The (proposed) FASER experiment
(ForwArd Search ExpeRiment)

Jamie Boyd (PBC workshop, accelerator session)

13 June 2018

This talk will cover FASER work and considerations related to the accelerator complex:
- experiment location & environment
- civil engineering
- background studies
- TS1 work
- implications of detector installation & operation (transport, services etc..)
- possible timelines

More physics oriented FASER talk tomorrow in BSM session!

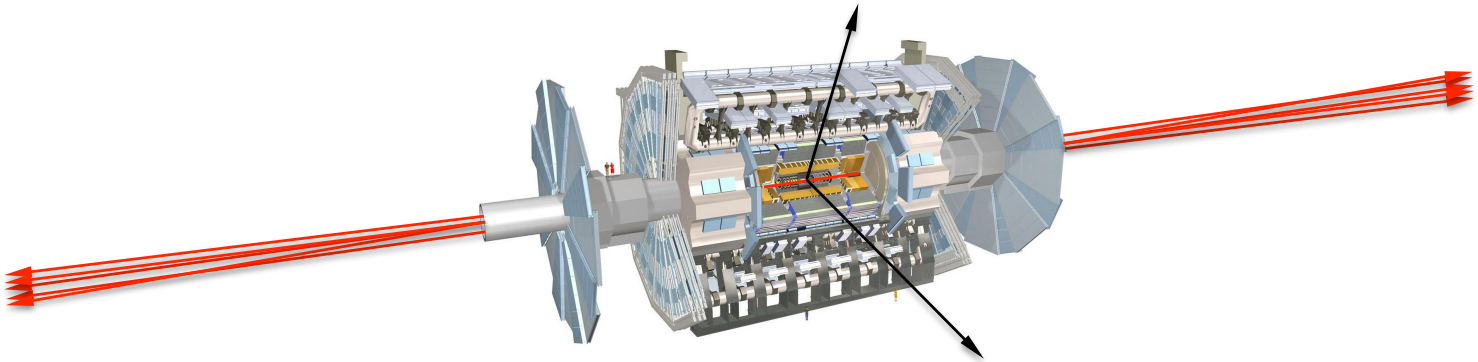
Many **thanks** for useful discussions with many CERN teams, and especially:
Mike Lamont, John Osborne, Jonathan Gall, Rhodri Jones, Salvatore Danzeca, Dominique Missiaen, Francesco Cerutti, Marta Sabate-Gilarte, Andrea Tsinganis, Attilio Milanese, Marzia Bernardini, Anne-Laure Perrot

FASER website:
https://twiki.cern.ch/twiki/bin/view/FASER/WebHome

FASER: THE IDEA (1-slide!)

- New physics searches at the LHC focus on high p_T. This is appropriate for heavy, strongly interacting particles
  - σ ~ fb to pb → N ~ 10^3 – 10^6, produced ~isotropically

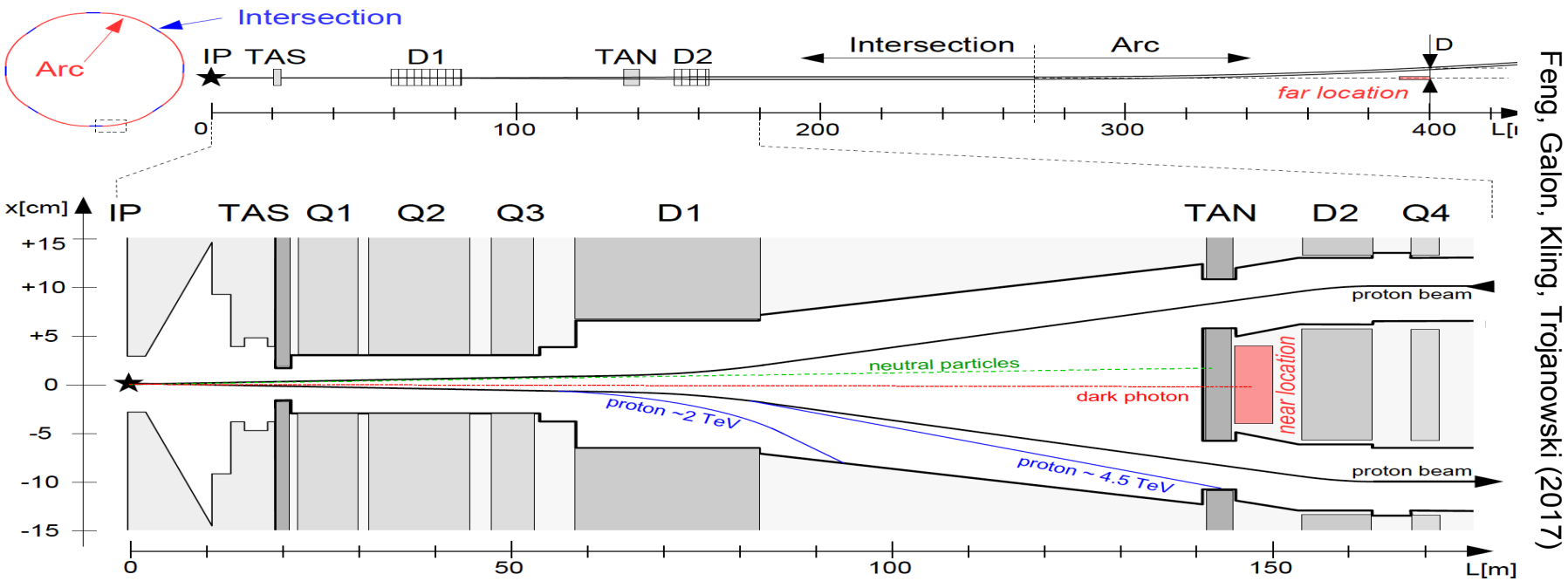
- However, if new particles are light and weakly interacting, this may be completely misguided. Instead should exploit
  - σ_{inel} ~ 100 mb → N ~ 10^{17}, θ ~ Λ_{QCD} / E ~ 250 MeV / TeV ~ mrad



- We propose a small, inexpensive experiment, FASER, to be placed in the very forward region of ATLAS/CMS, a few 100m downstream of the IP, and analyze its discovery potential

FASER LOCATION

- We want to place FASER along the beam *collision* axis
  - Location: ~400 m from IP, after beams curve, ~3 m from the beams

