# Some Lessons from HEP?
# ”A selection of dirty washing?”

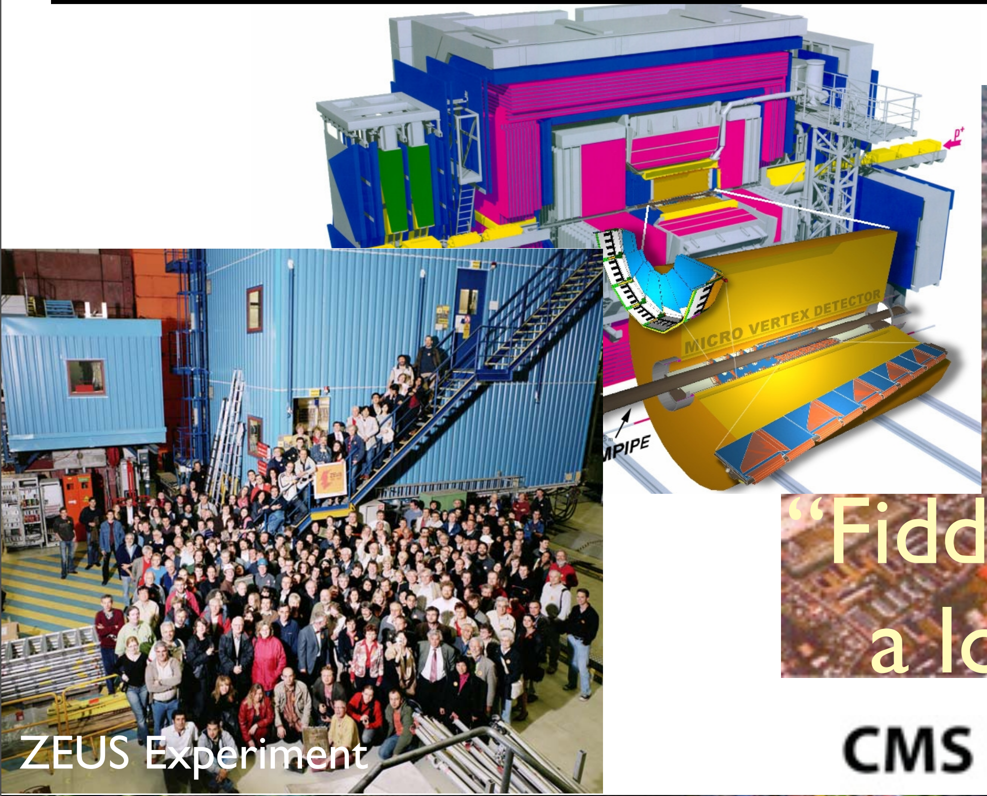
- Why me?
- ZEUS@HERA
- LHC
- CMS@LHC

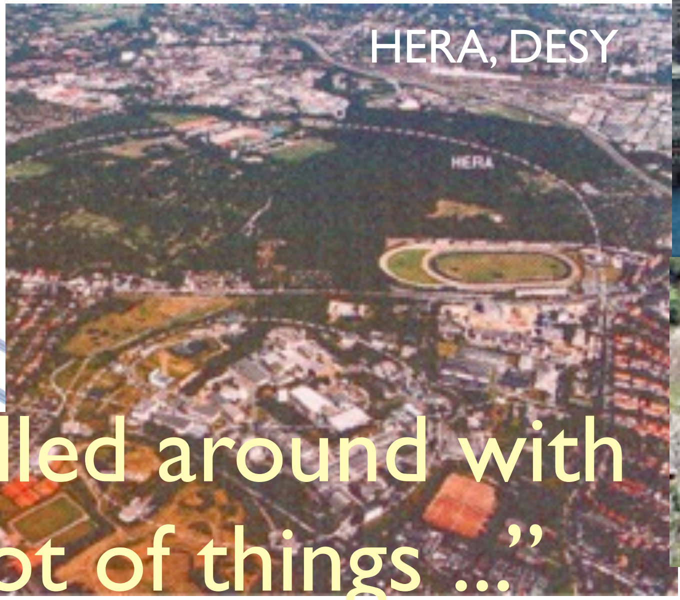
High Energy Shielding Kick-off Meeting
14 December 2012 (14/12/12)

Richard Hall-Wilton
Detector Group Leader, ESS
On Behalf of the ESS Detector Group

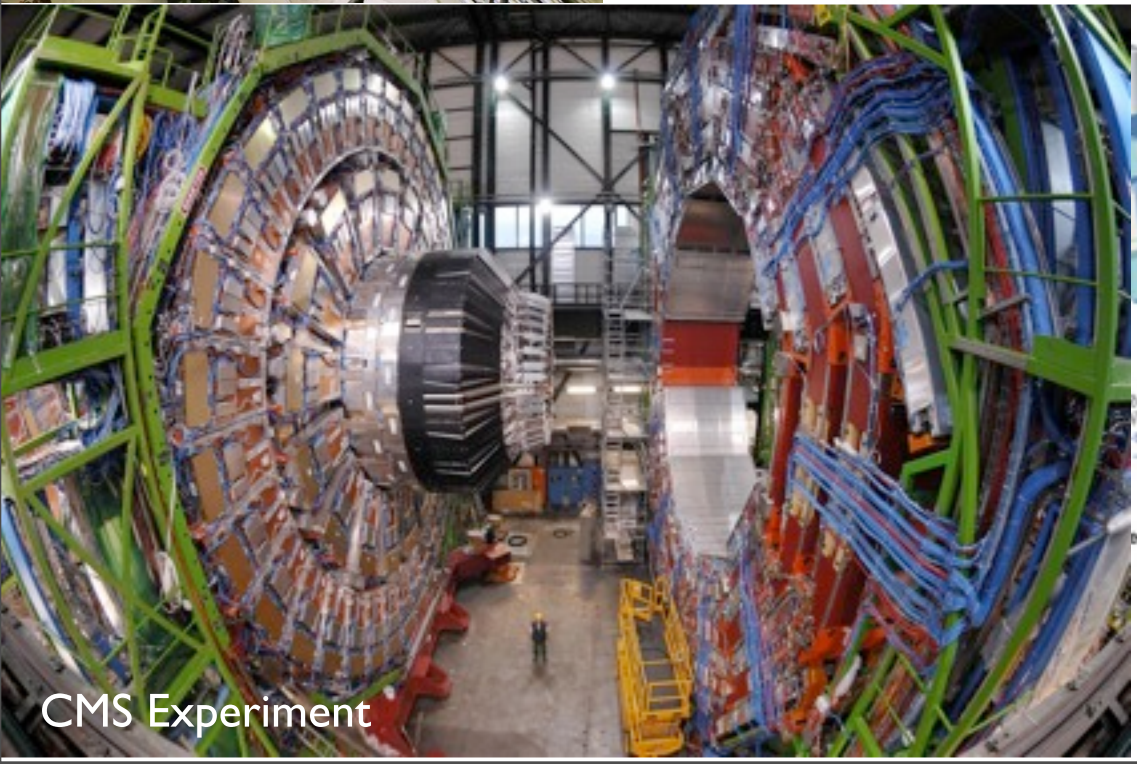
# Who am I?

