Optimizing the Neutrino Factory Capture Section

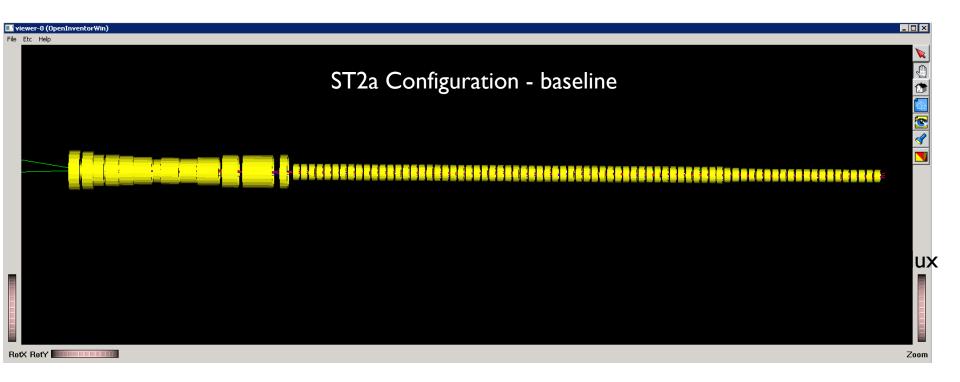
Ole Martin Hansen (CERN) and Ilias Efthymiopoulos (CERN) NUFACT-12, 25 July 2012

Optimization studies

- Fresh look at the NF solenoid target capture system
- Simulations using G4BeamLine and FLUKA
- Method:
 - Studies included alternative solenoid configurations
 - B-field tapering shape and inner shielding configurations
- Compare results by looking at the muon flux at z=50m
 - Muon selection (acceptance) cuts applied, i.e. select only muons that can be further transported in the Front-End

Alternative Solenoid Setups in G4BL

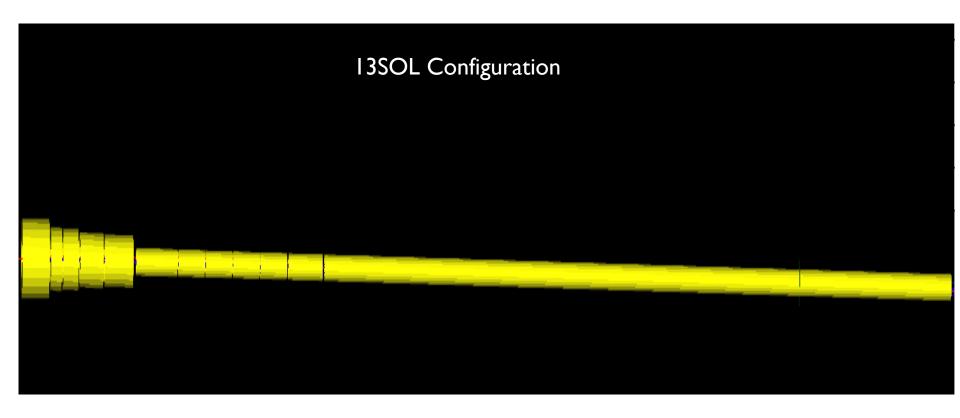
Magnets showed in yellow, picture from G4BL-viewer



- First solenoid starts at z=-1.3m
- ▶ Muon flux at z=50m measured as reference for comparison

