

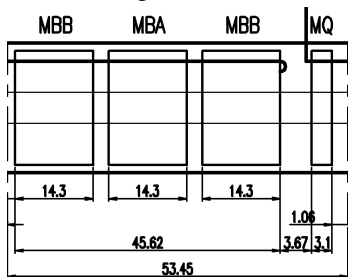
FLUKA simulations of UFO-induced losses in the LHC arc

A. Lechner and F. Cerutti (on behalf of the FLUKA team)
with valuable input by T. Baer

Meeting of the Quench Test Strategy WG
May 4th, 2012

Introduction

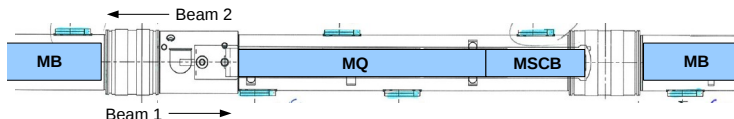
Considered region: arc cell 19R3



Outline

- **BLM pattern** for different potential UFO locations around the MBs
 - Comparison of simulation results against BLM data measured in 2011 (with only 6 BLMs present around the MQ)
 - Demonstration of the resolution gain due to additional BLMs installed in 2012: first comparison of simulations with measurements
- **Peak energy density** in MB coils for **3.5 TeV** and **7 TeV**

General BLM coverage of arc cells: **6 BLMs in proximity of each MQ**



Introduction

19R3: cell with one of the highest UFO occurrence in 2011

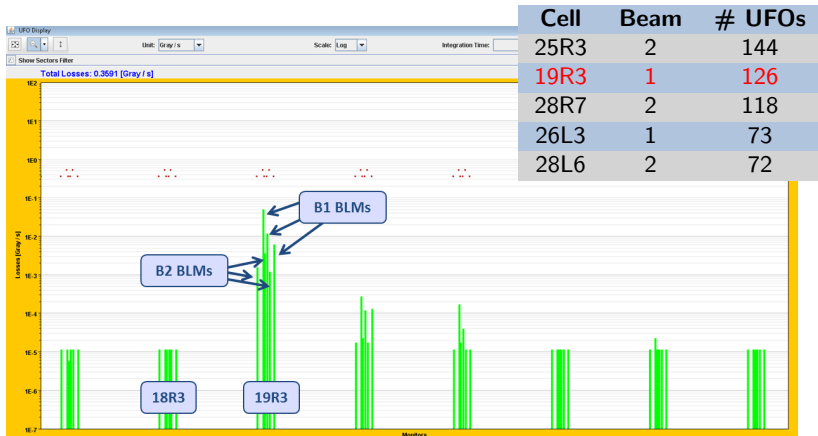
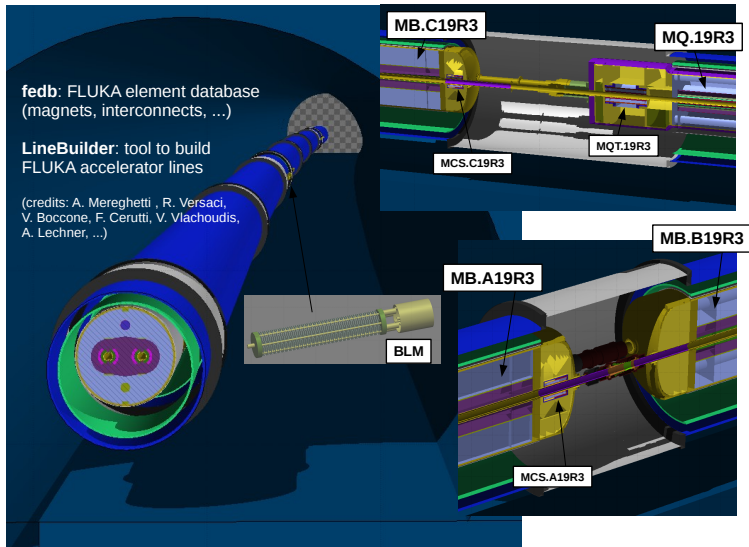


Figure: BLM loss pattern caused by UFO@19R3 (15/10/2011)

Table and figure by courtesy of Tobias.