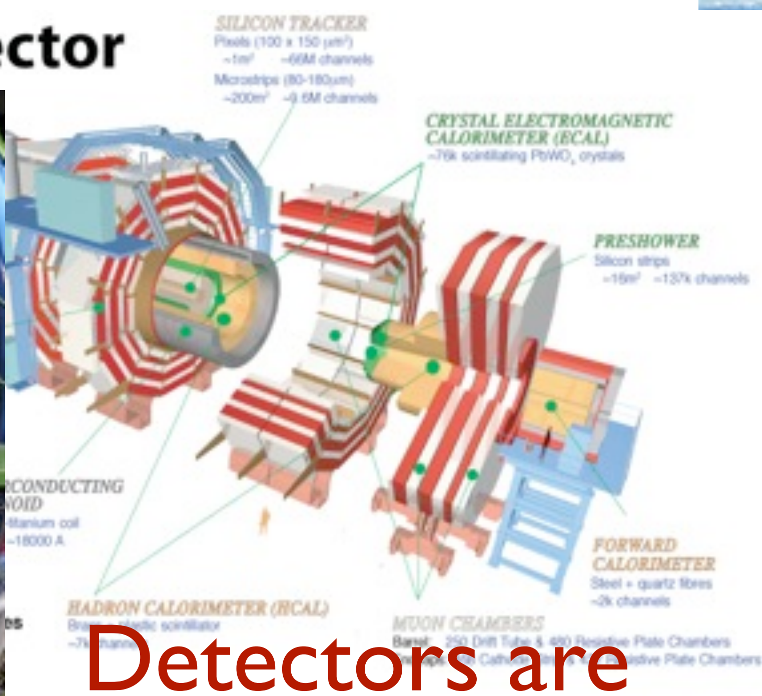
Before ESS, a particle physicist
speciality: detector physicist





"Fiddled around with
a lot of things ..."





Detectors are
inter-disciplinary

# Why am I here?

- Member of the RD42 Collaboration (Diamond Detector Development) (1995-6, 2006–)
- Member of the ZEUS Collaboration for HERA at DESY (1995-2006)
- Member of LHC Machine-Experiment Interface group (2005-2008)
- Member of the CMS Collaboration for LHC at CERN (2006–), part of CMS technical coordination team

Brief Synopsis:
CERN: Research Scientist (2008-2010)
CERN: Fellow (2005-2008)
At DESY: as RA with UCL (2001-2005)
Toronto: York University RA: (1999-2001)
Bristol: PhD (1995-1998)
Cambridge: Undergraduate (1992-1995)

However, I always seemed to get dragged into solving background problems:

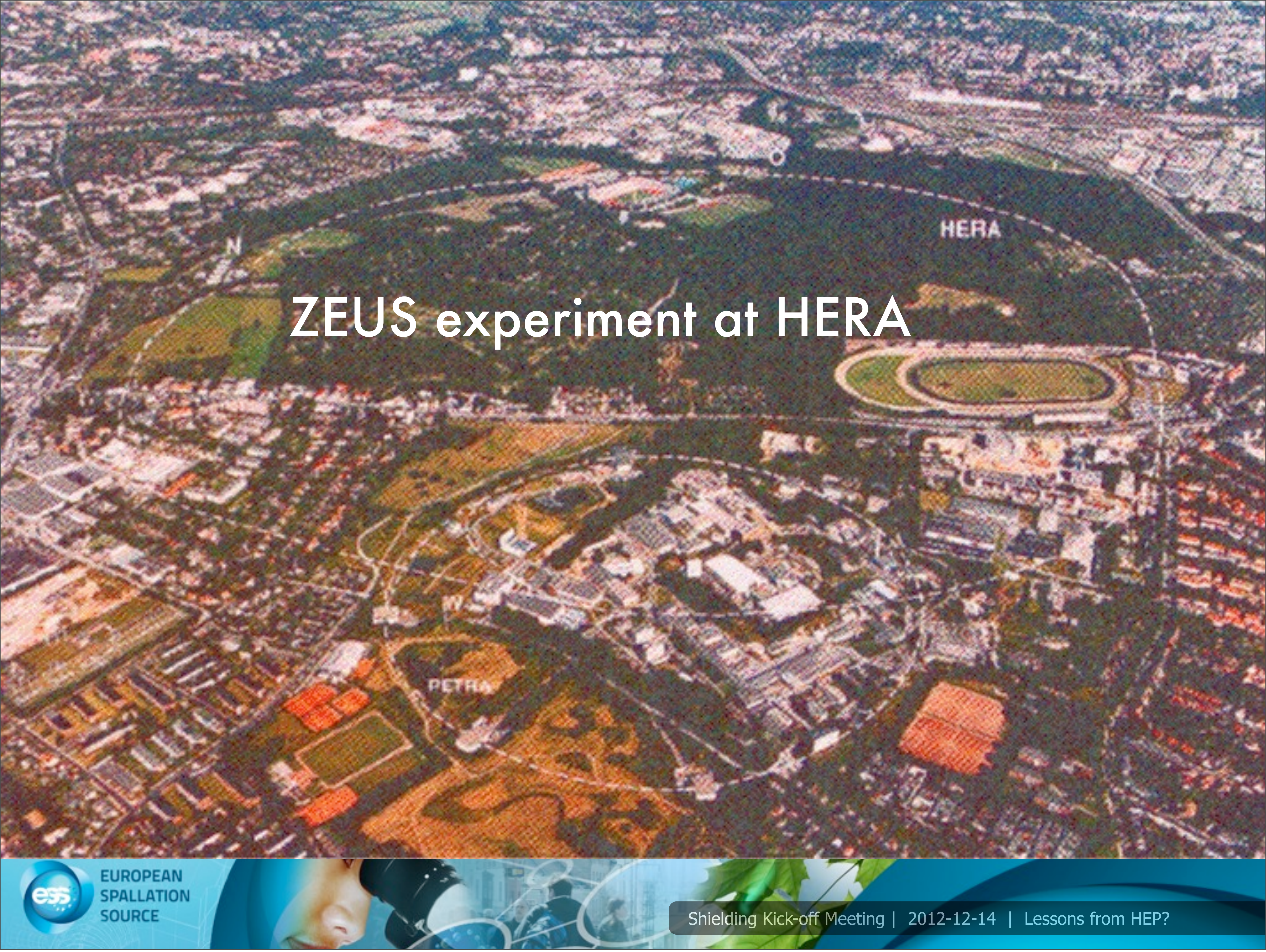
- ZEUS:
  - ZEUS Runcoordinator during restart for HERA-II upgrade
  - Brought together HERA-wide taskforce to solve problems
- LHC: group explicitly looked at backgrounds affecting experiments and accelerator
- CMS: project manager for beam and radiation monitoring (and shielding and background simulation)

