DETECTOR R&D FOR FCC REQUIREMENTS AND CHALLENGES

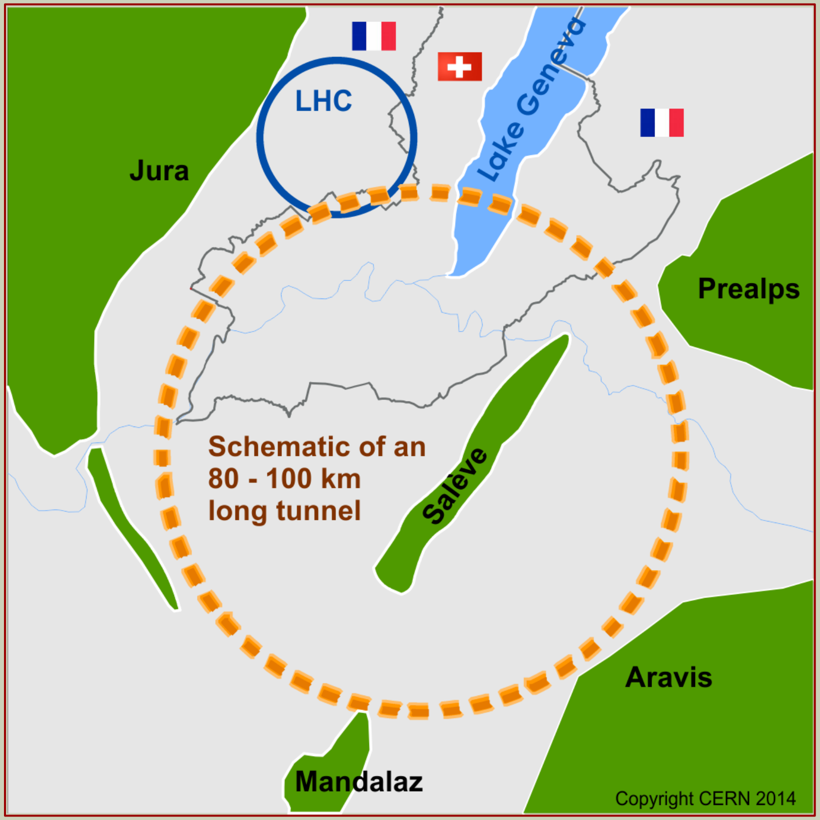
FCC-hh
Muon detectors

S. Vlachos
& M. Abbrescia

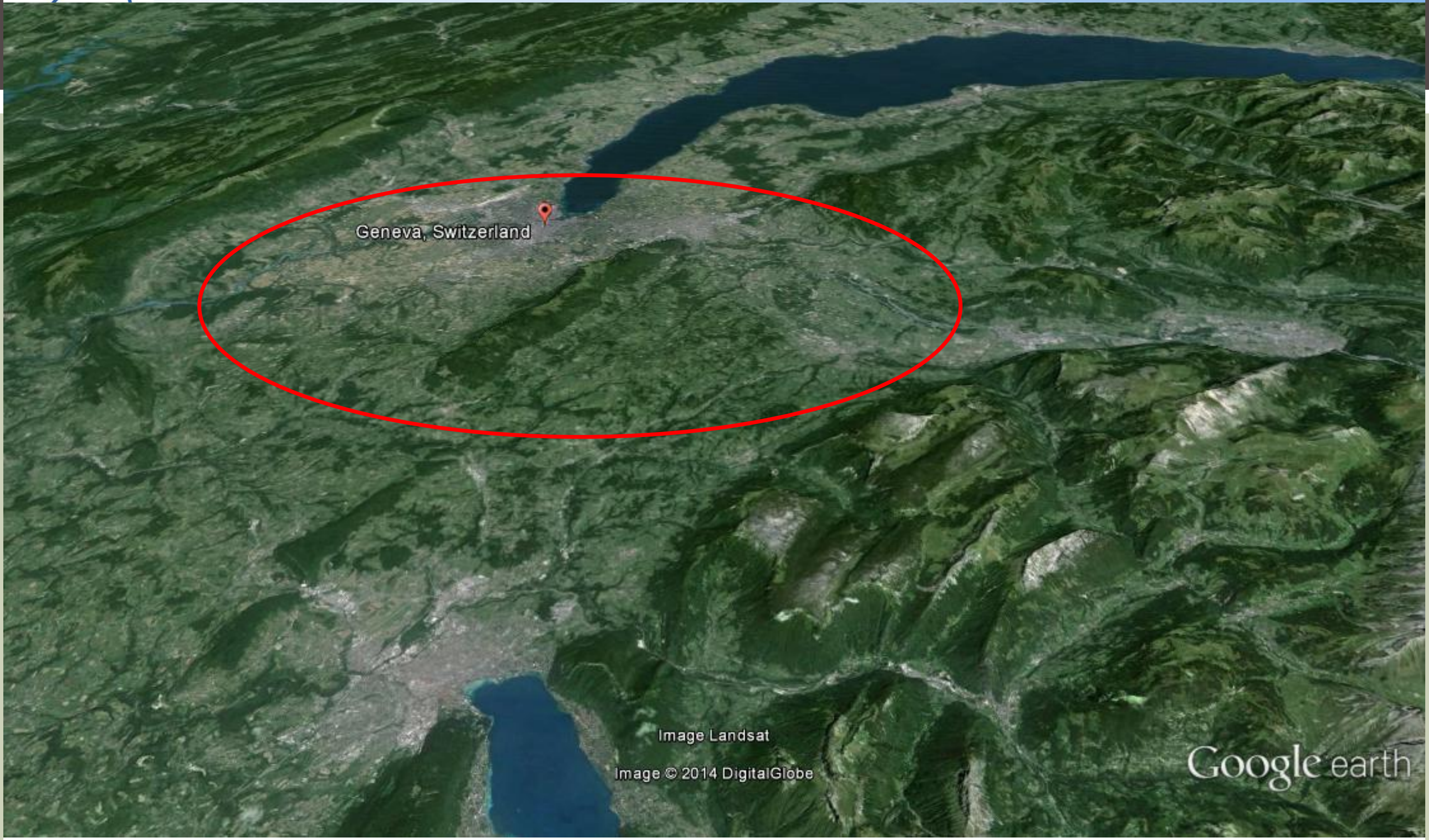
FUTURE CIRCULAR COLLIDER

First studies on a new 80-100 km tunnel around CERN

- 42 TeV with 8.3 T using present LHC dipoles
- 80 TeV with 16 T based on Nb3Sn dipoles
- 100 TeV with 20 T based on HTS dipoles



