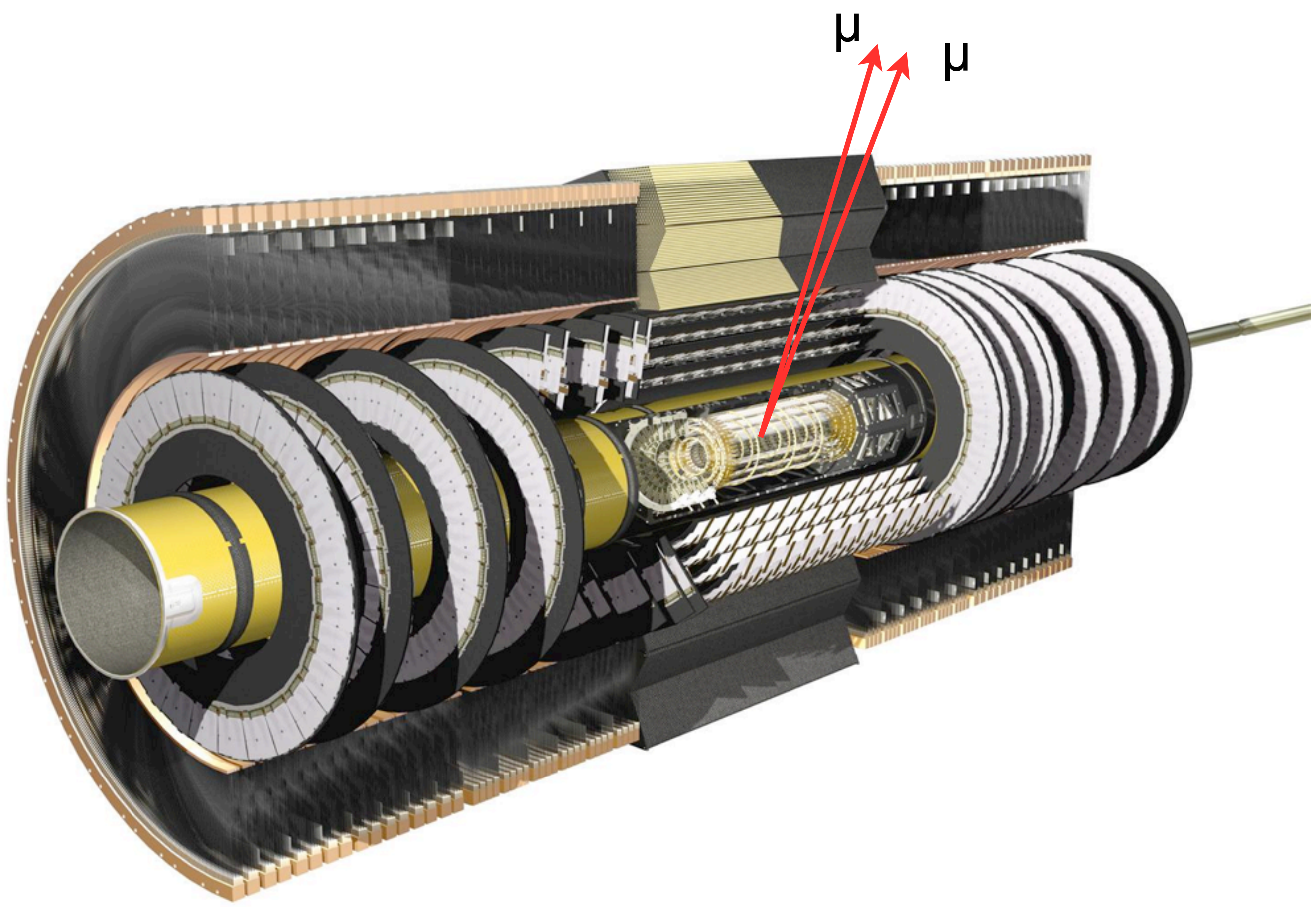


Examples of the simple field checks



⇒ ***Goal is to look at the effect of field changes to the trajectories of particles***

How can this be done?



Possible studies with muons

- J/Psi - seems most favourable since it has as very good boost with a small angle between the muons.
- Υ and Z are other options, but where the statistics may be better for some triggers the boost is worse

J/Psi production characteristics

- Trigger cuts, μ6μ4, μ4μ4, μ10+track
- Already at low centre-of-mass ~O(100) events
- Some 18 000 J/Psi per 1 pb^{-1} with μ4μ4

Possible particle trajectory distortions:

- Excess material
- Misalignment
- Other detector effects
- Bad reconstruction / computing effects

	Mass	Events (1y)	Boost
J/Psi (μ6μ4)	3.1 GeV	160×10^6	
Υ (μ6μ4)	9.5 GeV	50×10^6	
Z	91 GeV	-	

From D. Price, $L = 10^{33}\ cm^{-2}\ s^{-1}$

Study proposal

Possible cuts

- Small angle between the two muons, to make sure the B-field traversed is the same for the two muons
- Primary vertex cut to avoid muons coming from B → J/Psi