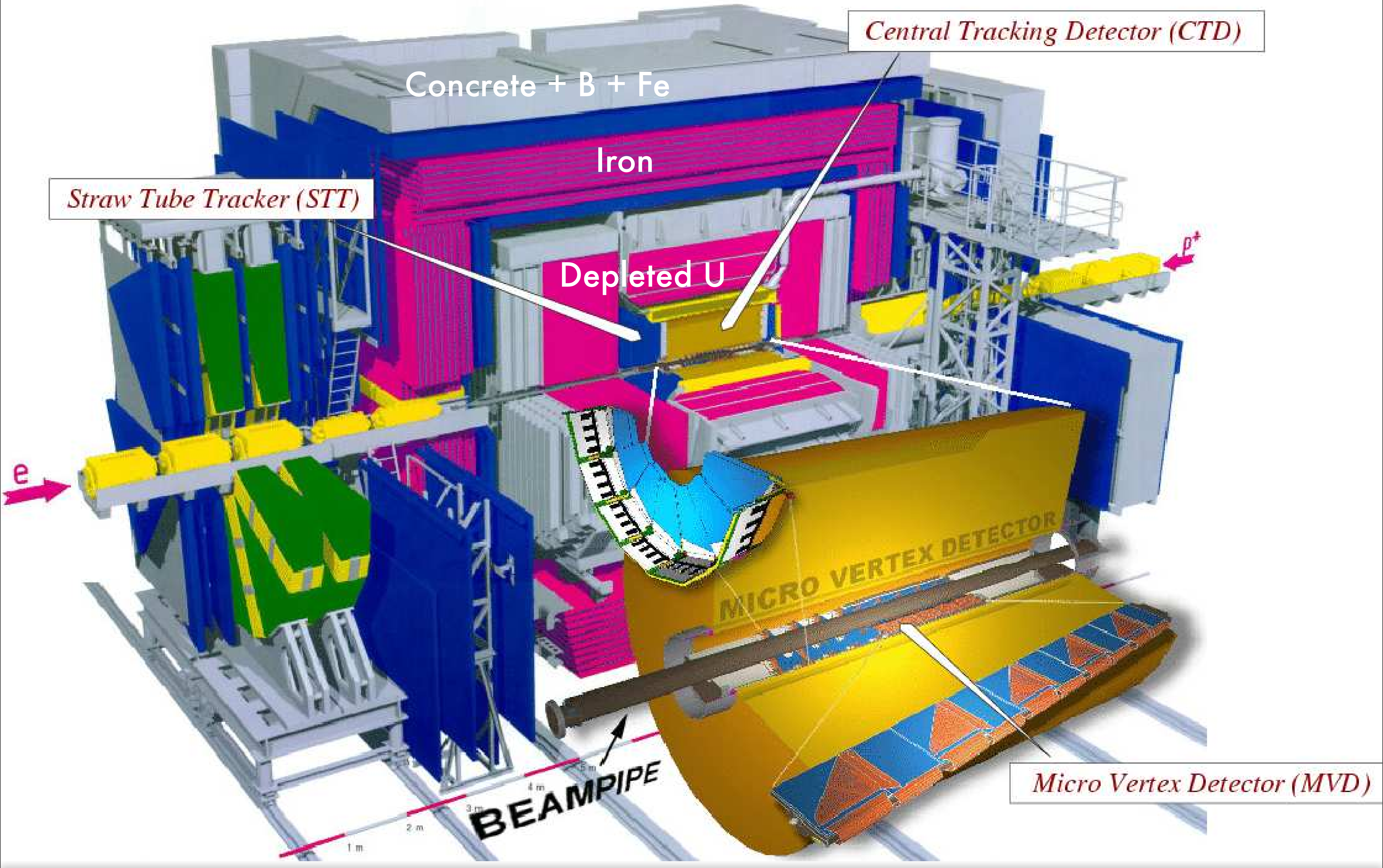
>2 days in the control room ...