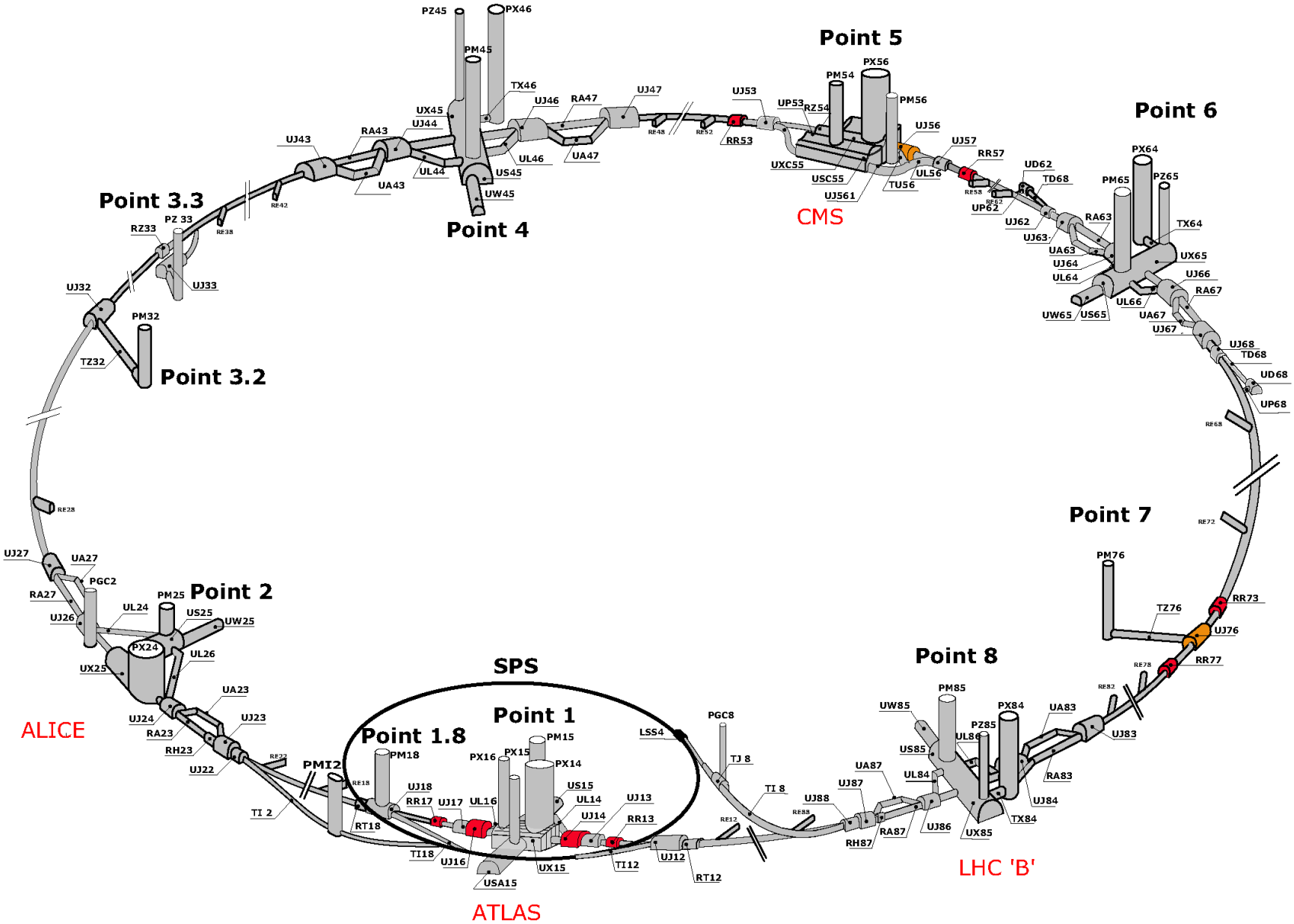


Feng, Galon, Kling, Trojanowski (2017)

Here assume FASER is exactly on-axis

- If ATLAS/CMS beams cross at 285 (590) μrad in vertical/ horizontal plane, far location shifts by 6 (12) cm

LHC RING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Point 6