FLUKA geometry implementation of the LHC arc



UFO case studies

Simulations were performed for **two potential UFO positions** ≈ 30 m apart (see figure below):

- **Pos #1:** in the **QBBI.A19R interconnect**
- **Pos #2:** in the **MB.C19R center**

Beam-UFO interactions:

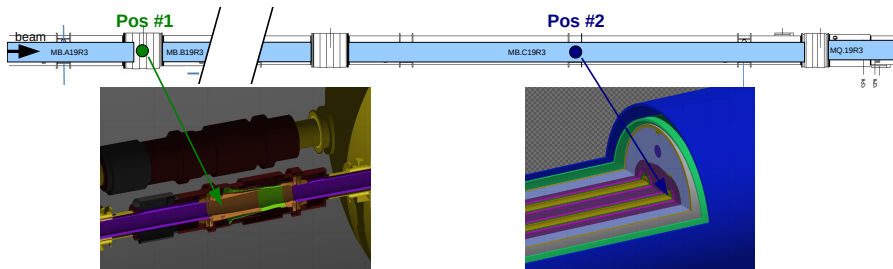
- UFOs were assumed to be composed of **Fe**
- Only **inelastic proton-UFO interactions** were simulated

Beam:

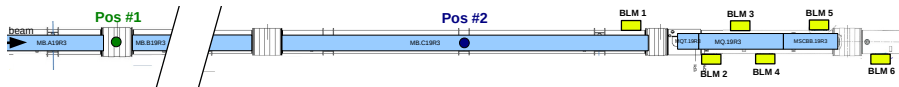
- Only **beam 1** was considered (internal beam) since most UFOs in 19R3 were observed for this beam
- Simulations were performed for **3.5 TeV** (both UFO positions) and **7 TeV** (UFO pos #1 only)

Uncertainties:

- Note that simulations can always be affected by a certain systematic error, e.g. due to geometry approximations (still, arc model is reasonably accurate)
- For some quantities, statistical error can be high, in particular BLM signals in BLMs upstream of UFOs or in BLMs at large distances



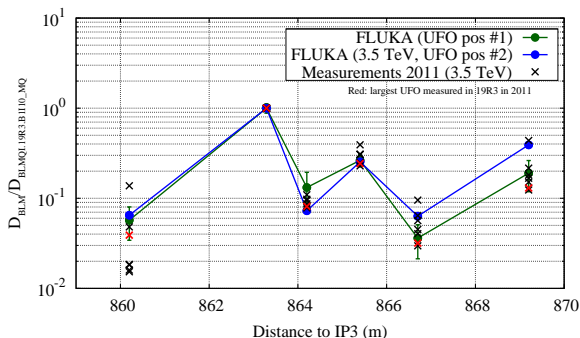
BLM signals: MC vs measurements (2011)



#	Name	From IP3 (m)
1	BLMQI.19R3.B2E30_MQ	860.2
2	BLMQI.19R3.B1I10_MQ	863.3
3	BLMQI.19R3.B2E20_MQ	864.2
4	BLMQI.19R3.B1I20_MQ	865.4
5	BLMQI.19R3.B2E10_MQ	866.7
6	BLMQI.19R3.B1I30_MQ	869.2

Figure right:

- Shows a set of BLM pattern measured between 04/2011 and 10/2011
- Red crosses:** one of the largest UFOs measured in 19R3 (15/10/2011), with RS7 of BLMQI.19R3.B1I10.MQ being 3.9×10^{-4} Gy/sec
- All values **normalized** to signal measured with **BLMQI.19R3.B1I10.MQ**
- Note:** statistical error of simulation results large for Pos #1 (more CPU time needed)



Given the **spread in measured BLM data** and the current statistical error of simulation results:

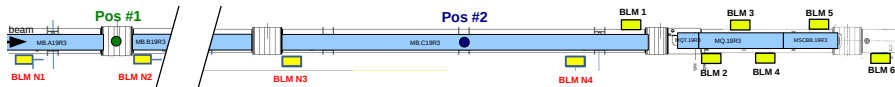
- no disentanglement of positions was possible for 2011 data**