Getting closer to the Alps



Ph. Lebrun FCC Study Kick-off Meeting 22

Parameters of a ~ 100 TeV pp collider

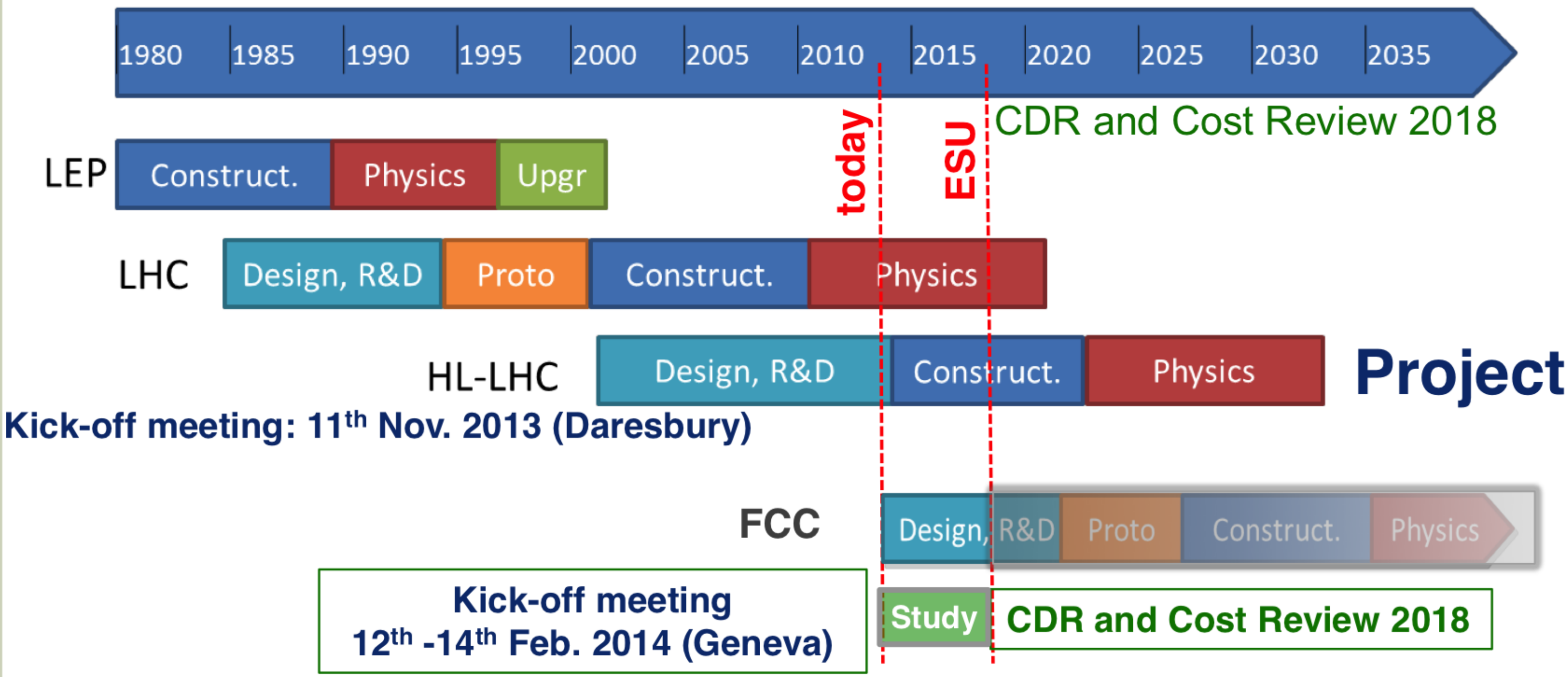
Version 1.0 (2014-02-11)	LHC	HL-LHC	FHC-hh
c.m. Energy [TeV]	14		100
Circumference *C* [km]	26.7		100 (83)
Dipole field [T]	8.33		16 (20)
Peak luminosity [10^{34} $cm^{-2}s^{-1}$]	1.0	5.0	5.0
Peak no. of inelastic events / crossing at - 25 ns spacing - 5 ns spacing	27	135 (lev.)	171 34
Number of bunches at - 25 ns - 5 ns	2808		10600 (8900) 53000 (44500)
Bunch population N_b [10^{11}] - 25 ns - 5 ns	1.15	2.2	1.0 0.2
Nominal transverse normalized emittance [mm] - 25 ns - 5 ns	3.75	2.5	2.2 0.44
IP beta function [m]	0.55	0.15 (min)	1.1
RMS IP spot size [mm] - 25 ns - 5 ns	16.7	7.1 (min)	6.8 3
Stored beam energy [GJ]	0.392	0.694	8.4 (7.0)

Nb_3Sn ok up to 16 T;
20 T needs HTS

Largest integrated luminosity needed for heavy physics
→ L=10^{35} may be reached
→ bunch-spacing 5 ns to mitigate pile-up and e-cloud

25 x LHC !

CERN and FCC timelines



- LHC and HL-LHC operation until ~2035
- Must start now developing FCC concepts to be ready in time

MUON DETECTION REQUIREMENTS

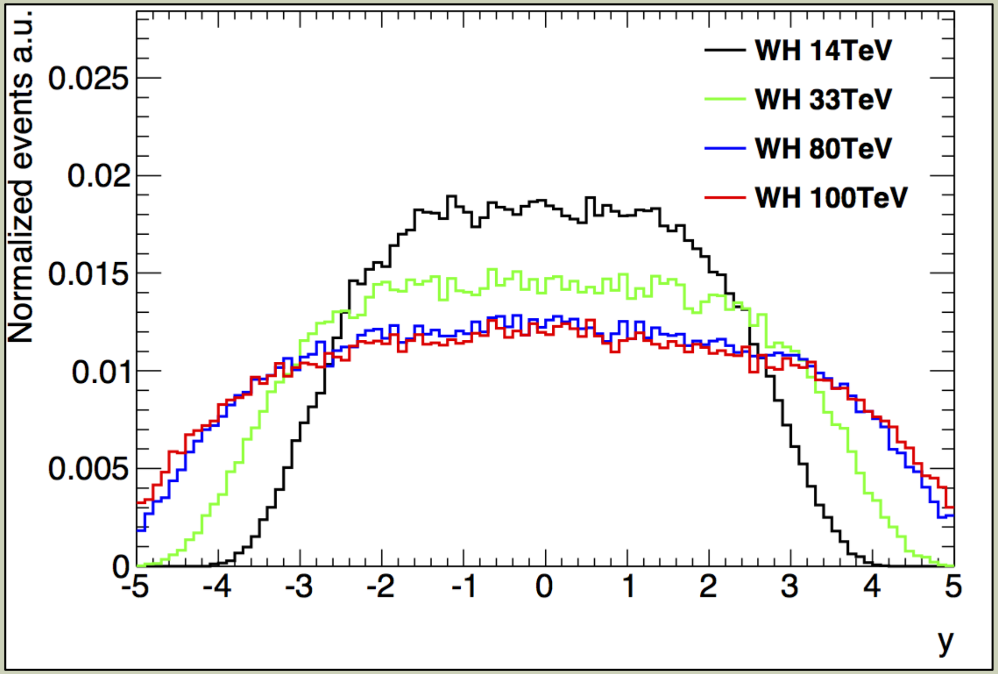
- Momentum resolution ~ 10% for 1TeV μ (≤ 100μm spatial res.)
- Extended η coverage
- Operation in intense magnetic field (~ 3T)
- Fast detectors (5ns BC) (≤1ns time res.)
- High pile-up (30-300) and intense background O(100KHz/cm^2)
- μ/K/π separation and cope with co-travelling EM bkg.
- Radiation hard and operation for decades

- Overall ~ 1 order of magnitude better than LHC !