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SPS
CMS
ALICE
ATLAS
LHC 'B'
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PX46
PM45
TX46
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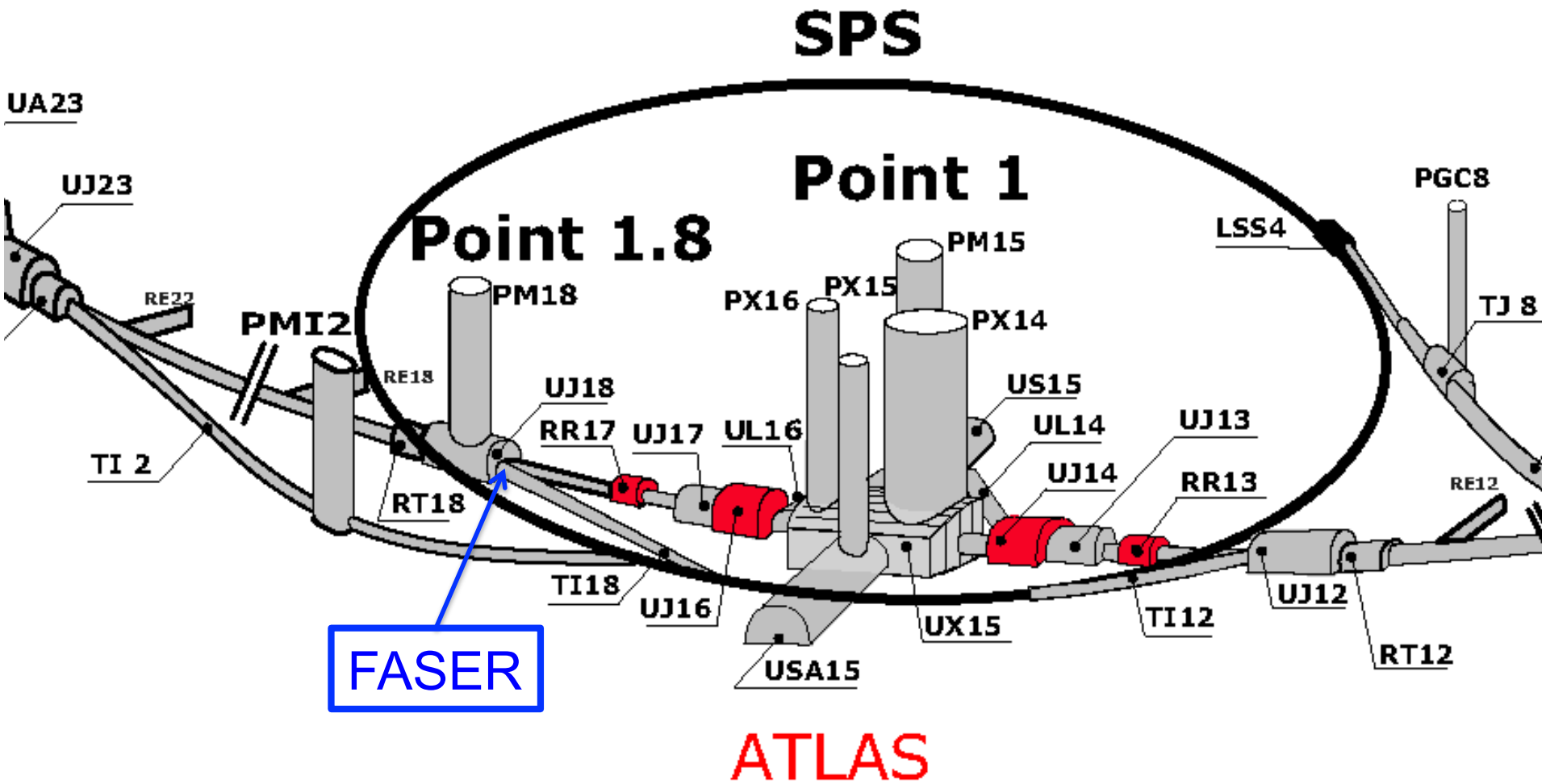
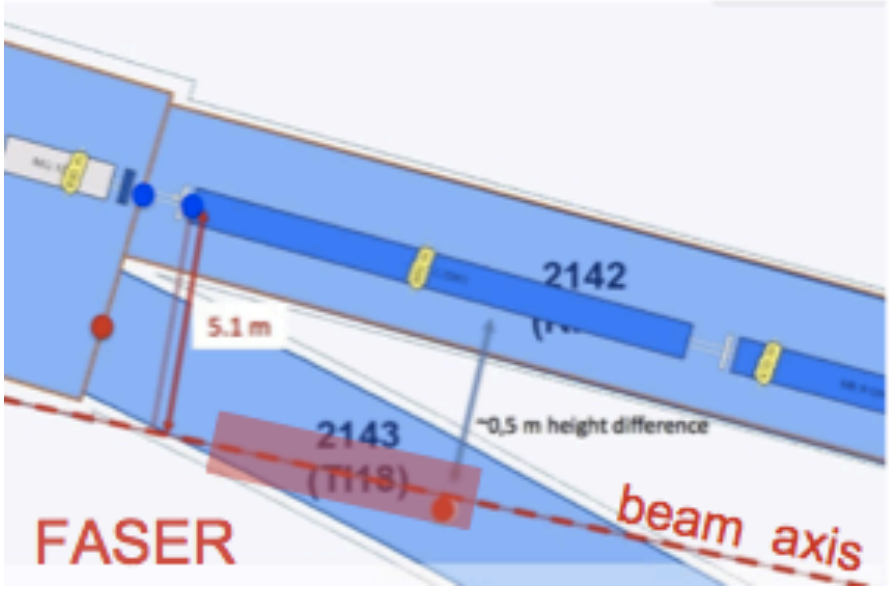
SERVICE TUNNEL TI18