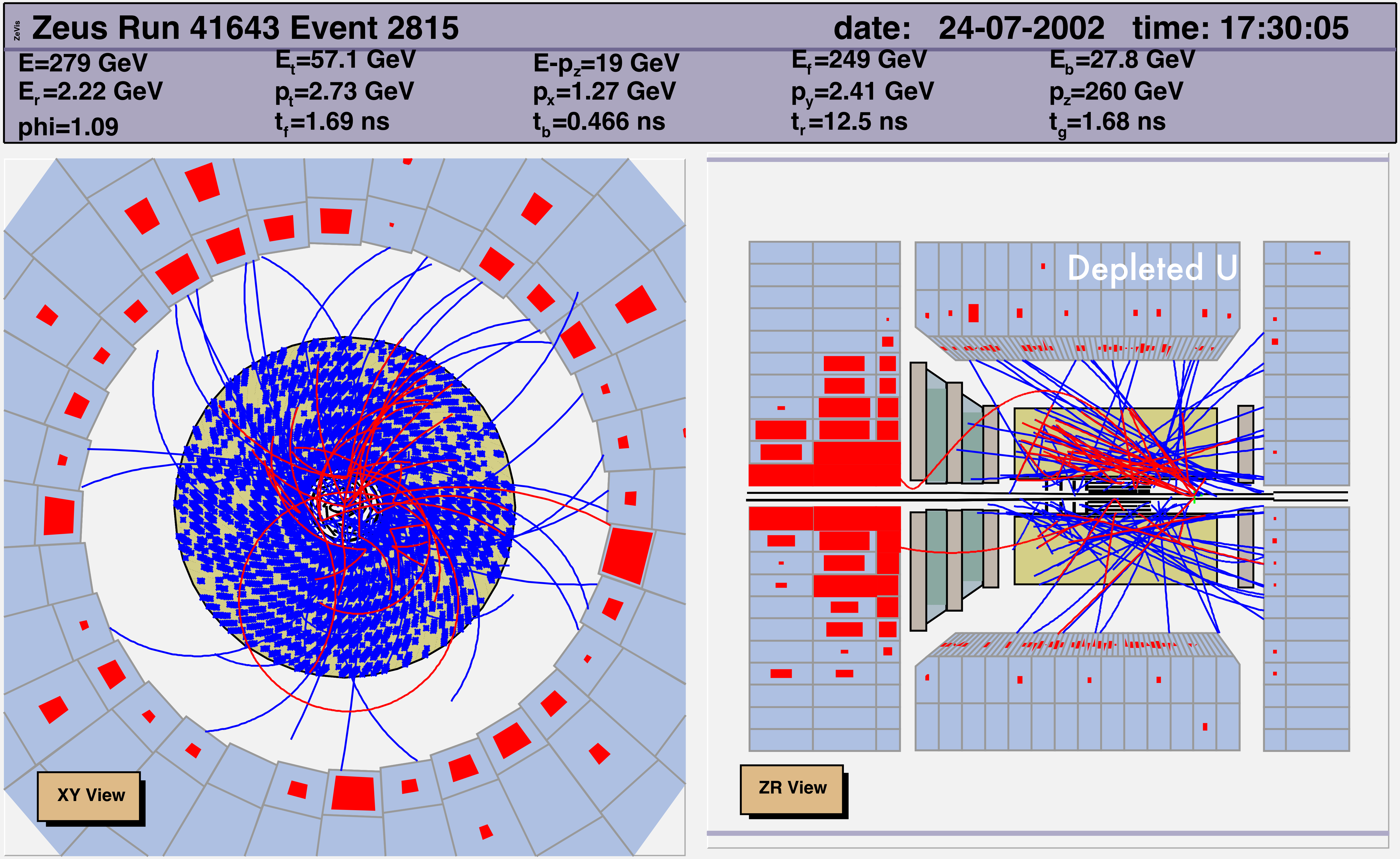
The CMS 1st Collisions PR photo 23rd Nov09


TEAMWORK
Share Victory. Share Defeat.

# ZEUS experiment at HERA

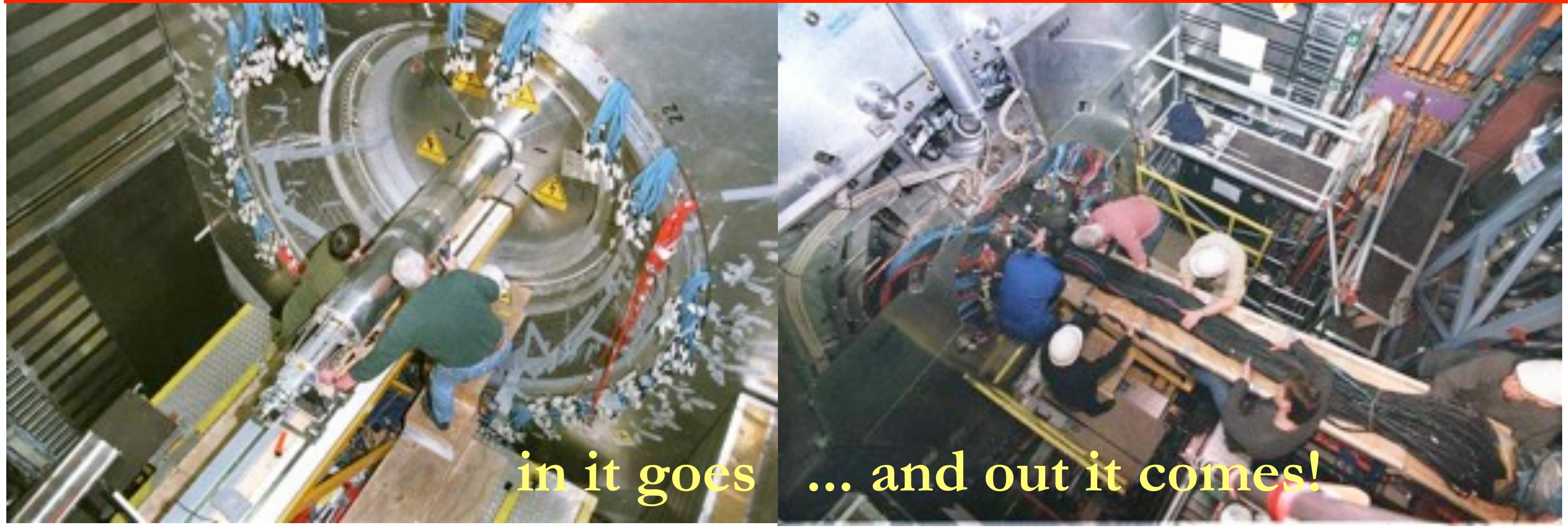



Central Tracking Detector (CTD)
Concrete + B + Fe
Iron
Straw Tube Tracker (STT)
Depleted U
p+
e
MICRO VERTEX DETECTOR
Micro Vertex Detector (MVD)
BEAMPIPE
1 m
2 m
3 m
4 m
5 m