SYSTEM ASPECTS

- … O(10000) m^2 !
- … mechanical rigidity, given the size
- … power consumption and cooling
- … accessibility and maintenance

RAPIDITY COVERAGE

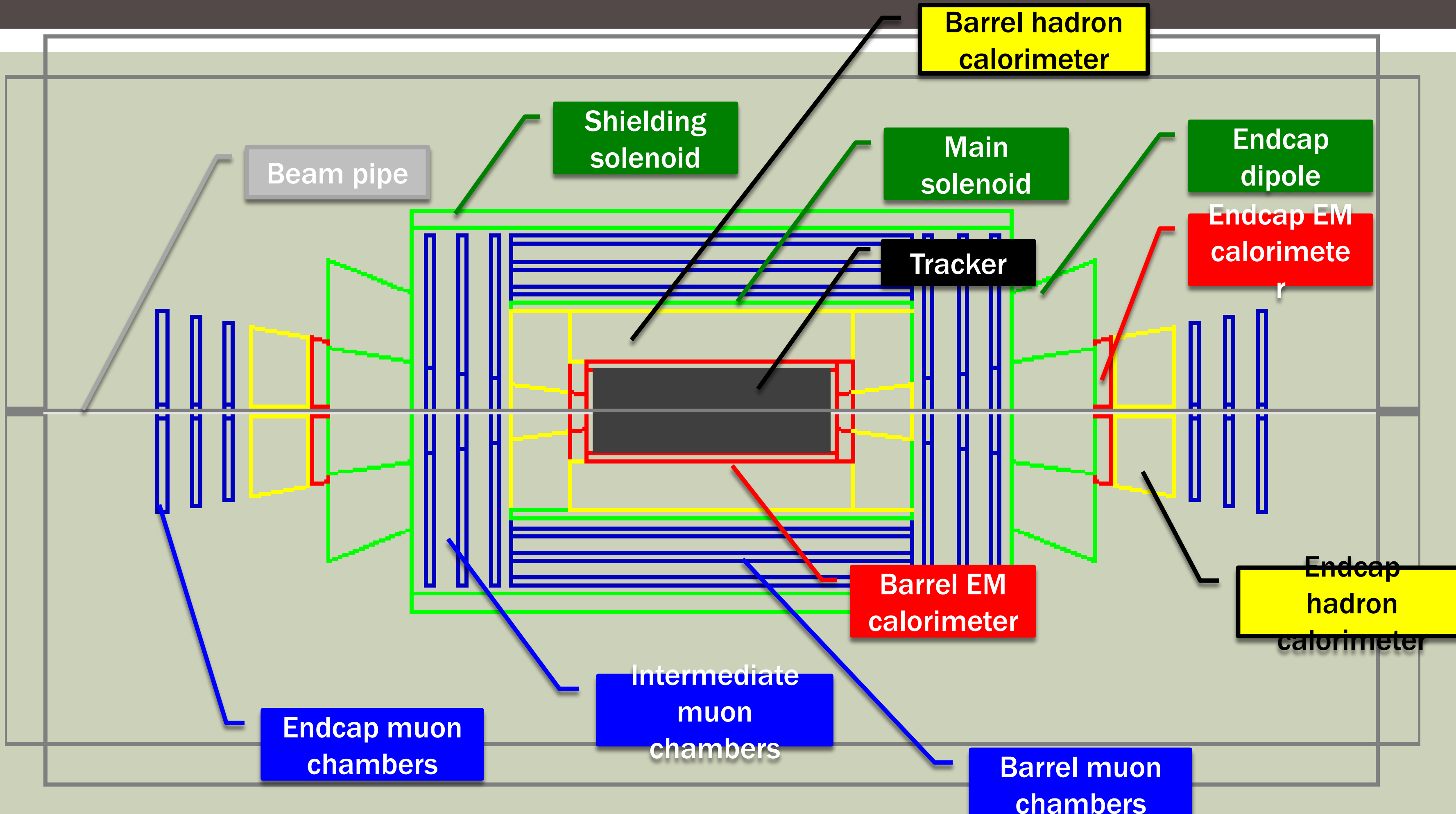


~40% acceptance loss
if tracking limited to |η|<2.5

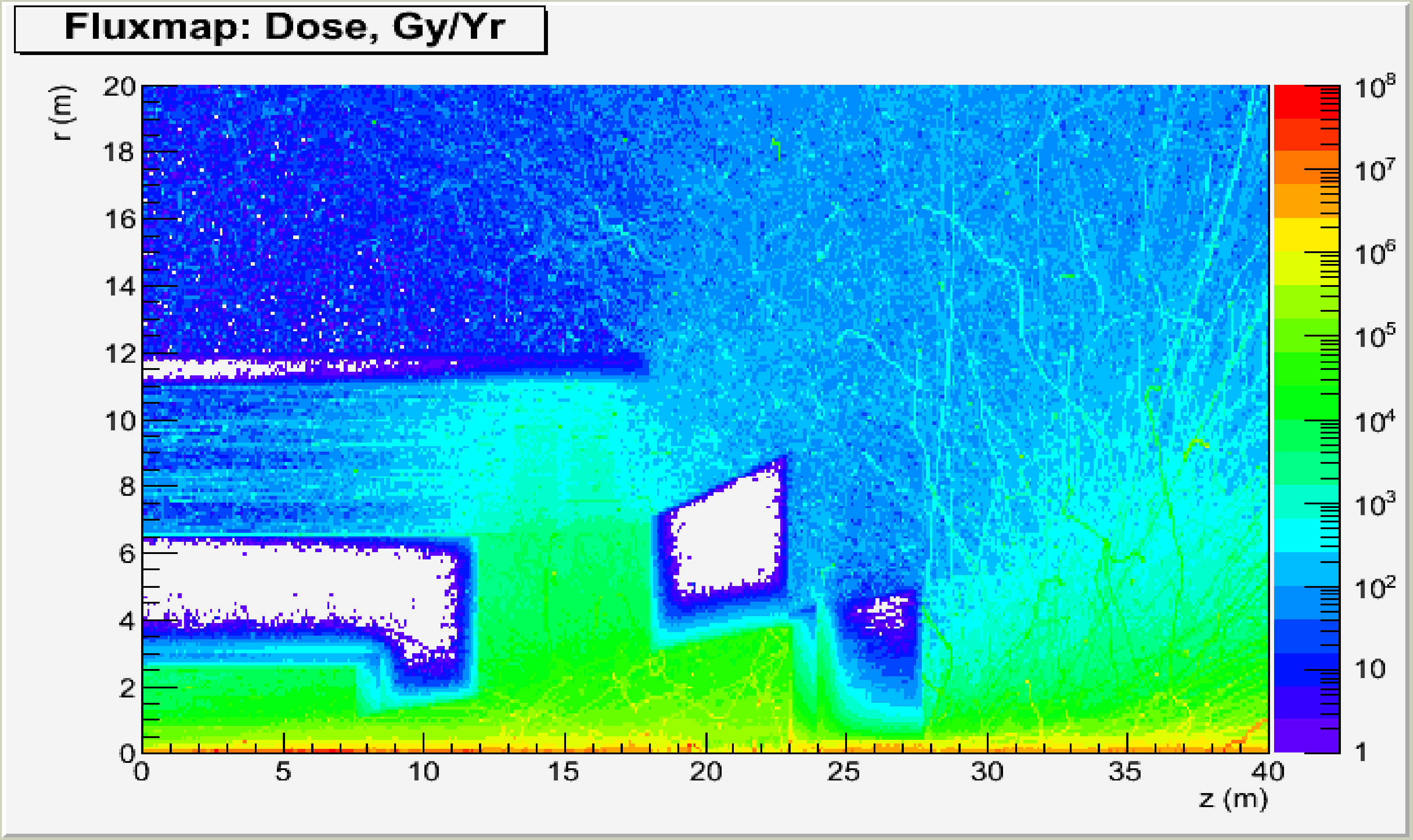
RATES AND BACKGROUND CONDITIONS

- Events
  - Generated by Phojet
  - $\sqrt{s} = 100\ TeV$
- Normalization assumptions
  - $\sigma_{pp} = 100\ mb$
  - "*year*" = $10^7\ sec$
  - Instantaneous luminosity = $10^{36}\ cm^{-2}\ s^{-1}$
  - Rescale to suit your assumptions