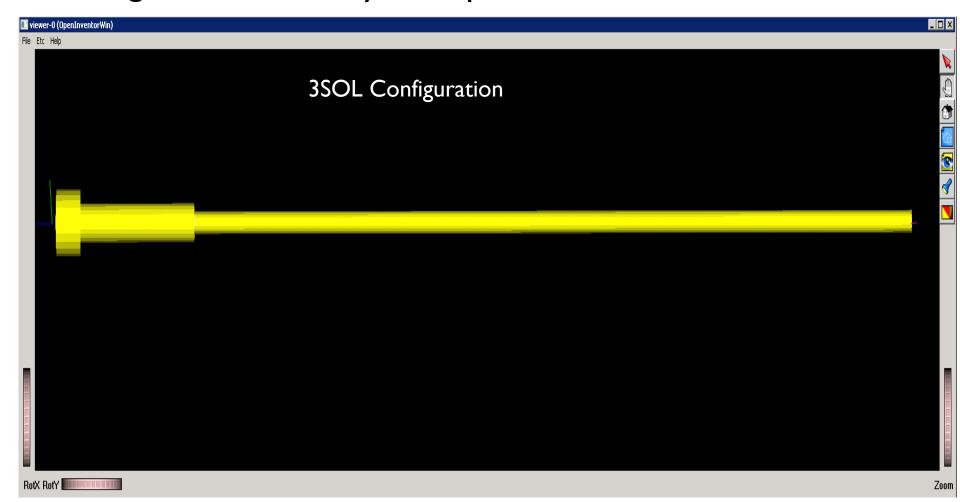
Alternative Solenoid Setups in G4BL

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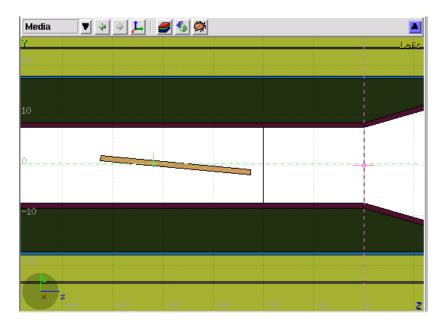
Alternative Solenoid Setups in G4BL

Magnets showed in yellow, picture from G4BL-viewer.



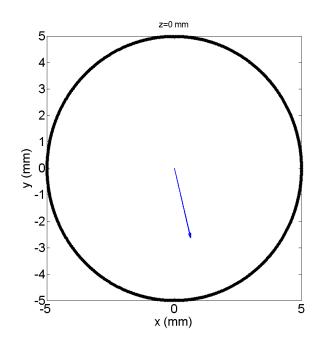
Beam and Target

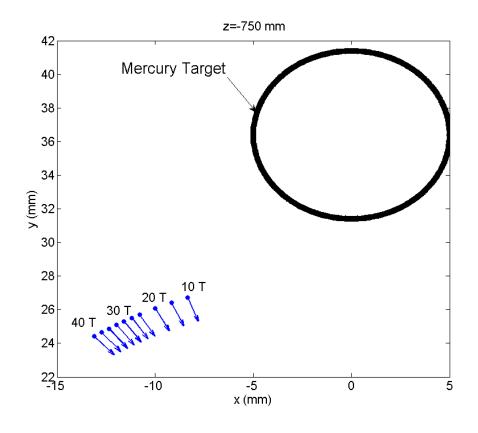
- ▶ 8 GeV Kinetic Beam Energy
- ▶ le5 POT
- \rightarrow σ = 1.5 mm
- Mercury target
- ▶ Radius=5 mm
- ▶ Length=30 cm
- ▶ Tilted 96.68mrad with respect to the z-axis
- Beam constraint:
 - Proton beam target axis angle at z=-37.5cm : $\theta_{BT}=30$ mrad



Beam Entry Direction

- ▶ Beam entry position, at -75 cm, varies with magnetic field strength. Calculated from the center of target, at (0,0,-37.5) with fixed angles:
- θ_{BT} =30 mrad
- → φ=144°





Acceptance Cuts

Used full front-end made by Pavel Snopok in G4BL (Thanks Pavel !!)

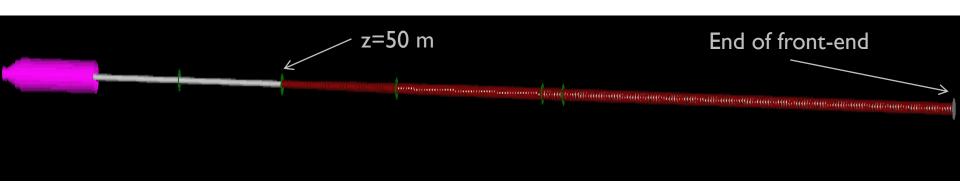
Useful muons defined as the ones arriving at the end of the front-end satisfying the cuts of ecal9f routine:

Momentum	Transverse acceptance	Longitudinal acceptance cuts
[MeV/c]	[m rad]	[m rad]
100 <p<sub>z<300</p<sub>	A _T <0.150	A _L <0.030