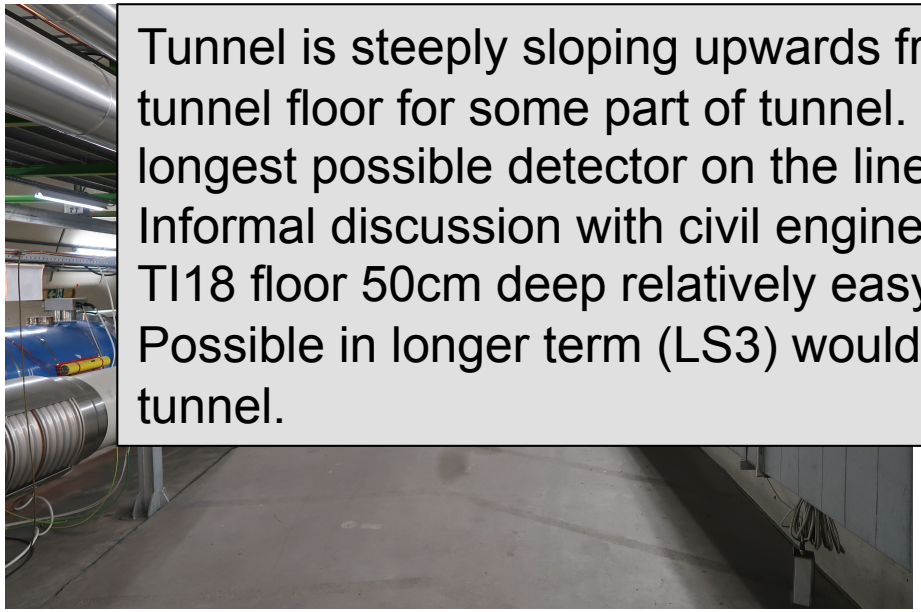


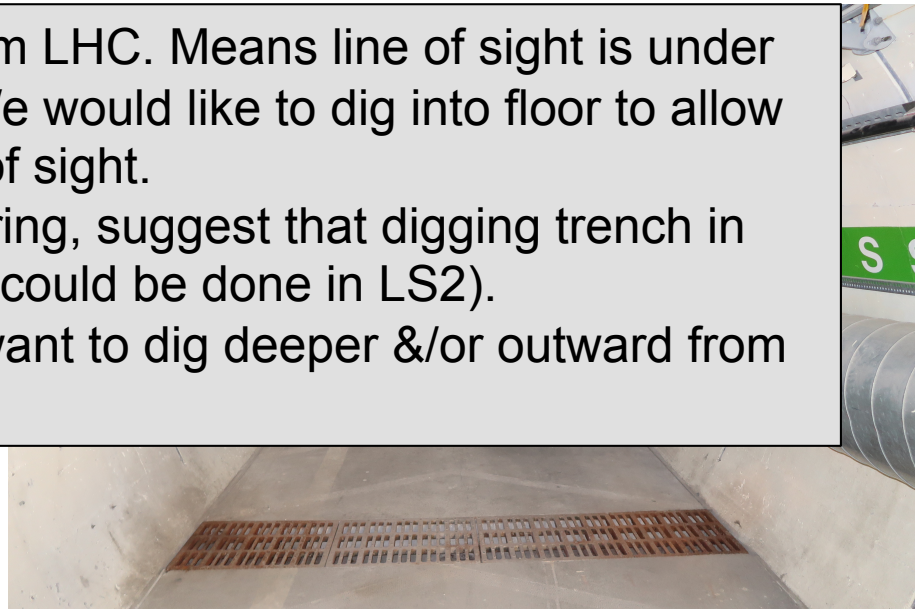
FASER: LOCATION

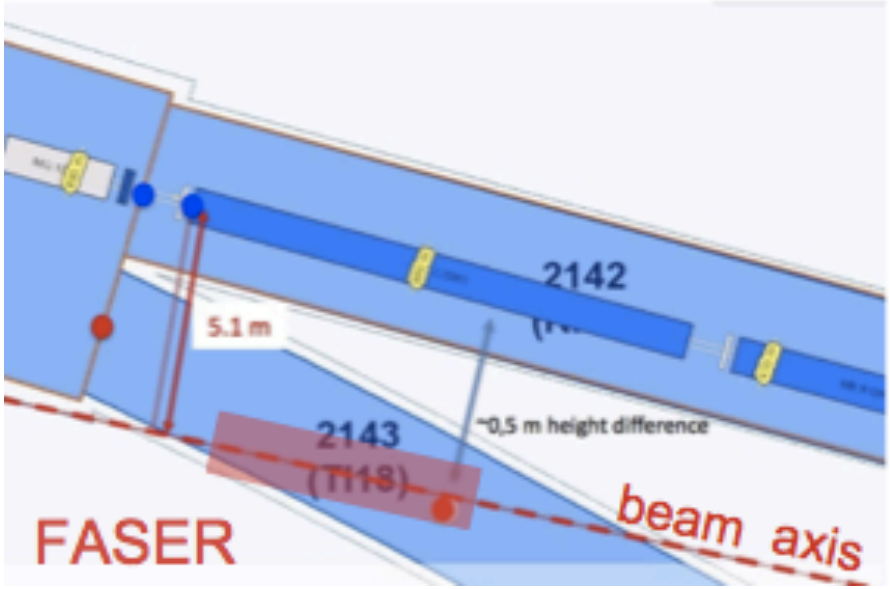


FASER: LOCATION

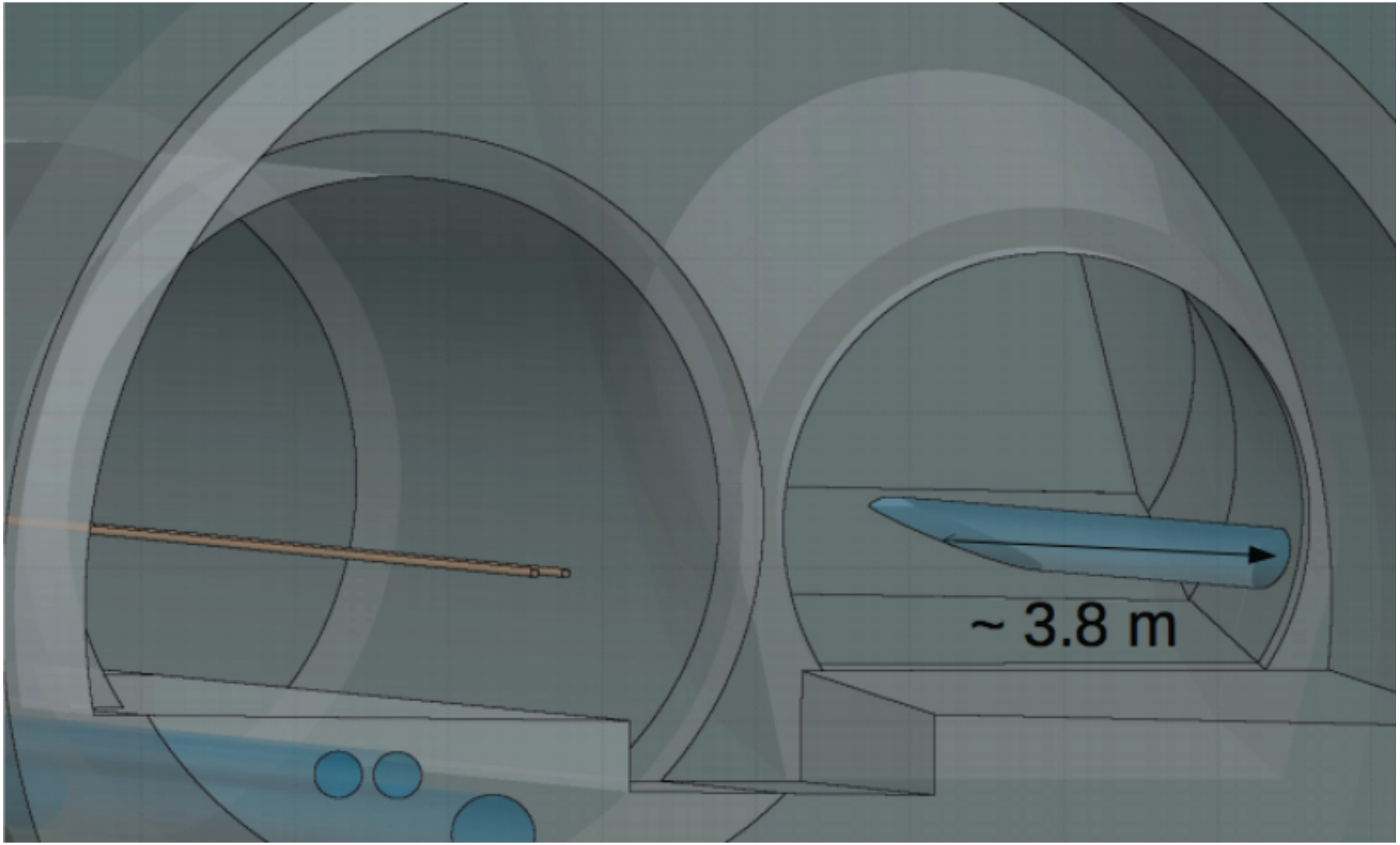
Tunnel is steeply sloping upwards from LHC. Means line of sight is under tunnel floor for some part of tunnel. We would like to dig into floor to allow longest possible detector on the line of sight.
Informal discussion with civil engineering, suggest that digging trench in TI18 floor 50cm deep relatively easy (could be done in LS2).
Possible in longer term (LS3) would want to dig deeper &/or outward from tunnel.







FASER: LOCATION



Above comes from FLUKA geometry assuming floor level reduced by 50cm. Will have survey of the area in TS1 (next week) to have a more accurate picture of exactly where LOS runs and how long detector can be.