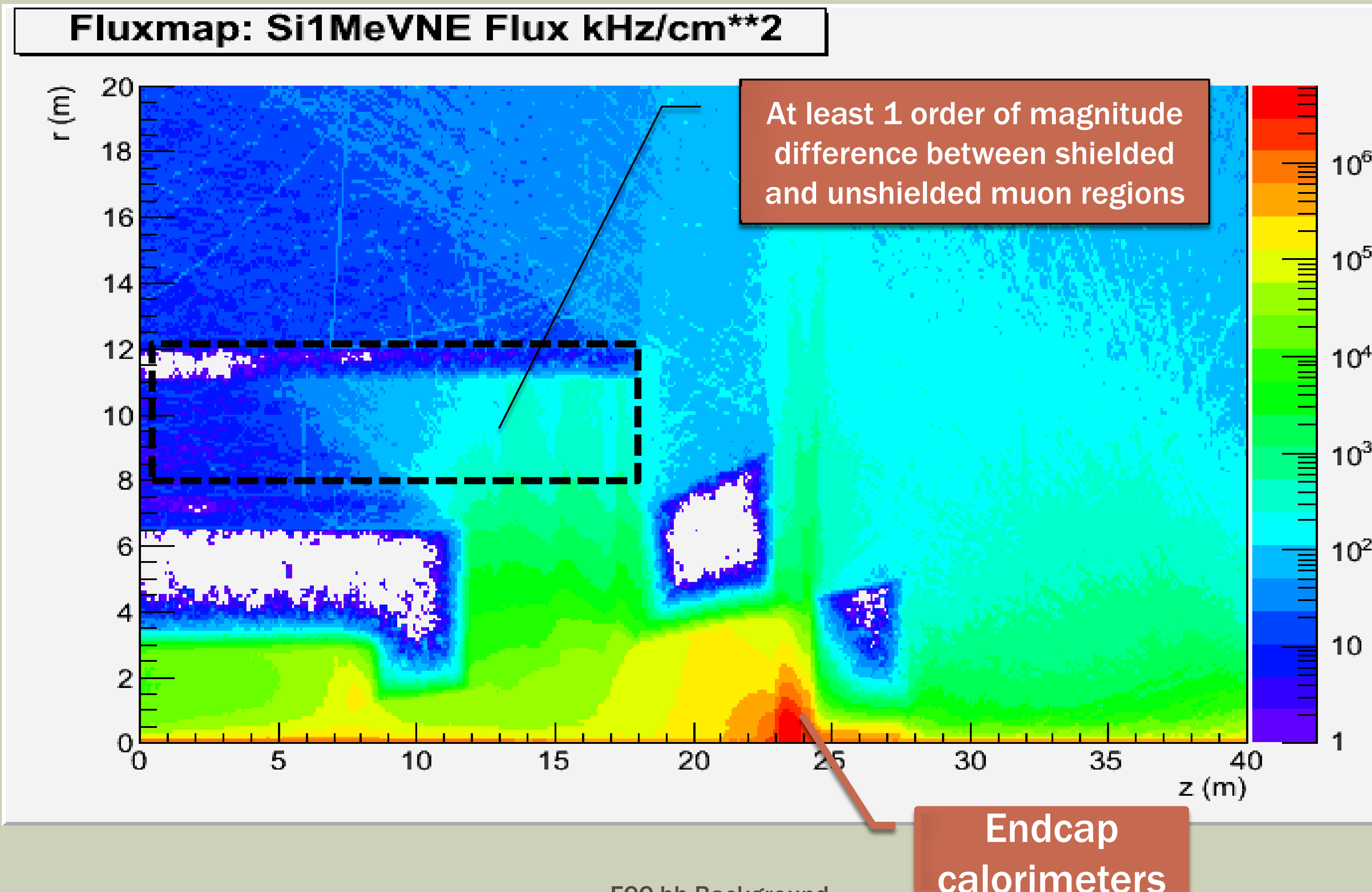
SIMULATION GEOMETRY



TOTAL IONIZING DOSE

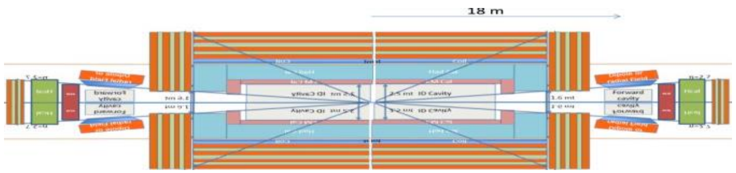


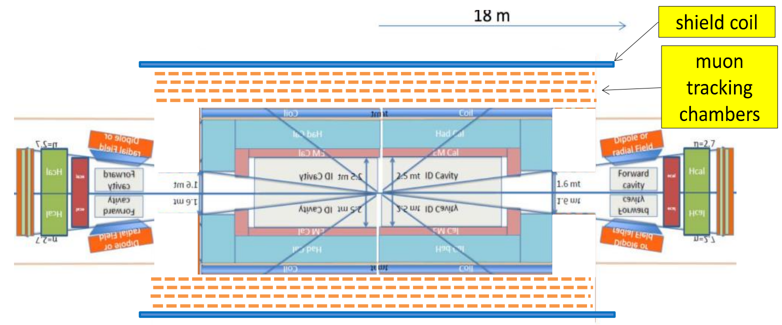
1-MEV N_{EQ} FLUENCE



B-FIELD CONFIGURATION

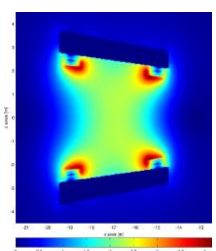
Long%solenoid%with%dipoles%

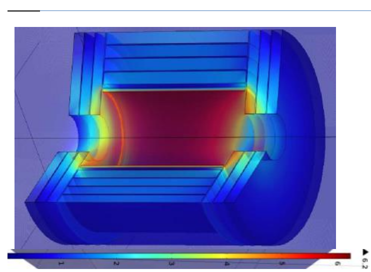


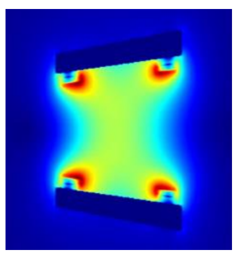


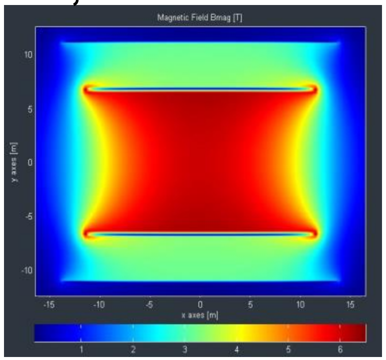
6T solenoid + iron yoke +2 T dipoles (54GJ!)

6T solenoid + 3T shield coil version (65GJ!)
+ 2T dipoles as before
(avoid 120,000 tonne return yoke!)