Possible assumptions

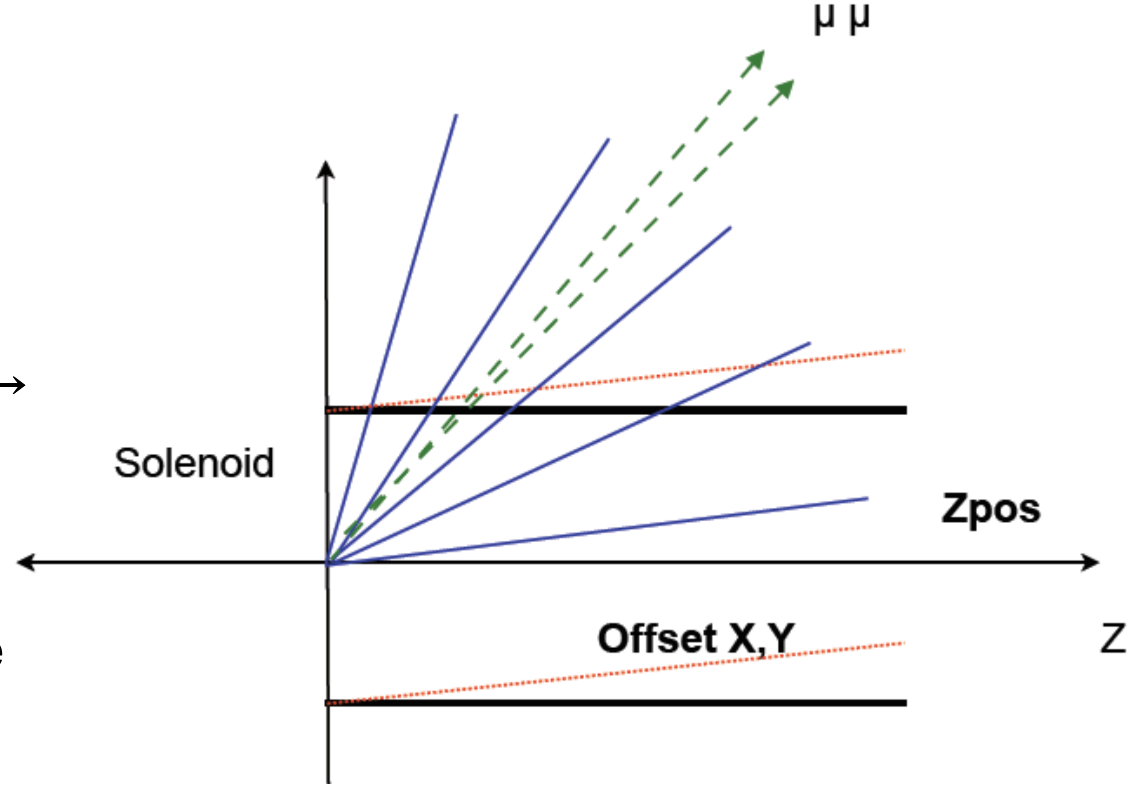
- Symmetric field in ϕ (which is not the case because of the return current)

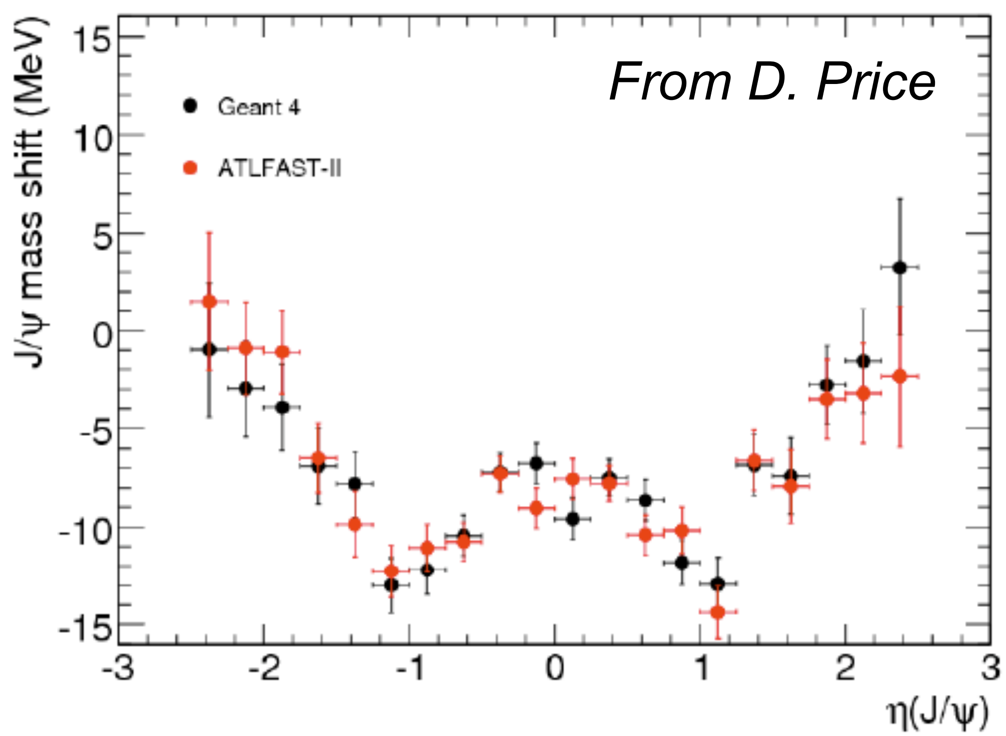
Sample AODs

- Without and with shift or/and tilt
- Subtract the two sets of data to be able to eliminate other effects, e.g. alignment, material ...

Study

- Look at the invariant mass variations both in η and ϕ
- Vary the shift and tilt to estimate the effect on the field





⇒ ***Work has already been started but no results yet due to technical difficulties***

Summary & Conclusion

- The ATLAS solenoid current and field is very stable
- The solenoid field is known very precisely
- A realistic field model has been successfully implemented in Athena
- Simple validation checks for shifts and tilt are included
- Studies with J/Psi will be tried as a tool to improve our understanding of the field in the interpolation region and the iron contributions

➡ ATLAS solenoid field is very well understood !

➡ Is it possible to understand it even better ?