FLUKA study of background

M. Sabaté-Gilarte, F. Cerutti, A. Tsinganis

Fluence in FASER

	Cut T > 100 GeV		Cut T > 500 GeV		Cut T > 1 TeV	
Part. type	fluence rate ($cm^{-2}\ s^{-1}$)	fluence per bunch crossing per cm^2	fluence rate ($cm^{-2}\ s^{-1}$)	fluence per bunch crossing per cm^2	fluence rate ($cm^{-2}\ s^{-1}$)	fluence per bunch crossing per cm^2
$\mu+$	0.18	$6.1 \cdot 10^{-9}$	0.02	$5.8 \cdot 10^{-10}$	0.002	$6.8 \cdot 10^{-11}$
$\mu-$	0.40	$1.3 \cdot 10^{-8}$	0.22	$7.4 \cdot 10^{-9}$	0.14	$4.6 \cdot 10^{-9}$
n_0	$\sim 10^{-7}$	$\sim 10^{-14}$	0	0	0	0
γ	$\sim 10^{-4}$	$\sim 10^{-12}$	$\sim 10^{-6}$	$\sim 10^{-13}$	$\sim 10^{-6}$	$\sim 10^{-13}$
π	$\sim 10^{-5}$	$\sim 10^{-12}$	$\sim 10^{-7}$	$\sim 10^{-14}$	0	0

- HL-LHC conditions: 5-10% uncertainty
  - Luminosity: $5 \cdot 10^{34}$ ($cm^{-2}\ s^{-1}$)
  - Cross section p-p collision: 85 mb
  - Pile-up: 140 (events/bunch crossing)
- To convert to LHC conditions: multiply the values in the table by a factor 0.2

Main background of high energy particles from collision debris, not from:
-proton showers in dispersion suppressor
-beam gas

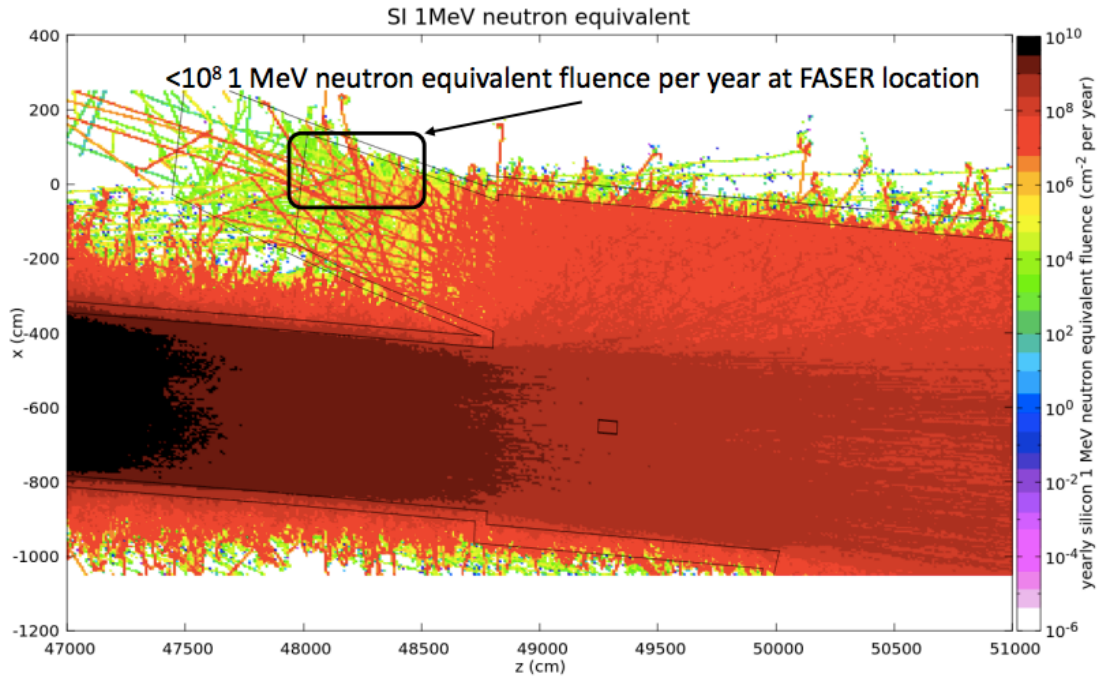
~0.6Hz/cm^2 of high energy muons from collisions (HL-LHC), not a problem for FASER physics.

Radiation level at FASER location (FLUKA)

M. Sabaté-Gilarte, F. Cerutti, A. Tsinganis

Proton losses in the DS

Yearly silicon 1 MeV neutron equivalent fluence



Also interpreted as:
Fluence rate of 0.1-1cm-2s-1
$<10^{-2}$G/year

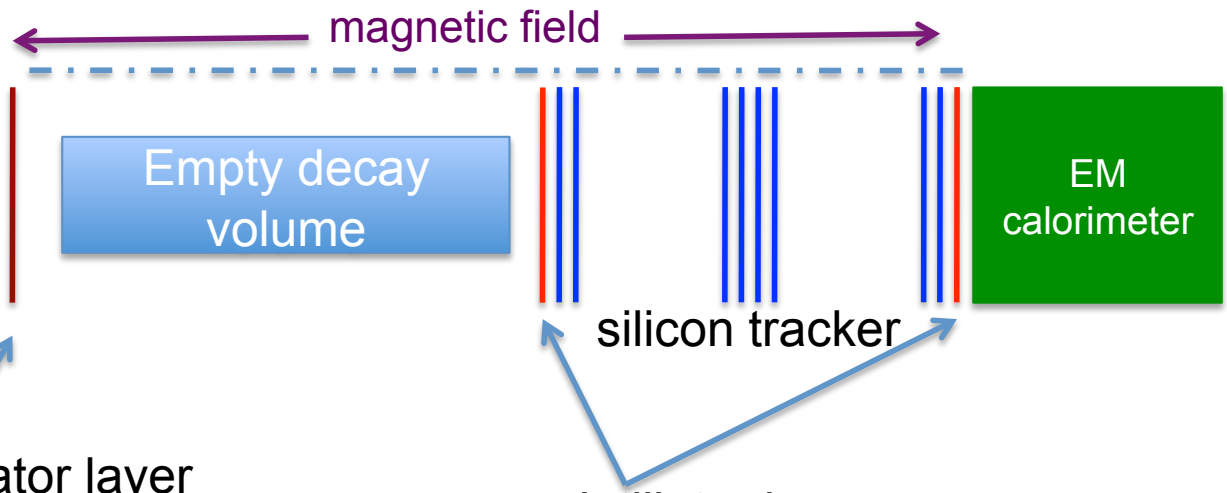
Similar (low) level of fluence from beam gas, due to excellent LHC vacuum

In general very quiet location for a detector!
Do not expect significant radiation damage to electronics.
Result to be validated with radiation monitoring device to be installed in TS1.

FASER: Detector considerations

- Currently have in mind an initial veto layer, followed by ~3 tracking stations and EM calorimeter, with volume largely empty and a magnetic field.