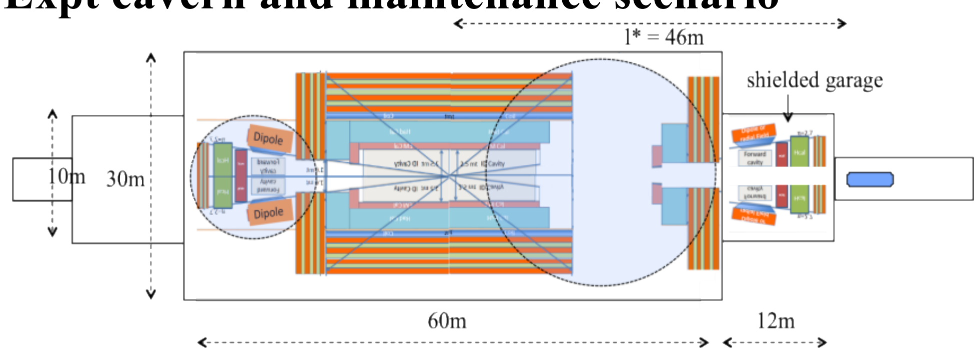






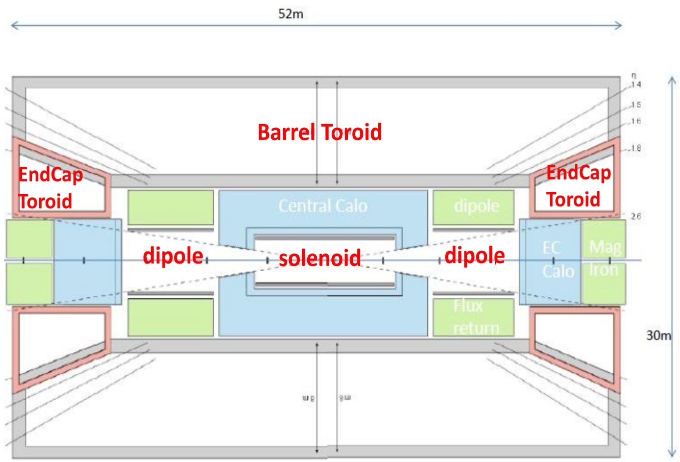


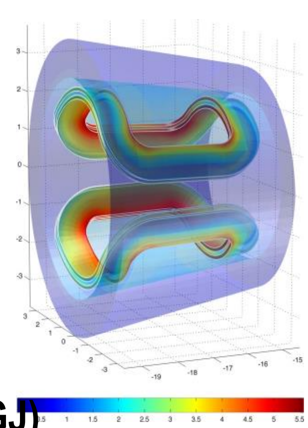
Expt cavern and maintenance scenario

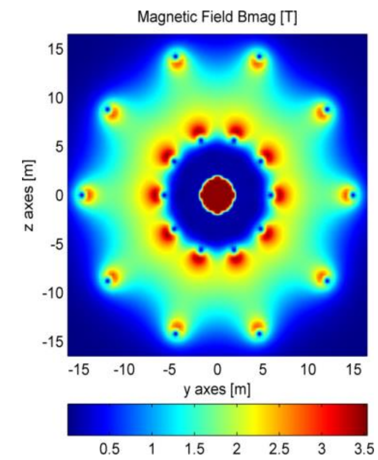


B-FIELD CONFIGURATION II

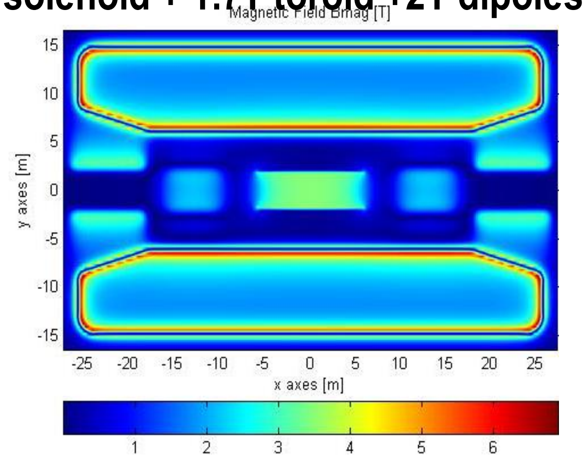
Toroid%with%diploles%

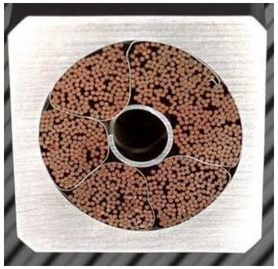






3.5T solenoid + 1.7T toroid +2T dipoles (55GJ)

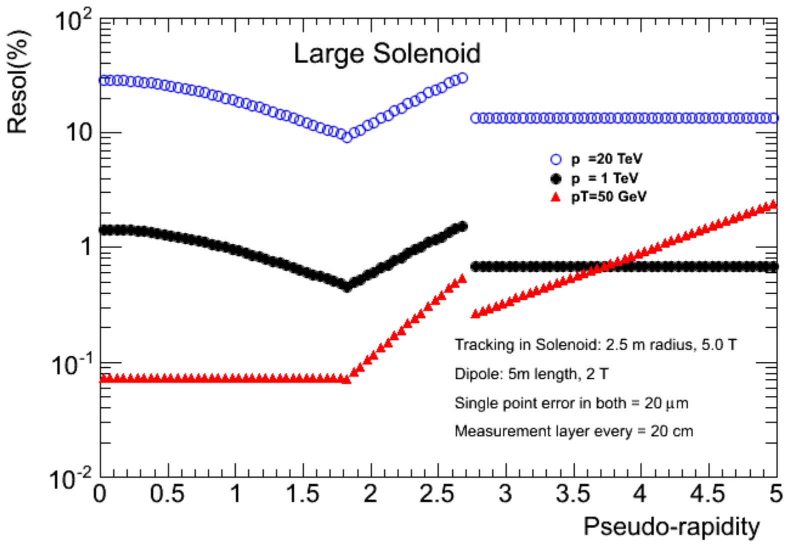




cable in conduit conductor for toroids & dipoles

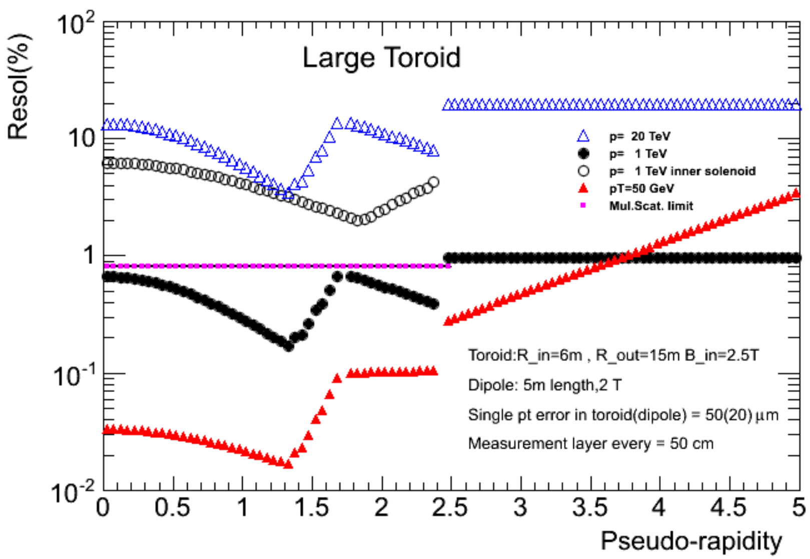
MUON RESOLUTION

"Ideal resolution "
(no mult scatt, pr f ect a ignment,...)