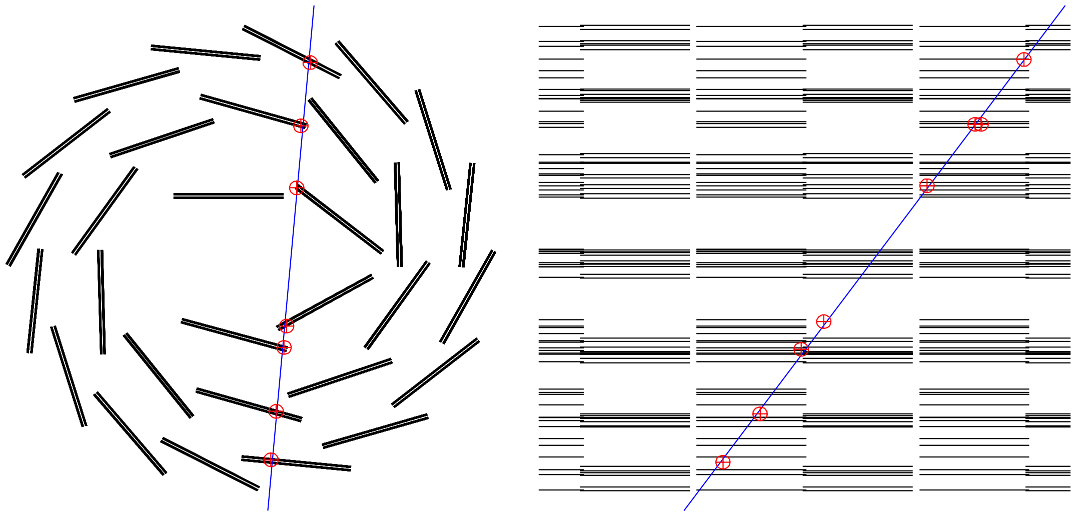

Zeus Run 41643 Event 2815
date: 24-07-2002 time: 17:30:05
E=279 GeV
$E_t$=57.1 GeV
E-$p_z$=19 GeV
$E_f$=249 GeV
$E_b$=27.8 GeV
$E_r$=2.22 GeV
$p_t$=2.73 GeV
$p_x$=1.27 GeV
$p_y$=2.41 GeV
$p_z$=260 GeV
phi=1.09
$t_f$=1.69 ns
$t_b$=0.466 ns
$t_r$=12.5 ns
$t_g$=1.68 ns
XY View
ZR View

Depleted U

# HERA II Restart and Run Coordination for ZEUS



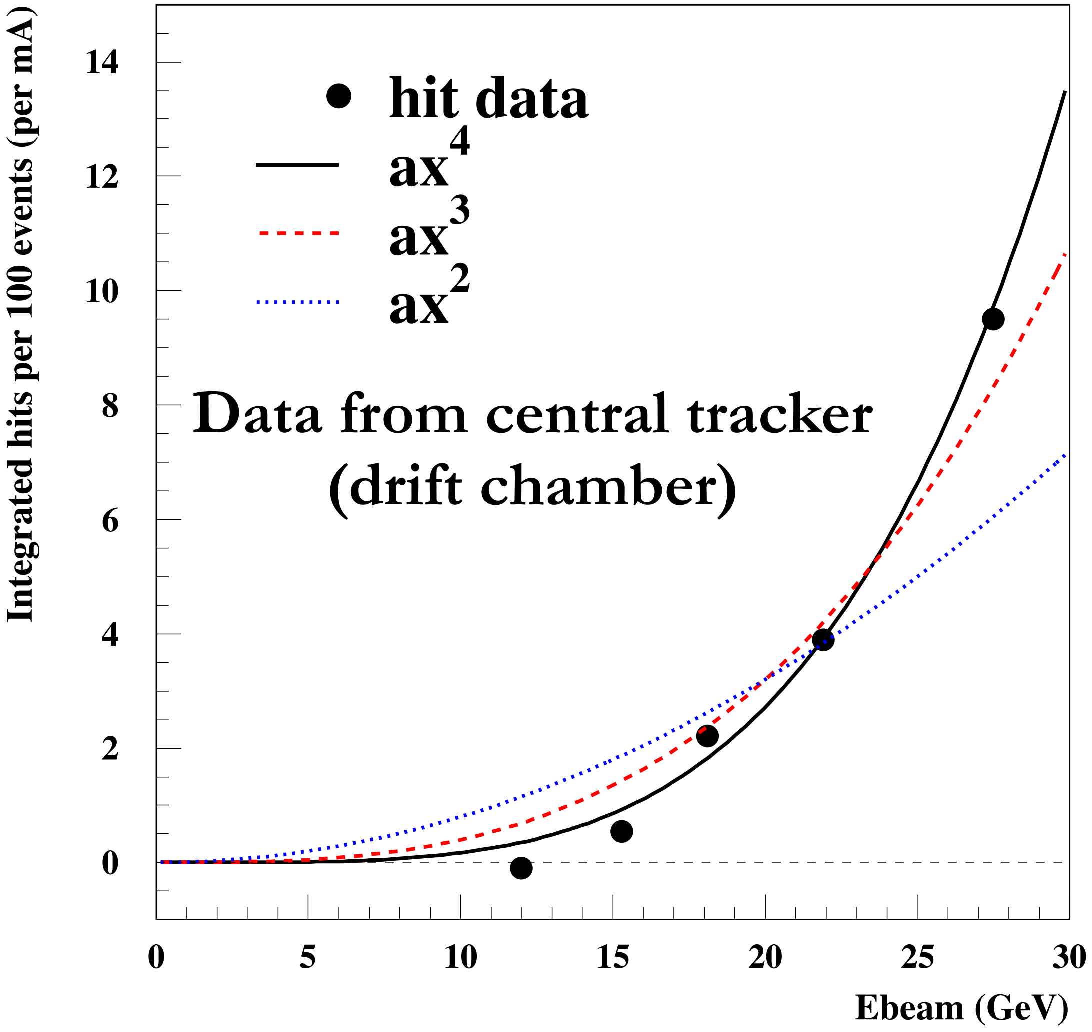
Installation of silicon microvertex detector