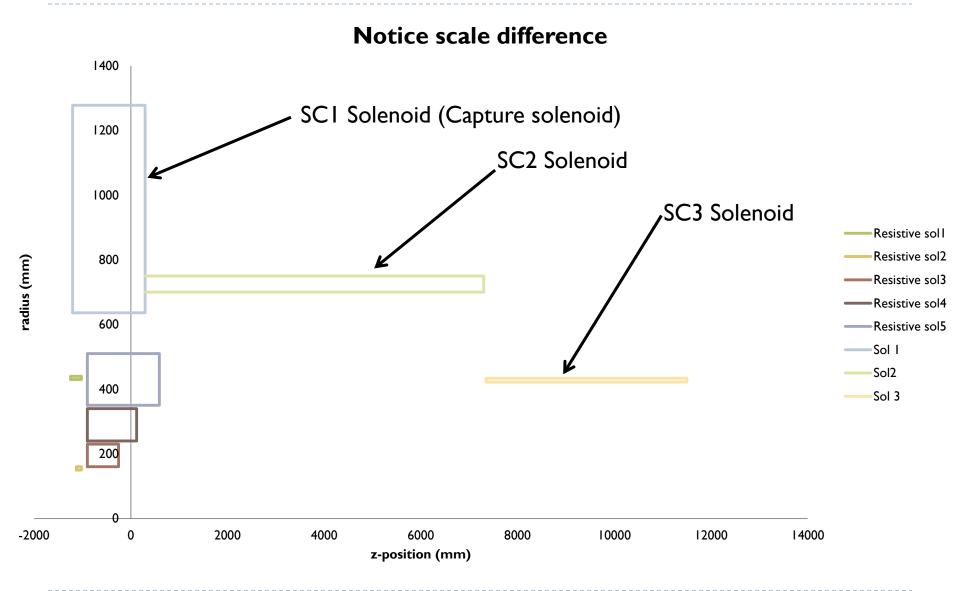
Acceptance Cuts

- ▶ Tracing back the useful muons to z=50 m
 - Use particle ID to find the survivors, define the time, momentum cuts.

Momentum	Transverse momentum	Time	Radius (mm)
[MeV/c]	[MeV/c]	[ns]	[mm]
100 <pz<300< td=""><td>P_T<50</td><td>160<t<240< td=""><td>r<200</td></t<240<></td></pz<300<>	P _T <50	160 <t<240< td=""><td>r<200</td></t<240<>	r<200



3 sol setup, without shielding

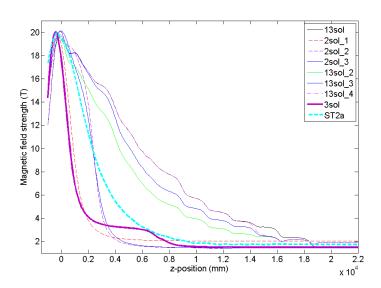


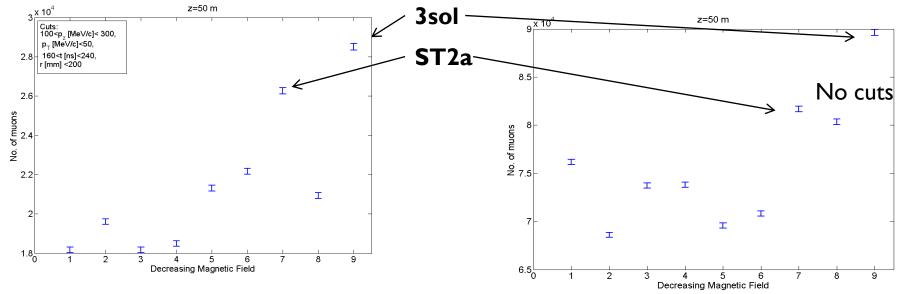
Magnetic field tapering

The 3SOL configuration gives
~9% higher # of muons after the acceptance cuts wrt ST2a

baseline

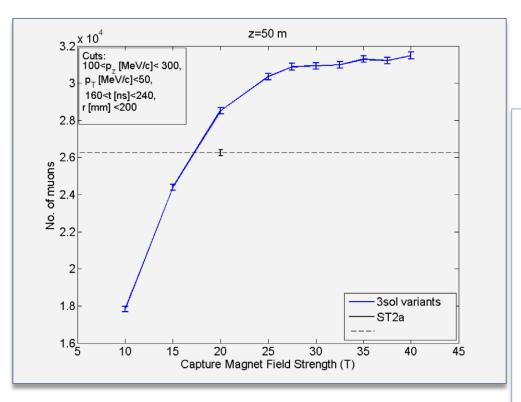
No. of muons at z=50 m			
	ST2a	3 sol	Ratio
w/cuts	26262	28513	1.09
No cuts	81682	89624	1.10