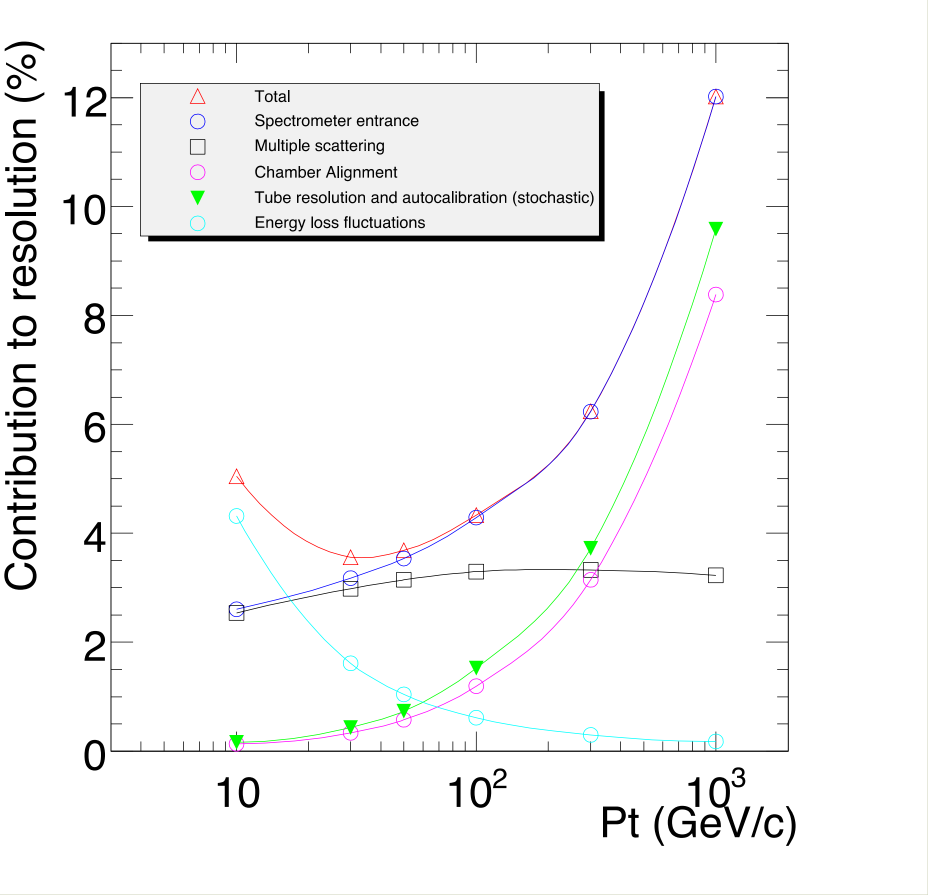


CMS:
12% at 1 TeV

Large Toroid: ideal resolution



ATLAS RESOLUTION CONTRIBUTIONS



INTENSE B FIELD

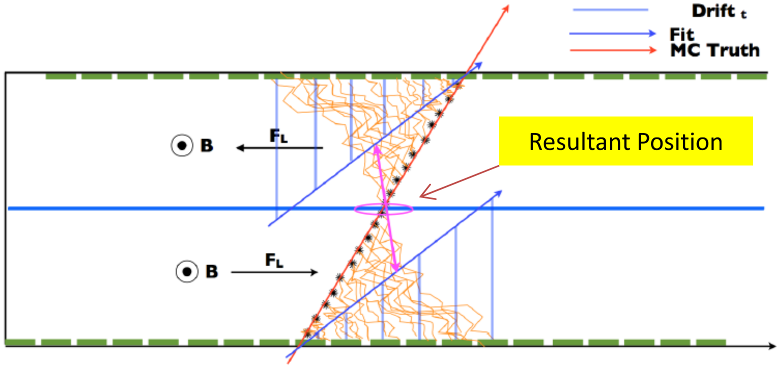
- Lorentz angle
  - Deployment in large B-field will result in a large L-angle depending on gas and E-operating point
    - Drift vector $\mathbf{V_D}$ rotates away from **E**
  - Naive configuration is to make the wires || to B but serious consideration of effect needed for any gas technology in the large B-field options