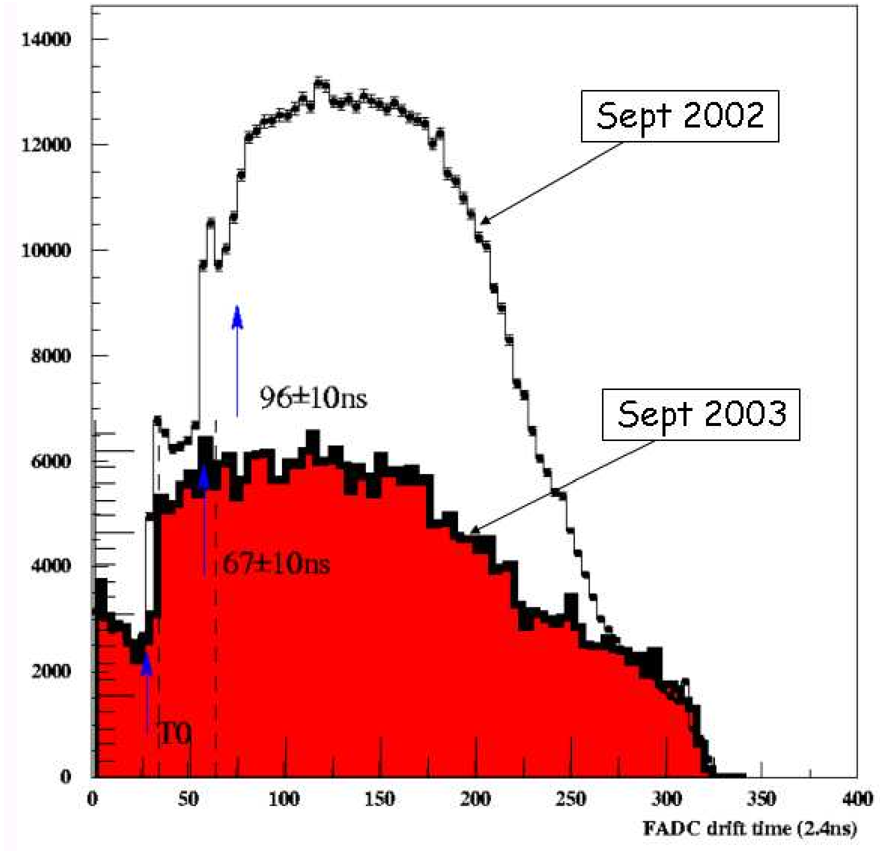


First cosmic ray observed after installation

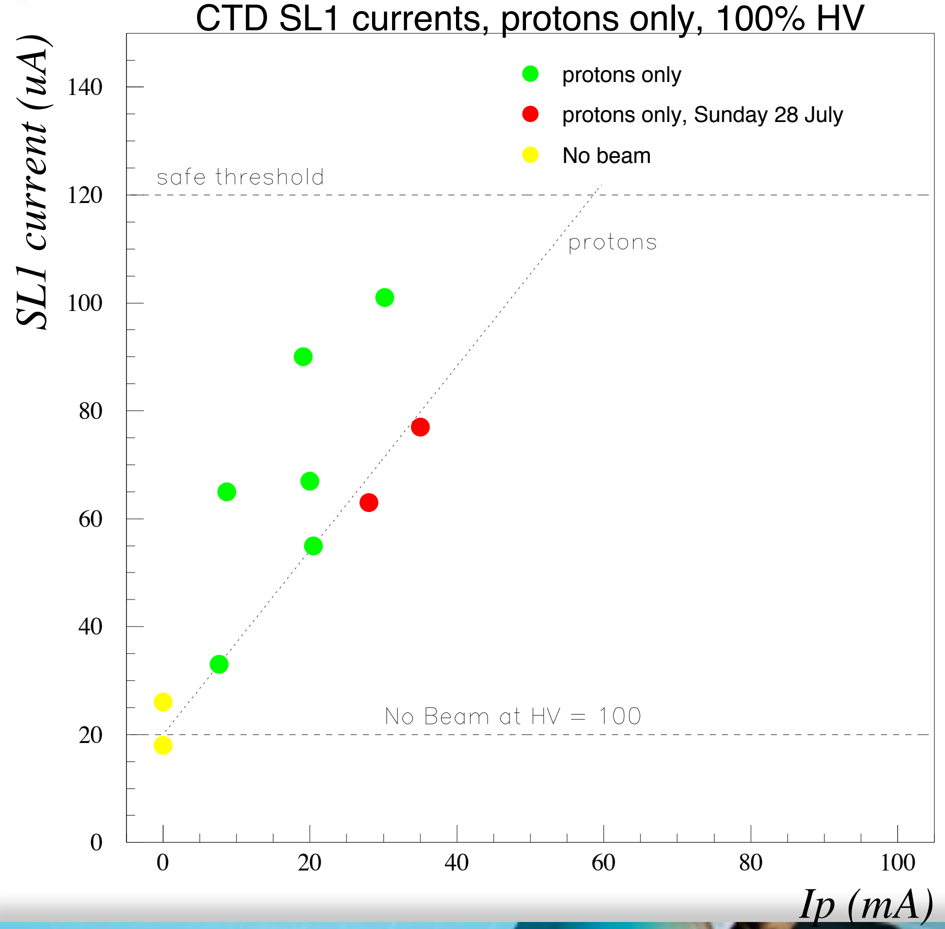
Synchrotron radiation hits: SL1

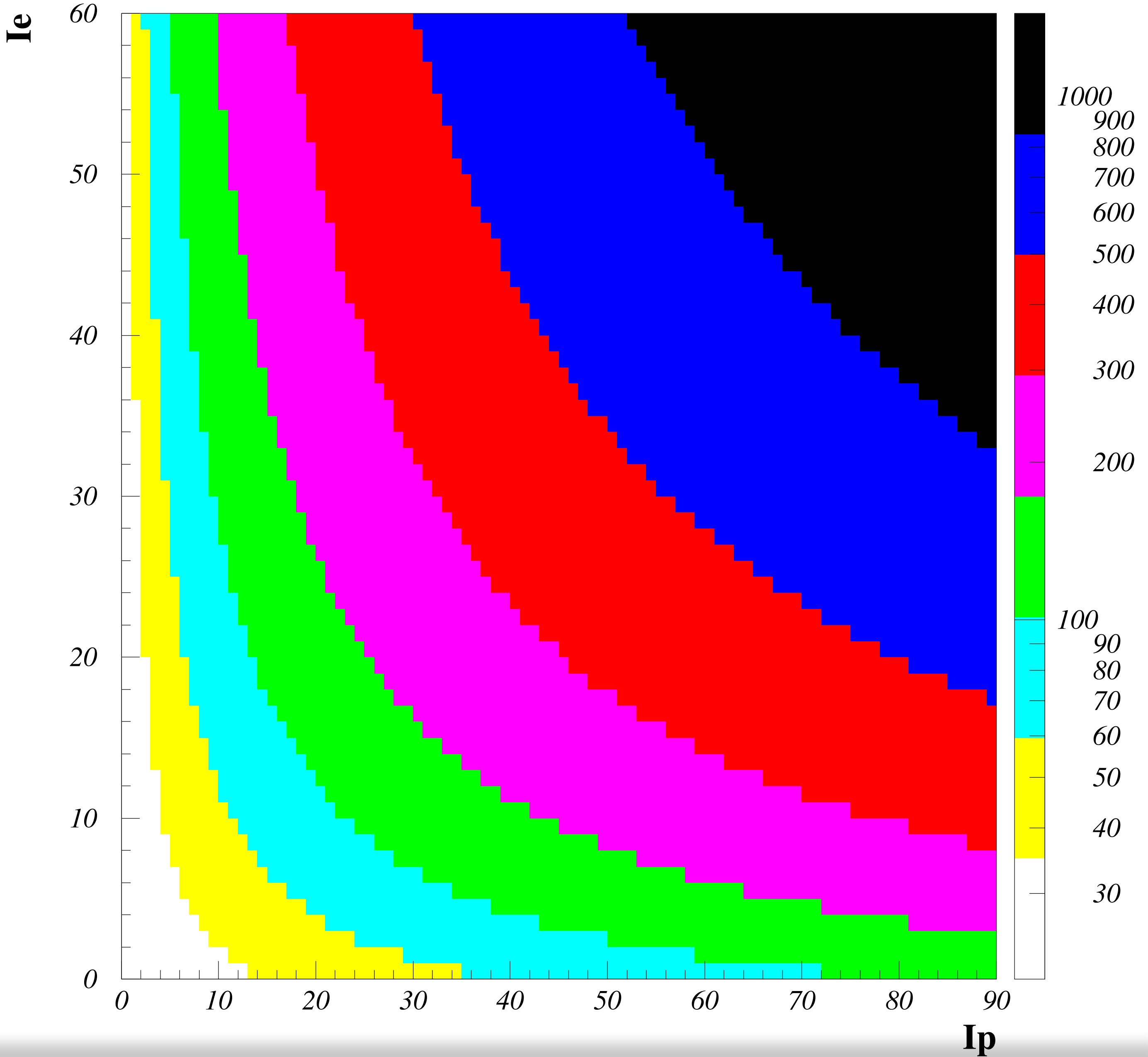
- I had been involved in three of the ZEUS upgrades
  - (MVD, STT, GTT)
- Prerun-coordinator, run-coordinator for the startup period (2001-2)
- Successful cosmic run prior to beam
- But background problems on restart - initially a factor of 10 000 too high