BLM signals: Measurements (2012)

Additional BLMs in 2012:

- Four additional BLMs were installed along the MBs in 19R3 by the BLM team (S. Grishin, R. Tissier) in Feb 2012 (installation triggered by Tobias)

#	Name	From IP3 (m)
N1	BLMEI.19R3.B1I20.MBB.A19R3	826.8
N2	BLMEI.19R3.B1I30.MBB.A19R3	830.8
N3	BLMEI.19R3.B1I10.MBB.B19R3	846.5
N4	BLMEI.19R3.B1I20.MBB.B19R3	858.1



Found UFOs (26/200 datasets)

UFO ID	Time (local)	Loss/Threshold	Loss RS4 (kvs)	Energy (GeV)	Int B1 (# charges)	Int B2 (# charges)	Beam mode	Filnumber	Verification level
BLMEI.19R3.B1I20.MBB.B19R3	2012-04-05 16:12:05.0	5.22E-4	2.49E-4	3999.99	5.65E12	5.69E12	STABLE	2471	VERIFIED
BLMEI.19R3.B1I10_MQ	2012-04-08 22:25:23.0	8.88E-4	8.73E-4	4000.00	1.06E13	4.06E13	RAMP	2481	VERIFIED
BLMEI.19R3.B1I20.MBB.B19R3	2012-04-08 22:44:04.0	2.79E-3	1.13E-3	4000.00	4.05E13	4.03E13	SQUEEZE	2481	VERIFIED
BLMEI.19R3.B1I20.MBB.B19R3	2012-04-07 01:59:05.0	1.42E-3	6.79E-4	4000.00	3.60E13	3.59E13	ADJUST	2482	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-08 04:57:46.0	6.68E-2	2.81E-2	3999.99	3.16E13	3.13E13	STABLE	2488	VERIFIED
BLMEI.19R3.B1I30.MBB.A19R3	2012-04-08 08:45:29.0	2.23E-4	2.23E-4	3237.48	3.59E13	3.59E13	RAMP	2489	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-08 22:21:39.0	1.32E-2	4.48E-3	4000.00	7.75E13	7.68E13	STABLE	2491	VERIFIED
BLMEI.19R3.B1I30.MBB.A19R3	2012-04-08 23:33:11.0	5.66E-3	3.58E-3	4000.00	7.54E13	7.63E13	STABLE	2491	VERIFIED
BLMEI.19R3.B1I20.MBB.B19R3	2012-04-08 07:18:22.0	6.32E-3	2.74E-3	4000.00	8.89E13	8.85E13	FLATTOP	2492	VERIFIED
BLMEI.19R3.B1I30.MBB.A19R3	2012-04-08 10:02:26.0	4.69E-4	7.13E-4	3999.99	8.89E13	8.80E13	FLATTOP	2493	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-09 13:51:08.0	1.94E-3	7.26E-4	4000.00	8.19E13	8.27E13	STABLE	2493	VERIFIED
BLMEI.19R3.B1I10.MBB.B19R3	2012-04-10 05:55:45.0	8.83E-4	5.89E-4	3999.99	8.39E13	8.57E13	STABLE	2497	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-12 15:38:10.0	1.02E-3	4.13E-4	3999.99	1.11E14	1.12E14	SQUEEZE	2508	VERIFIED
BLMEI.19R3.B1I30.MBB.A19R3	2012-04-14 06:22:45.0	2.19E-3	3.00E-3	4000.00	1.32E14	1.29E14	STABLE	2513	VERIFIED
BLMEI.19R3.B1I10.MBB.B19R3	2012-04-14 10:05:36.0	3.34E-4	2.43E-4	3999.99	1.24E14	1.19E14	STABLE	2513	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-15 11:27:47.0	5.37E-2	2.21E-2	3999.99	1.46E14	1.45E14	STABLE	2515	VERIFIED
BLMEI.19R3.B1I10.MBB.B19R3	2012-04-15 11:38:05.0	3.00E-3	2.99E-3	3999.99	1.45E14	1.44E14	STABLE	2515	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-15 22:21:16.0	1.67E-3	6.90E-4	3999.99	1.29E14	1.29E14	STABLE	2516	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-15 22:50:43.0	1.05E-3	3.45E-4	3999.99	1.27E14	1.24E14	STABLE	2516	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-16 13:58:04.0	2.15E-3	8.17E-4	3947.52	3.47E13	3.42E12	RAMP	2519	VERIFIED
BLMEI.19R3.B1I10.MBB.B19R3	2012-04-16 18:06:46.0	1.25E-3	2.35E-3	2929.68	3.34E12	3.42E12	RAMP	2520	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-18 02:29:33.0	7.16E-3	2.87E-3	3999.99	1.79E14	1.79E14	SQUEEZE	2527	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-20 04:17:16.0	3.12E-4	4.24E-4	560.16	1.95E14	1.95E14	RAMP	2536	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-20 04:27:06.0	4.66E-2	1.74E-2	3674.64	1.95E14	1.95E14	RAMP	2536	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-20 06:57:16.0	1.03E-3	4.13E-4	3999.99	1.79E14	1.79E14	STABLE	2536	VERIFIED
BLMQI.19R3.B1I10_MQ	2012-04-20 10:50:58.0	9.90E-4	3.96E-4	3999.99	1.62E14	1.63E14	STABLE	2536	VERIFIED