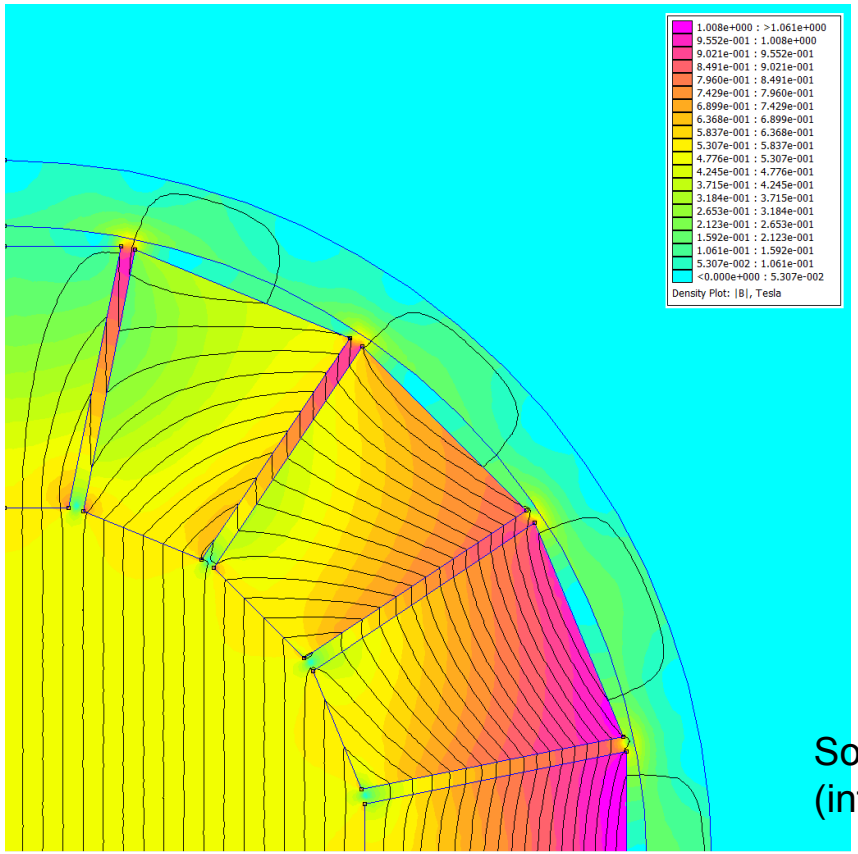
sketch:



Currently optimizing the detector layout also based on re-using parts / spare-parts of existing detectors (e.g. for tracker).
Looking at different options for calorimeter.
Considering a permanent dipole magnet (suggested by CERN experts).
Detector needs to sit very close to the floor of the tunnel to lie on the line-of-sight, and needs to fit in available length (~4m, depends on crossing angle and possible digging).

FASER: Detector considerations

- Currently have in mind an initial veto layer, followed by ~3 tracking stations and EM calorimeter, with volume largely empty and a magnetic field.

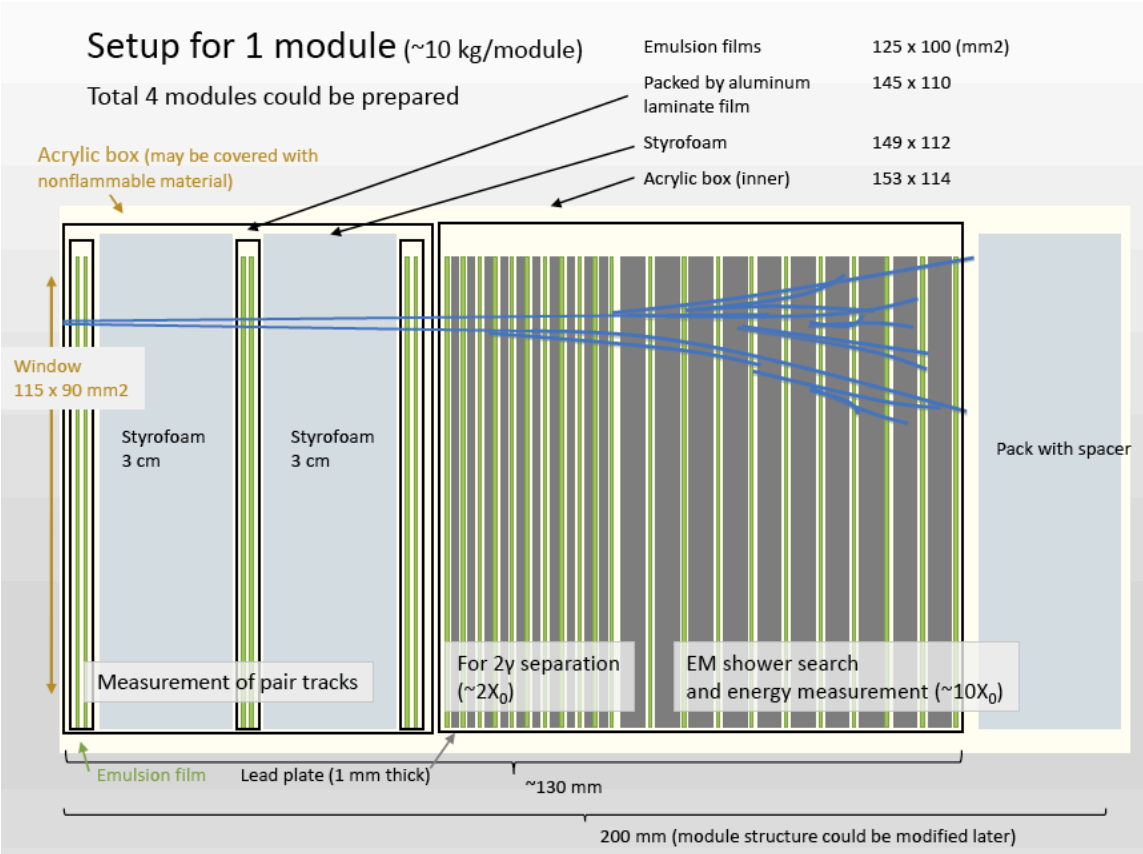


Parameter	Value	Unit
Central field	0.52	T
Integrated field	0.67	T.m
Good field region	Ø 200	mm
Field homogeneity	+/- 2	%
Free aperture	Ø 200	mm
Outside diameter	430	mm
Magnet length	1300	mm
Magnet weight	1200	kg

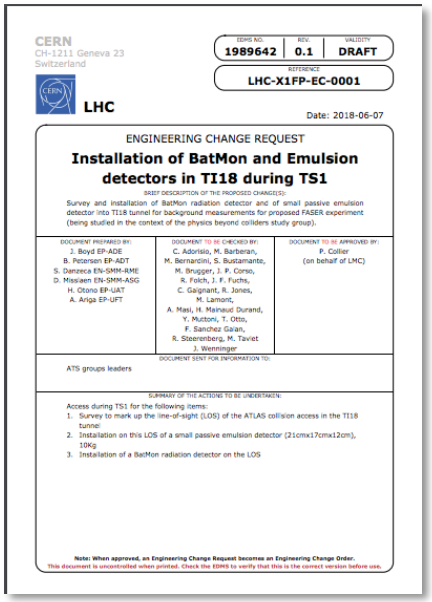
Some idea of a permanent dipole magnet we could use (informal discussion with Attilio Milanese of CERN magnet group)

TS1 installation

Plan to do the following work in TS1 (next week):
- CERN survey team to calculate the location of the IP1 collisions axis (line of sight) in TI18 and to mark this on the floor
- Install a BatMon (LHC radiation monitoring device, with no services)
- Install a small test emulsion detector (20cmx20cmx10cm ~10Kg) – to assess possible use of emulsion in FASER, and also to help assess backgrounds – to be removed in TS2 or before



ECR for above work to be discussed for approval at the LMC today!