- Problem was that ALL diagnostic equipment had been removed
- Determined that this was synchrotron radiation
- This was only the beginning ...





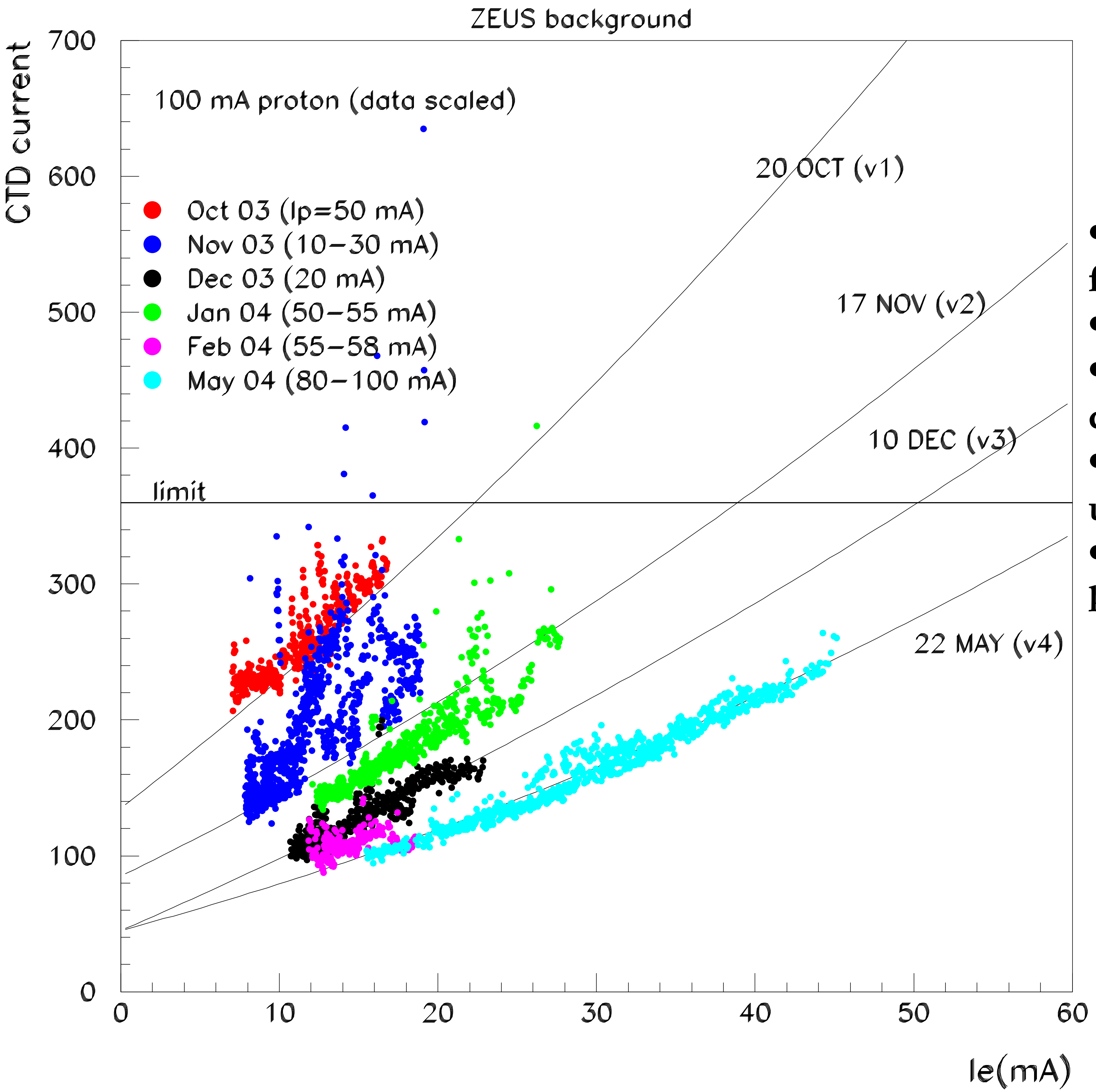
- Still problems with electron backgrounds (2 sources)
- And proton backgrounds ...
- And when together, the result was more that sum of the 2 parts
- Why hadnt this been predicted?
  - Measurements had been made in 2005, compatible with 0
  - Extrapolation of 1000 of a small number can be large