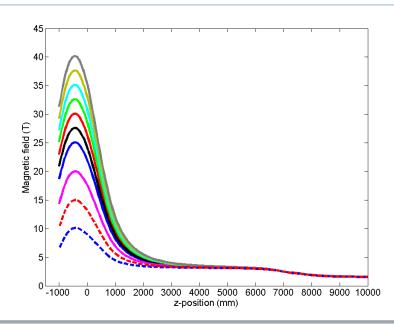




3SOL Layout - Varying SC1

- Magnetic field strength varied from 10-40 T
- ▶ 20 T seems to be a good compromise





Conclusions - I

Using simple layout configuration:

- Rapidly decreasing magnetic field tapering as in the 3SOL case is a good alternative to the adiabatically tapered magnetic field
- The lower current in SC2 may allow this solenoid, expected to receive the peak of the radiation from the target, to have a larger radius thus less exposed to radiation
- The capture magnet producing a 20 T field seems to be a good compromise
- Next : Studies with inner shielding
 - Variation of SCI, SC2, SC3 field strengths independently

Inner Shielding layout

Assuming adiabatic tapering:

- The magnetic flux at the center of SC1 ($\Phi_1 = \pi B_1 R_1^2$) and at the end of the capture/tapering section ($\Phi_2 = \pi B_2 R_2^2$) must be conserved.
- ► This results: $R_2^2 = (B_1/B_2)*R_1^2$

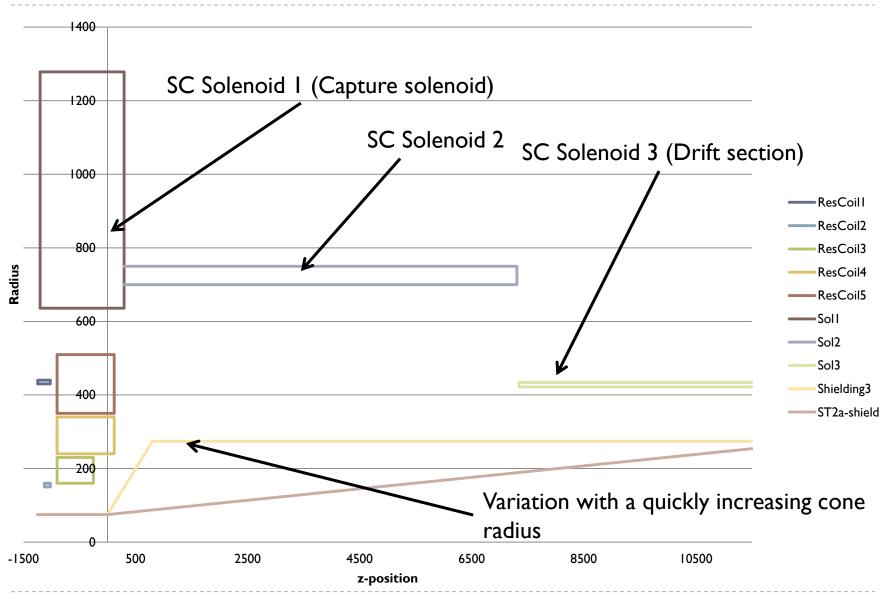
► ST2a:

$$R_1 = 7.5$$
cm, $R_2 = 25.4$ cm; when $B_1 = 20$ T, $B_2 = 1.75$ T

▶ 3SOL:

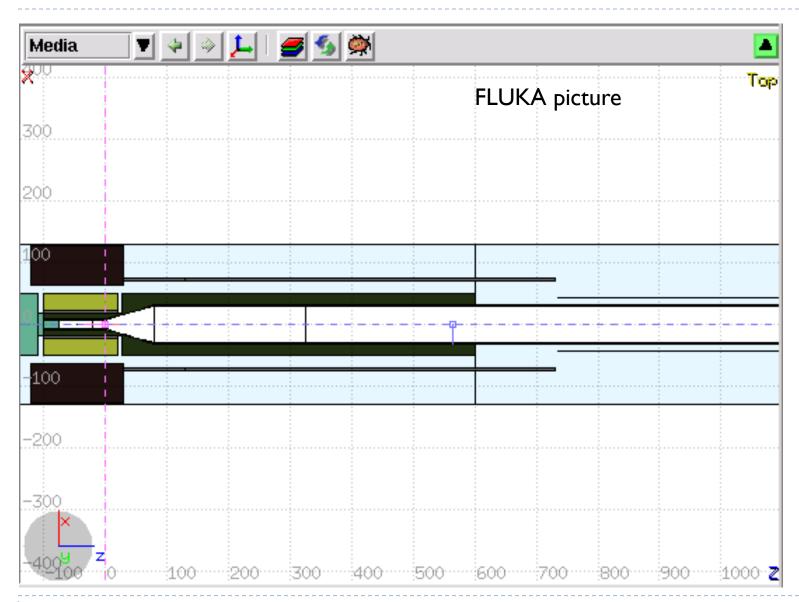
$$R_1 = 7.5$$
cm, $R_2 = 27.4$ cm; when $B_1 = 20$ T, $B_2 = 1.5$ T

3SOL configuration – inner shielding

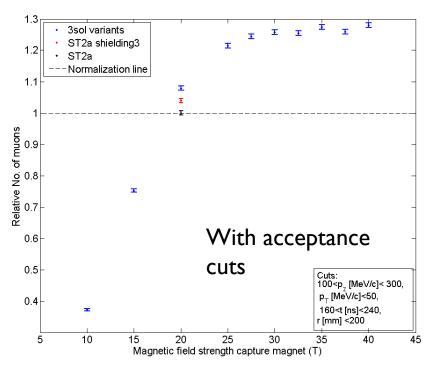


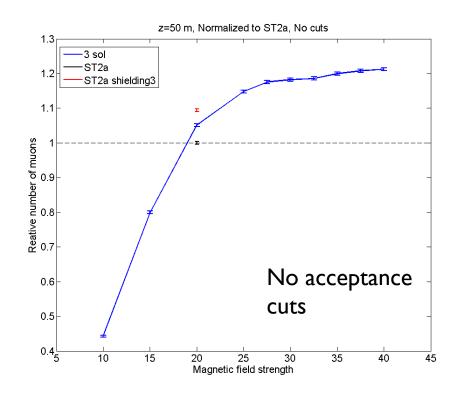
15

3SOL configuration – inner shielding

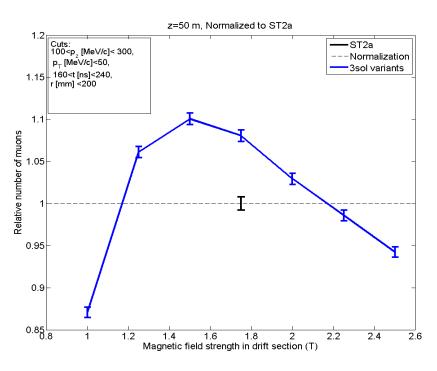


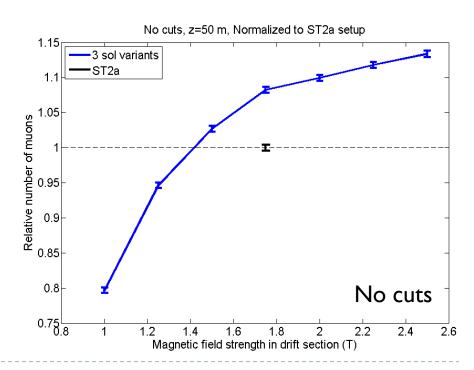
- Want the highest field possible without loosing touch with reality, assume ~20 T
- ST2a_modified has 3sol shielding

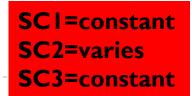




- The I.5 T field in the drift section gives the highest muon flux, when applying acceptance cuts
- Without any cuts, the higher the magnetic field strength the better