Table on the right:

- By courtesy of Tobias
- UFOs in 19R3 measured so far in 2012 (up to the end of April)
- Largest BLM signals seen in different BLMs
- The few largest of all UFOs were recorded in BLMQI.19R3.B1I10.MQ

BLM signals: MC vs measurements (04/2012)

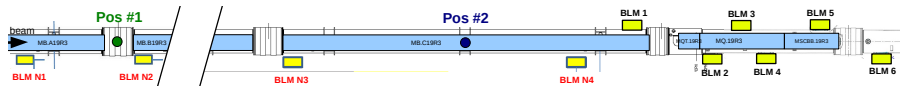
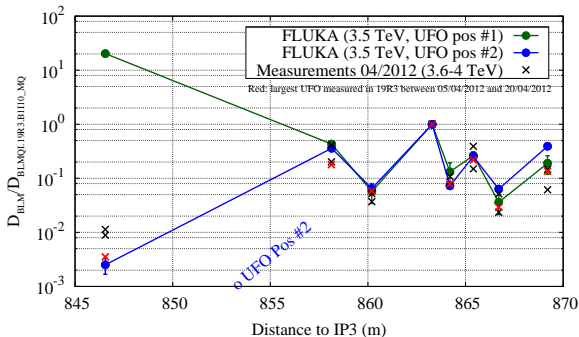


Figure right:

- Shows the BLM pattern for the **three largest UFO events in 19R3** so far observed in **2012** (largest UFO indicated by **red crosses**, where $RS7$ of $BLMQI.19R3.B1I10.MQ = 2.5 \times 10^{-4}$ Gy/sec)
- BLMs N1 and N2 not shown since measured signal is very small
- All values **normalized** to signal measured with $BLMQI.19R3.B1I10.MQ$
- Note:** simulation results obtained for 3.5 TeV, while measurements are at energies between 3.67 and 4 TeV (ramp, stable beams)
- Note:** statistical error of simulation results large for Pos #1 (more CPU time needed)



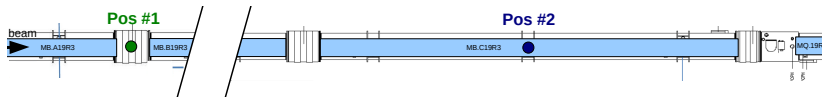
Inelastic proton-UFO interactions required to produce a signal as measured on 8/4/2011:

- Assuming **Pos #2**: $\sim 4 \times 10^6$

UFO location:

- For these UFO events, simulation results strongly suggest UFO location to be rather closer to **Pos #2** than **Pos #1**
- More UFO locations need to be studied to get more conclusive results

Peak energy density in MB coils for p@3.5 TeV and 7 TeV



Only UFO in Pos # 1 considered

Figure right:

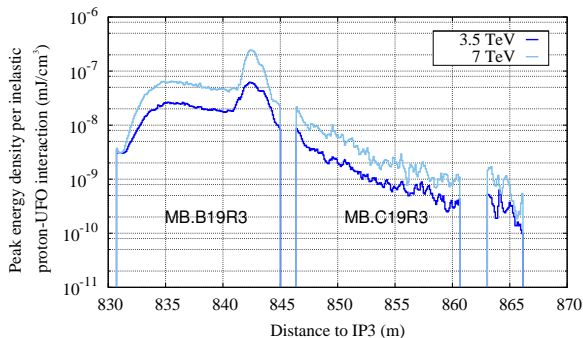
- Shows peak energy density in MB magnet coils
- All values **per inelastic proton-UFO interaction**

Maximum peak energy density:

- Caused by neutral particles hitting the bent magnet aperture

Maximum peak energy density per interaction:

- p@3.5 TeV: $\sim 6 \times 10^{-8} \text{ mJ/cm}^3$
- p@7 TeV: $\sim 2.5 \times 10^{-7} \text{ mJ/cm}^3$



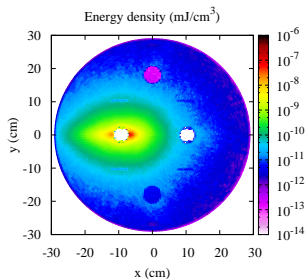
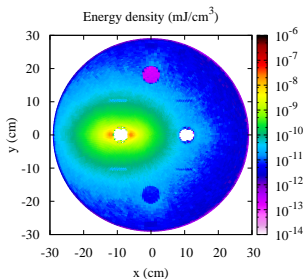
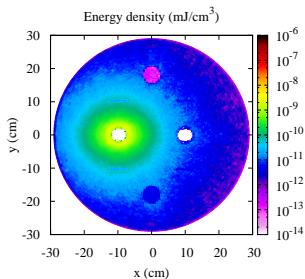
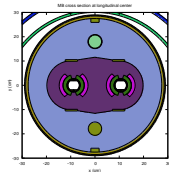
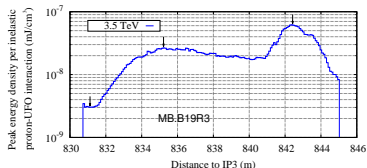
Lateral energy density profile in MB magnet for p@3.5 TeV

Only UFO in Pos # 1 considered:

- o UFO in interconnect upstream of MB.B19R3 (see previous slide)

Plots below:

- o Lateral energy density profiles per inelastic proton-UFO interaction (in a longitudinal layer of 10 cm thickness)
- o Longitudinal position as indicated by arrows in plot on the right



- o Negative x: internal beam
- o Beam direction: out of the screen

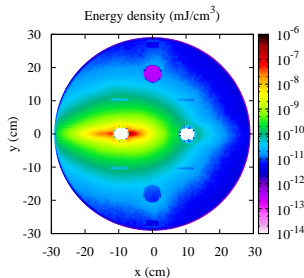
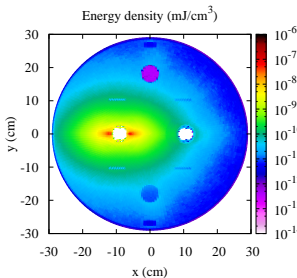
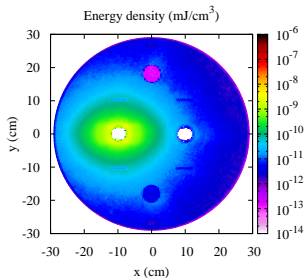
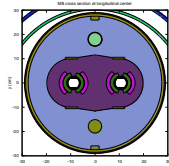
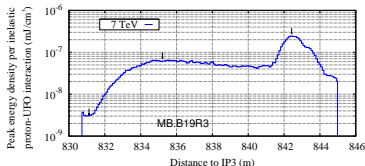
Lateral energy density profile in MB magnet for p@7 TeV

Only UFO in Pos # 1 considered:

- o UFO in interconnect upstream of MB.B19R3

Plots below:

- o Lateral energy density profiles per inelastic proton-UFO interaction (in a longitudinal layer of 10 cm thickness)
- o Longitudinal position as indicated by arrows in plot on the right



- o Negative x: internal beam
- o Beam direction: out of the screen

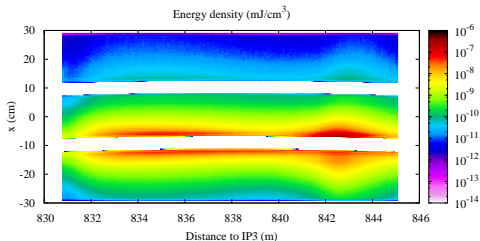
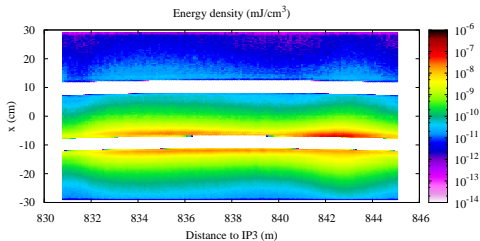
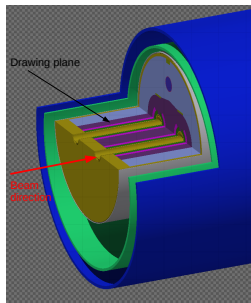
Longitudinal energy density profile for p@3.5 and 7 TeV

Only UFO in Pos # 1 considered:

- o UFO in interconnect upstream of MB.B19R3

Plots right:

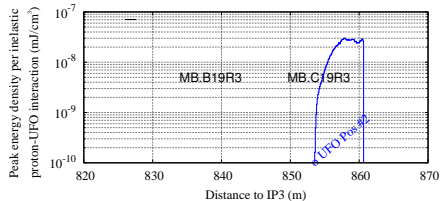
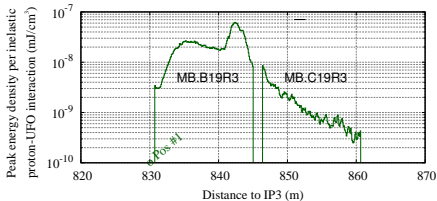
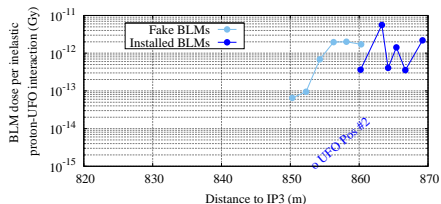
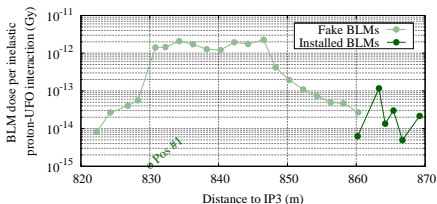
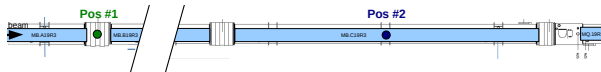
- o Longitudinal energy density profile in the **horizontal plane** of the MB.B19R3 (again per proton-UFO interaction)
- o Plot at top: p@3.5 TeV
- o Plot at bottom: p@7 TeV



BLM dose & peak energy density in MB coils for p@3.5TeV

Additional BLMs:

- Fake BLMs were included in simulation to study in more detail the BLM pattern



Summary and conclusions

- **UFO location** in arc cell 19R3
 - New BLMs yield a significant gain in resolution
 - First observations in 2012: UFOs seem to occur all along the arc cell
 - Largest UFOs events observed so far in 2012 were “close” to MQ (potentially in the MB located just upstream)
 - More simulations (involving different UFO locations) would be required to narrow down individual UFO locations
- For the **same number of interactions** and assuming the UFO to be located **just upstream of an MB**:
 - The simulation predicts a **peak energy density in the MB coils about 4 times higher** at 7 TeV than at 3.5 TeV
- Correspondance between maximum BLM signal and peak energy density in MB coils:
 - Impacted by UFO location in arc cell