Example of compensation by using back-to-back HV planes in a Micromega

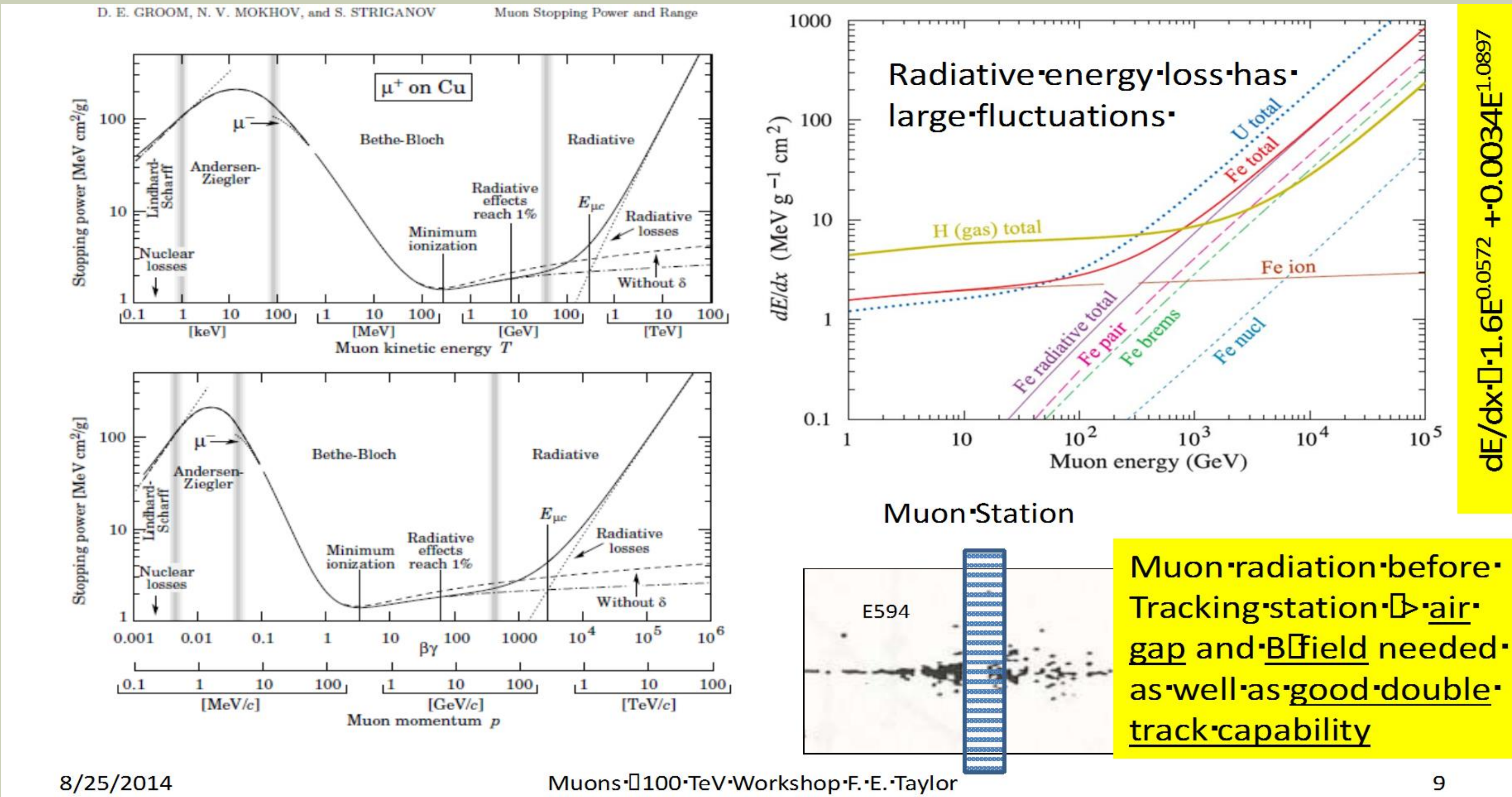
$$\omega = \frac{eB}{m} = 17.6MHz / G$$

$$Tan\alpha = \omega\tau$$

$$V_D = \left(\frac{e\tau}{m}\right) E \frac{1}{\sqrt{1+\omega^2\tau^2}}$$

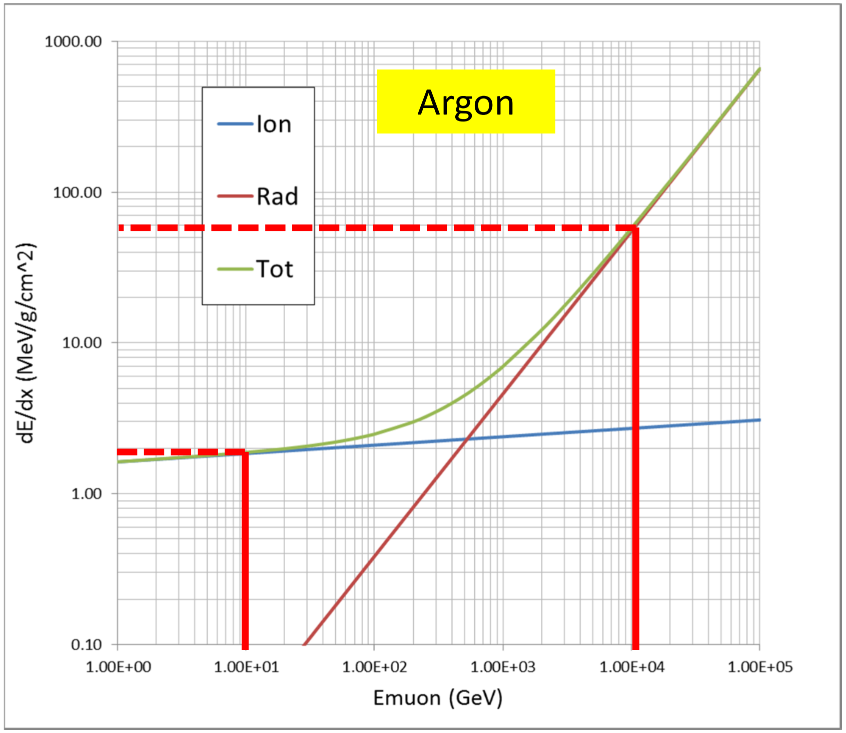


EM CO-TRAVELLING BACKGROUND



HIGH ENERGY MUONS

- dE/dx
  - Larger dynamic range needs to be accommodated as muon ionizes gas in chamber
  - Roughly a factor of 25 N_T = 94 x 25 = 2,350 ion pairs/cm
  - Frontend electronics has to have a larger dynamic range
  - Chamber HV system has to be 'stiff' enough not to saturate
  - Perhaps operate at ~ 10^3 gain
- Effect needs a more definitive calculation with realistic gas mixtures and chamber design



dE/dx in gaseous Argon estimated by scaling critical energy to 565 GeV

TIME MEASUREMENT

BCID with 5 ns bunch crossing operation requires sub-ns time resolution at least for triggering

O(10-100)ps timing resolution may be needed for Muon tagging etc in high radiation environment

CONCLUSIONS

How to develop appropriate MPGDs for FCC ?

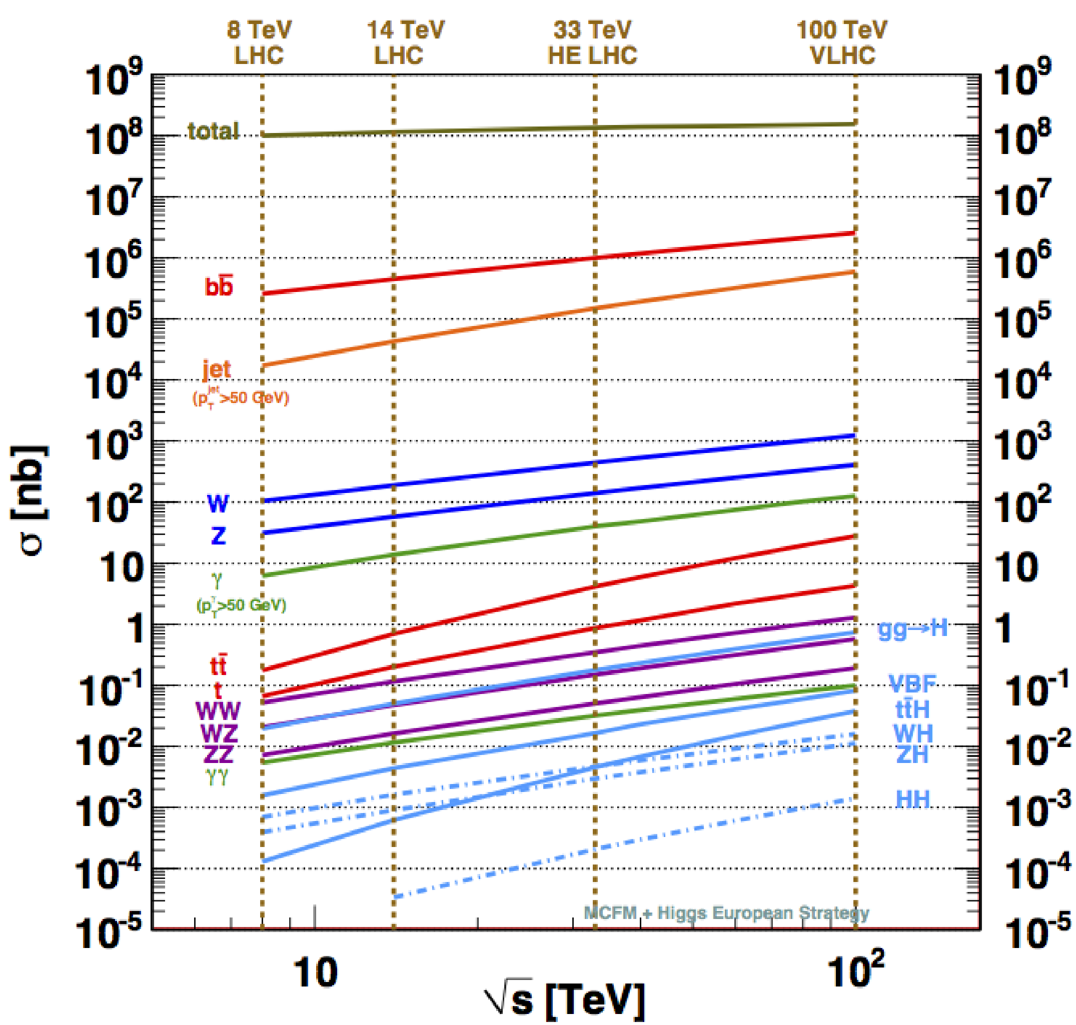
This is just an invitation for:

- R@D
- Sharing results and ideas
- Keeping an open mind to new proposals

We are planning to organize a mini-workshop,
in agreement with the RD51 management,
to fix more precisely ideas on the possible uses of MPGDs in FCC