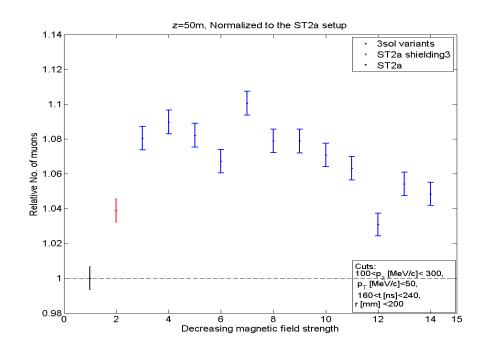


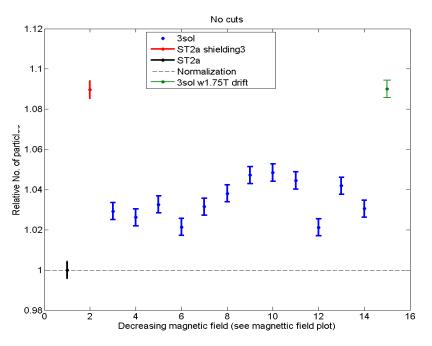




	Setup	Muons w/cuts	Relative w/cuts	Relative no cuts
25	ST2a	23671	1.00	1.00
	ST2a_shield3	24591	1.04	1.09
20-	3sol	26049	1.10	1.05
€ Best	3sol w1.75 drift	24801	1.05	1.09
Magnetic field strength (T) 15 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -				
0 -1000 0 1000 2000 3000 4000 5000 z-position (mm)		10000		

SC1=constant
SC2=varies
SC3=constant

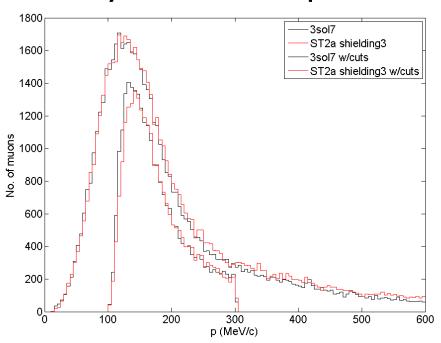


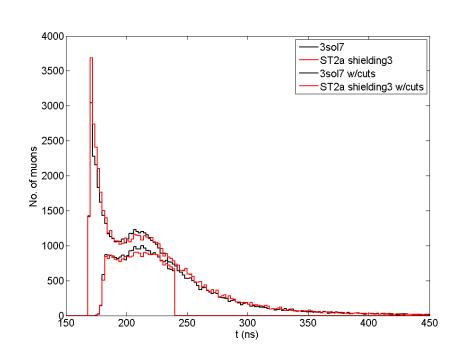


20

3SOL Sensitivity to acceptance cuts

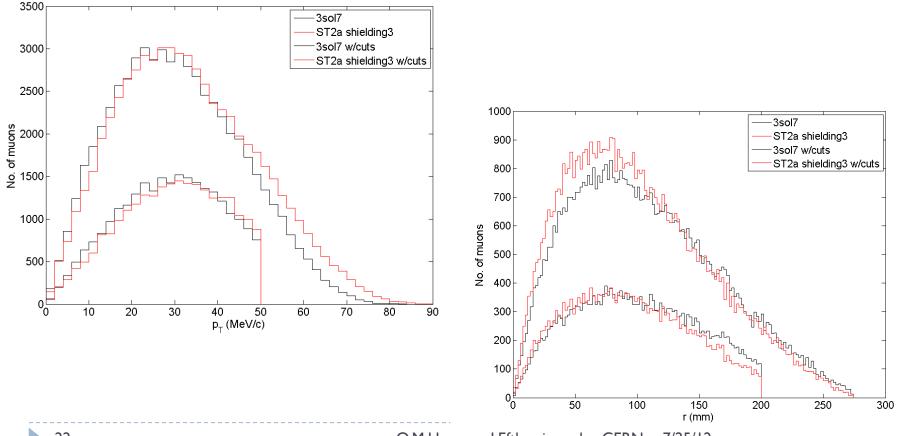
- 3sol captures more particles with the right time, position and momentum
- ST2a_modified captures more of the faster particles, but they are not accepted