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EDMS NO. 1989642 | REV. 0.1 | VALIDITY DRAFT
REFERENCE LHC-X1FP-EC-0001

LHC

Date: 2018-06-07

ENGINEERING CHANGE REQUEST

Installation of BatMon and Emulsion detectors in TI18 during TS1

BRIEF DESCRIPTION OF THE PROPOSED CHANGE(S):
Survey and installation of BatMon radiation detector and of small passive emulsion detector into TI18 tunnel for background measurements for proposed FASER experiment (being studied in the context of the physics beyond colliders study group).

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DOCUMENT TO BE APPROVED BY:
P. Collier
(on behalf of LMC)

DOCUMENT SENT FOR INFORMATION TO:
ATS groups leaders

SUMMARY OF THE ACTIONS TO BE UNDERTAKEN:
Access during TS1 for the following items:
1. Survey to mark up the line-of-sight (LOS) of the ATLAS collision access in the TI18 tunnel
2. Installation on this LOS of a small passive emulsion detector (21cmx17cmx12cm), 10Kg
3. Installation of a BatMon radiation detector on the LOS

Note: When approved, an Engineering Change Request becomes an Engineering Change Order.
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Proposed LS2 work

Hope to install a small FASER detector in LS2 for running in Run-3.
Would include:
- digging 50cm from floor of TI18 tunnel in FASER location to allow bigger detector on line of sight
- installation of detector:
    - magnet 2-4m (upto ~3tonnes but in sections) – no services
    - silicon tracker + cooling/power/read-out
    - calorimeter +cooling/power/readout
    - veto and trigger scintillator layers
- some (small) work needed by CERN technical teams (transport, civil engineering, cabling, ..)
- many aspects of what we need not yet clear – e.g. cables, fibres, etc…

Above work not confirmed yet. Dependent on getting funding (expect to know by end of year), and CERN approval (requires LHCC discussion etc…). Hope that can all happen by end of year.

Possible LS3 work

Assuming a small FASER detector installed in LS2 and runs (successfully) in Run-3. Would try to have a bigger/better experiment installed in LS3. Main (CERN) work here would be possible larger digging in TI18 in order to have a bigger detector:
-both longer decay volume (ideal case would be ~10m long detector)
-larger radius detector (e.g. 1m radius would be best case)
This would require further digging into the side of the tunnel, and experts are starting to see the cost/implications of this.

Such a detector (with HL-LHC dataset) would have sensitivity to additional new physics models on top of dark photons (heavy neutral leptons, axion-like-particles, dark higgs, …)

Summary

FASER proposed new small, inexpensive experiment to search for light, weakly coupled new physics – complementary to existing (LHC and other) experiments.

FLUKA studies suggest backgrounds and radiation at proposed location acceptable.

Plan to install monitors at location in TS1 to validate FLUKA results.

Assuming funding/CERN-approval would like to install a small detector (r=10cm, L=4m) in LS2 to run through Run-3. Main work for CERN teams:
-digging 50cm from floor of tunnel
-transport of detector parts (magnet…)
-possible cabling/fibres etc…
Would act as a prototype for final FASER experiment, but would already have world beating sensitivity for dark photons.

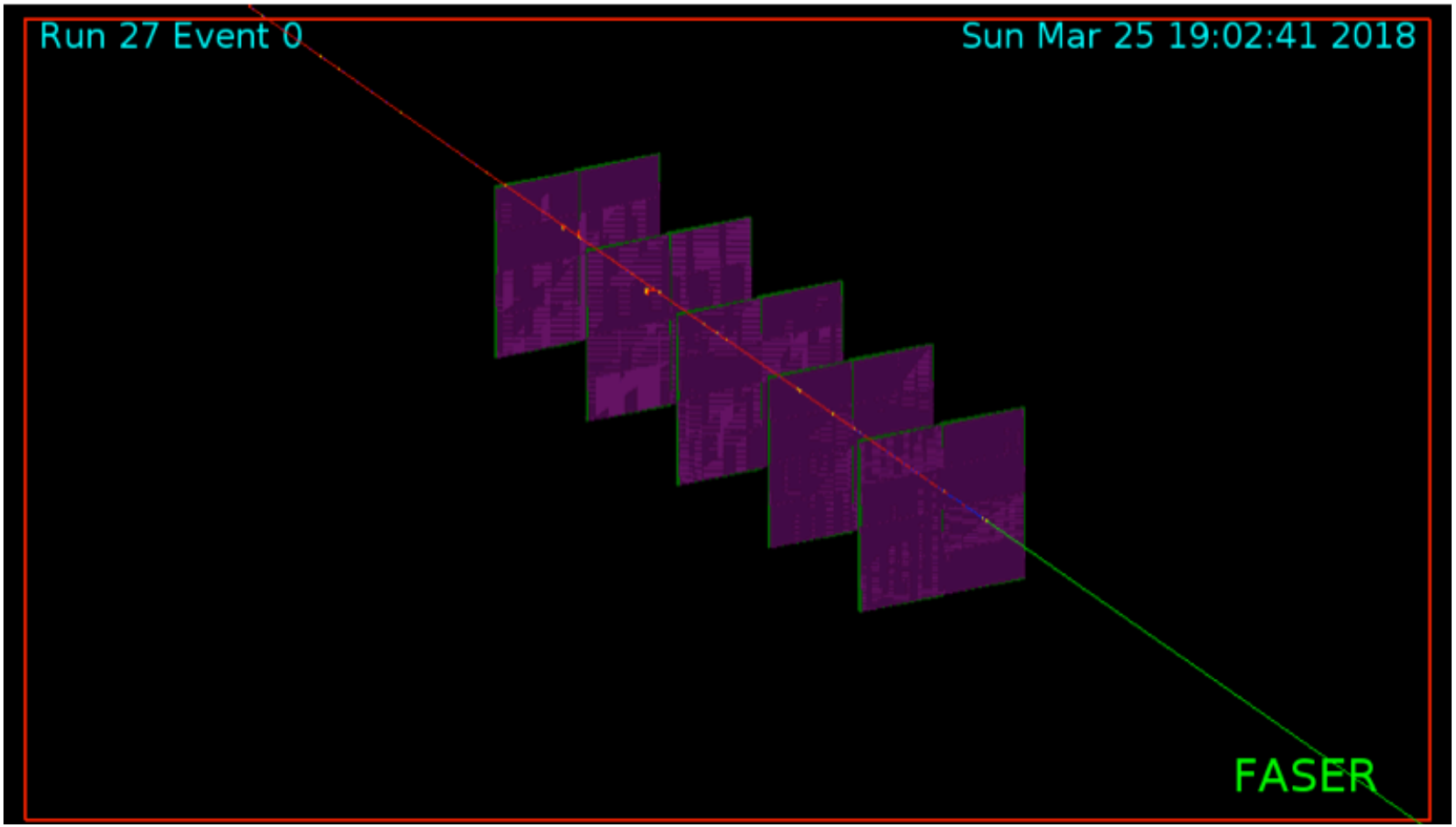
If successful, would like to install a bigger/better detector in LS3 for Run-4+, which would improve physics reach for additional interesting models
-would require additional digging in TI18