BACK-UP

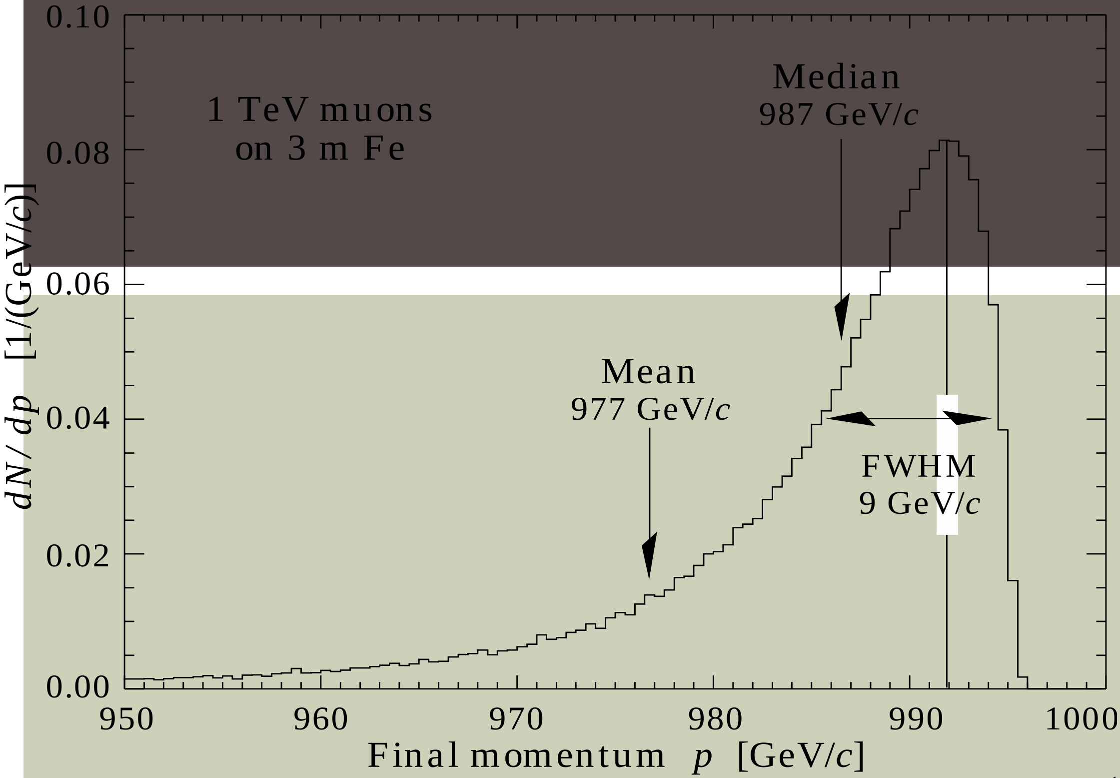
CROSS SECTIONS



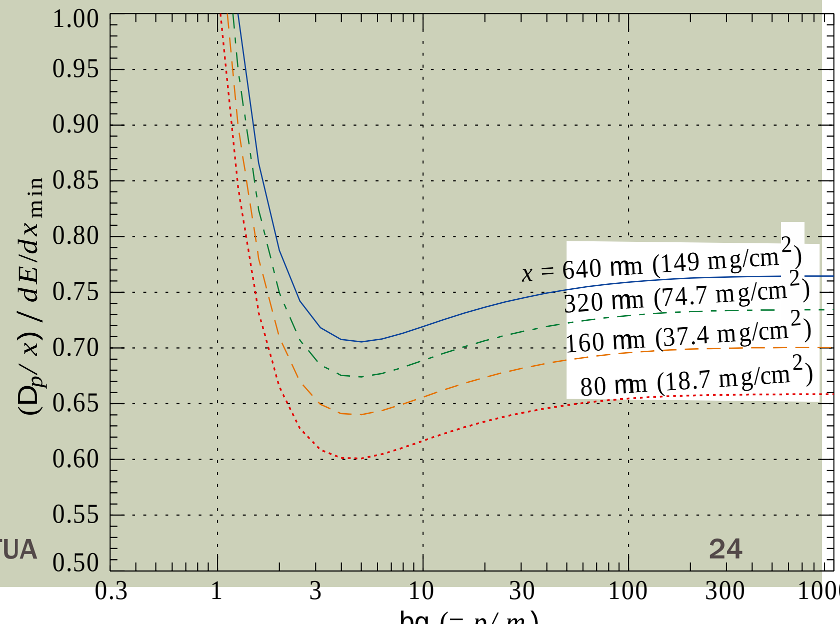
Process	σ (100 TeV)/σ (14 TeV)
Total pp	1.25(*)
W	~7
Z	~7
WW	~10
ZZ	~10
tt	~30
H	~15 (ttH ~60)
HH	~40
stop (m=1 TeV)	~10^3

(*) Note: radiation doses only x2 LHC for same integrated luminosity

Energy of a 1 TeV muon after 3 m of Fe

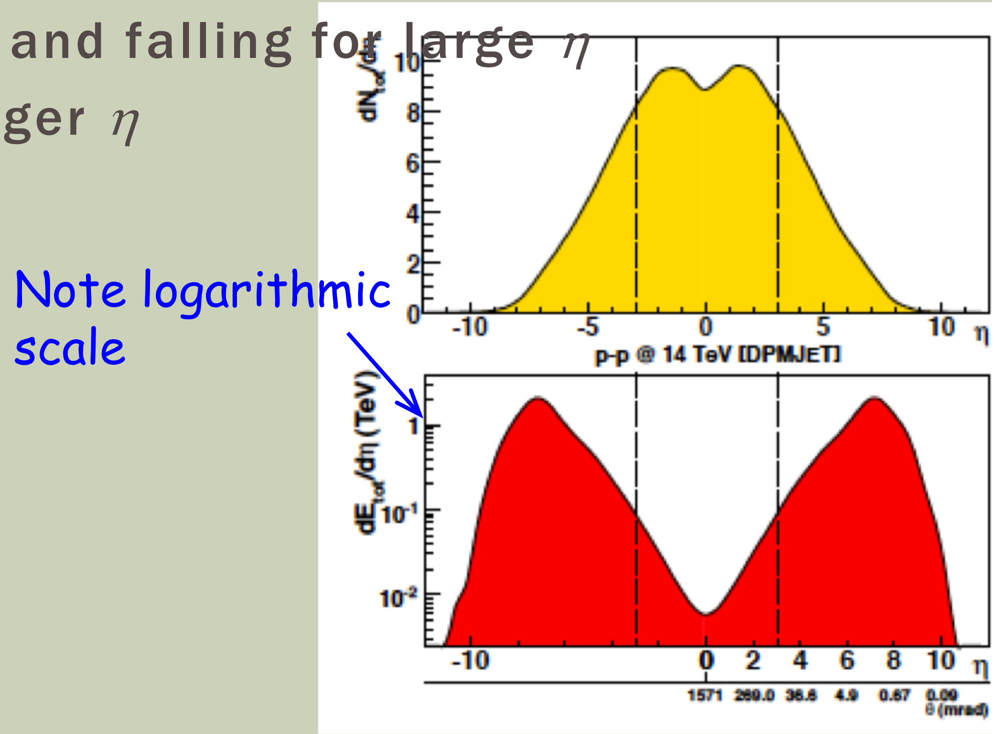


Most probable energy loss in Silicon…



ETA DEPENDENCE OF BACKGROUND

- Multiplicity flat in central η and falling for large η
- Outgoing energy peak at larger η
  - η_{peak} ~ 7 – 8 for √s = 14 TeV



- Background typically much more benign in barrel region than in endcap / forward regions

USEFUL LINKS

- Workshop on requirements for future detector technologies in view of FCC-hh : https://indico.cern.ch/event/358198/other-view?view=standard

- FCC-detector twiki : https://twiki.cern.ch/twiki/bin/view/LHCPhysics/DetectorGeneral

- FCC egroups : https://twiki.cern.ch/twiki/bin/view/FCC/WebHome