3SOL Sensitivity to acceptance cuts

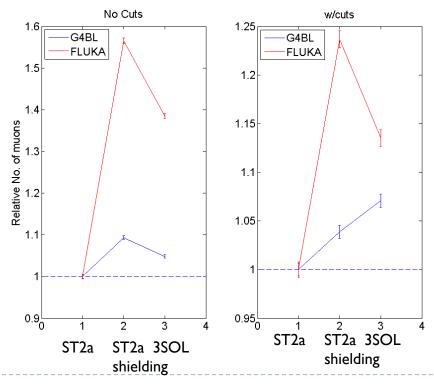
3sol has a slightly higher mean radius <r> and a slightly lower mean transverse momentum<p_T>, resulting overall in a slightly higher yield of captured muons



Muon flux: FLUKA vs G4BL

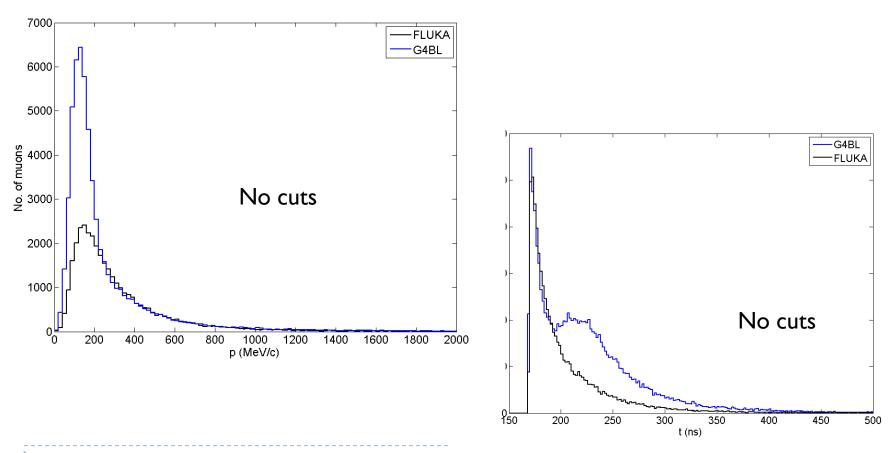
- ▶ Identical setups made for G4BL and Fluka
- The table and the plot shows the relative muon flux, normalized to the ST2a-setup
- FLUKA results are more sensitive to change of shielding

Relative No. of muons wrt ST2a				
Setup	No cuts		w/cuts	
	G4BL	FLUKA	G4BL	FLUKA
ST2a_shielding3	1.09	1.57	1.04	1.24
3SOL	1.05	1.38	1.10	1.14



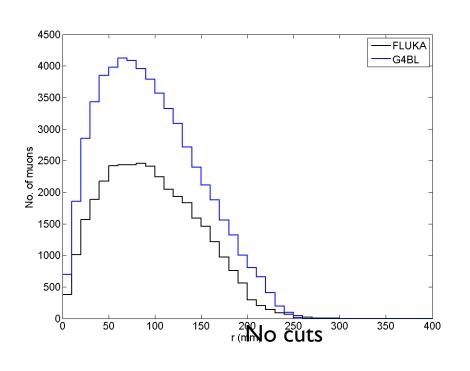
ST2a: FLUKA vs G4BL

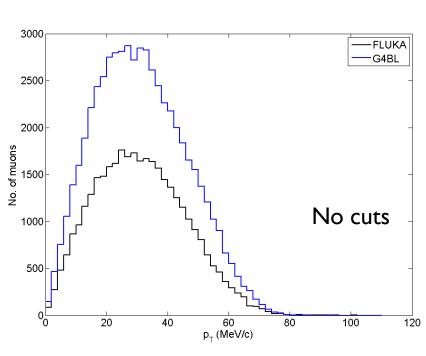
▶ G4BL produces softer momentum spectrum, resulting in a different time distribution wrt FLUKA



ST2a: FLUKA vs G4BL

P_T and r distributions are similar, but G4BL gives a higher muon flux





Conclusions - II

- Using the muon acceptance cuts, the 3SOL setup gives higher yield of muons compared to ST2a
 - ▶ 10% difference using G4BL
 - ▶ 14% difference using FLUKA
- Before applying the acceptance cuts, the difference is much higher:
 - **+5**% in G4BL for 3SOL, and **38**% for 3SOL in FLUKA compared to ST2a
- FLUKA is more sensitive to the shielding layout
- Next steps:
 - study the energy deposition using FLUKA
 - Investigate further the particle production difference between G4BL and FLUKA