More physics details in talk tomorrow in BSM session.

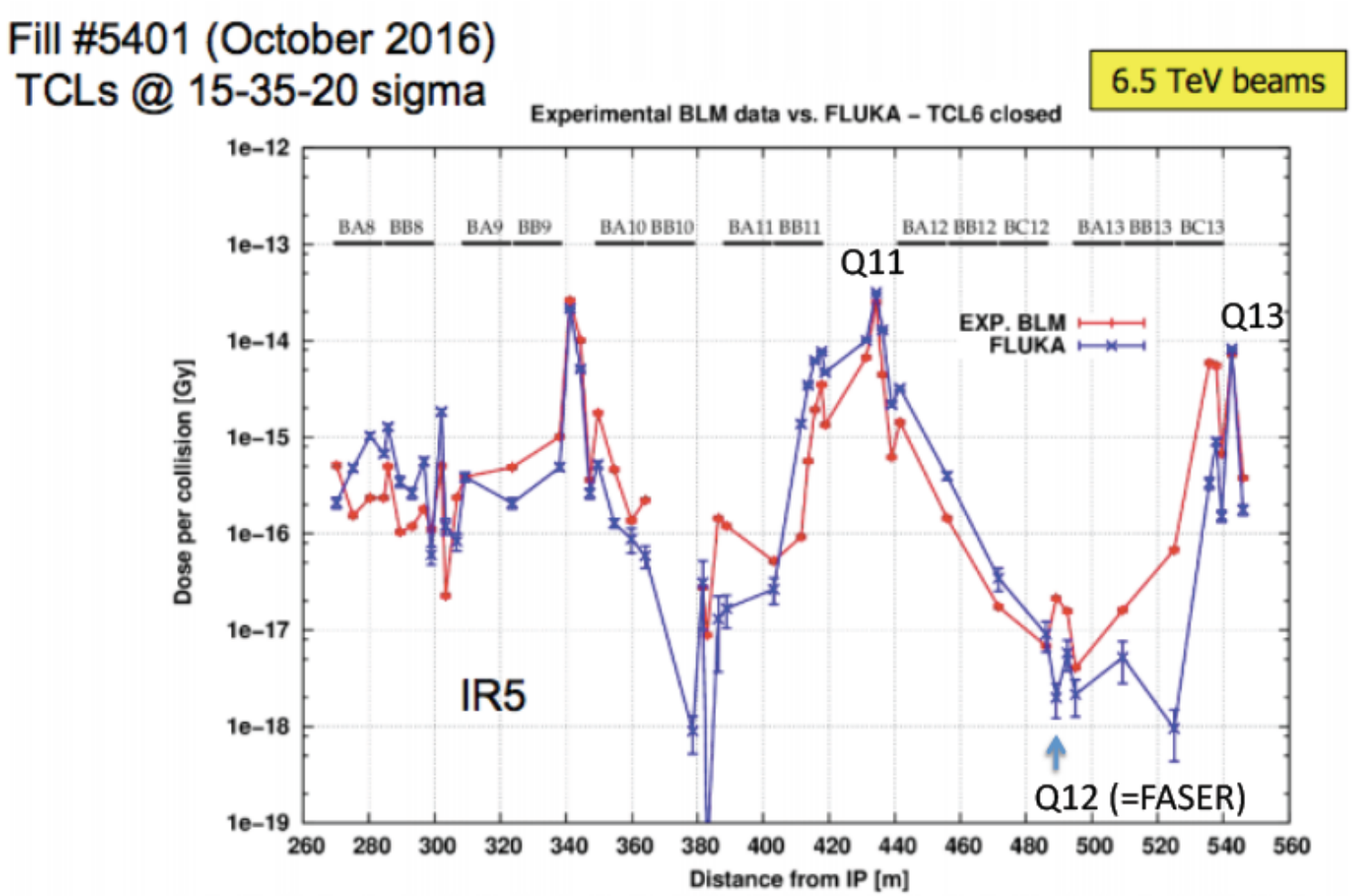
Back Up

FASER: GEANT STUDY UNDERWAY

- Currently have in mind an initial veto layer, followed by ~5 tracking layers and EM calorimeter, with volume largely empty and a magnetic field.



FASER: FLUKA STUDY UNDERWAY



Plot from F. Cerutti's talk at Chamonix 2018.
Comparing FLUKA and BLM data for 2015 fill (reasonable agreement).
FASER location close to Q12 – lucky low background from collision debris, background peaks at Q11/Q13 due to dispersion at these points (these are +/-~50m along ring from FASER location). (In theory this depends on the optics, but should also be valid for HL-LHC)

2

FASER team

Current team:

FASER e-group is: faser-all@cern.ch Active members:

- Jonathan Feng (UCI, theorist) (contact with PBC BSM group)
- Iftah Galon (Rutgers, theorist)
- Sebastian Trojanowski (UCI, theorist)
- Felix Kling (UCI, theorist)
- Dave Casper (UCI, experimentalist)
- Jamie Boyd (CERN, experimentalist) (contact with PBC accelerator group)
- Brian Petersen (CERN, experimentalist)
- Shih-Chieh Hsu (Washington, experimentalist)
- Hidetoshi Otono (Kyushu, experimentalist)
- Aaron Soffa (UCI, experimentalist)
- Akitaka Ariga (Kyushu, experimentalist)
- Tomoko Ariga(Kyushu/Bern, experimentalist)
- Osamu Sato (Nagoya, experimentalist)

With great help from various CERN teams, contact via physics beyond colliders study group (contact: Mike Lamont).
We are looking at various detector options based on existing detectors to use in FASER prototype to be installed in LS2.