# *Solutions*

- As a result of the extensive studies, several improvements were identified that would have a significant effect of the sense wire currents in the detector:
- C5 collimator geometry inside the detector (at -80cm) - tertiary reflections were eliminated, and a gap in collimator geometry was closed
- Better thermal contact between the C5 and the beampipe
- Vacuum pumps improved near to detector, and along the upstream proton beamline
- Vacuum pump installed inside magnet where most e-beamgas interactions created
- CTD sensitivity reduced - gain of chamber reduced by a factor of 2
    - ▷ Sense wire high-voltage reduced by 5%.
    - ▷ Field high voltage unchanged, so as not to distort drift field
    - ▷ To minimise loss in performance, post amplifier gain was increased by factor 2
- All of these changes were performed during a 4 month shutdown in summer 2003 ...

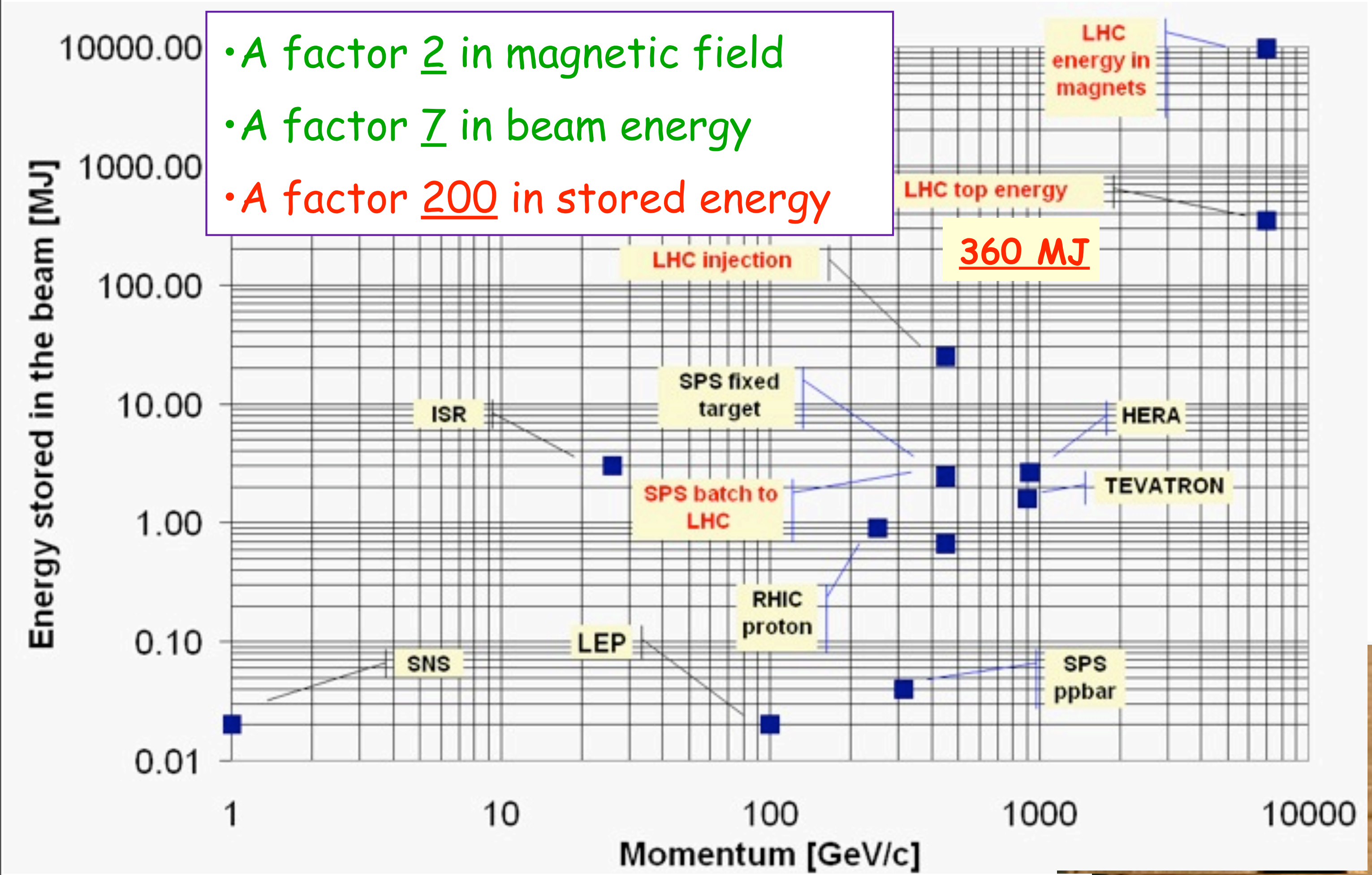


- **Eventually solved ... 3 years work for a taskforce**
- **Not necessarily a single cause**
- **Data is golden - you need all the data you can get ...**
- **And need simulation to show you understand it ...**
- **Qualifying the simulation is the key part of the job ...**


LHC

# Large Hadron Collidor

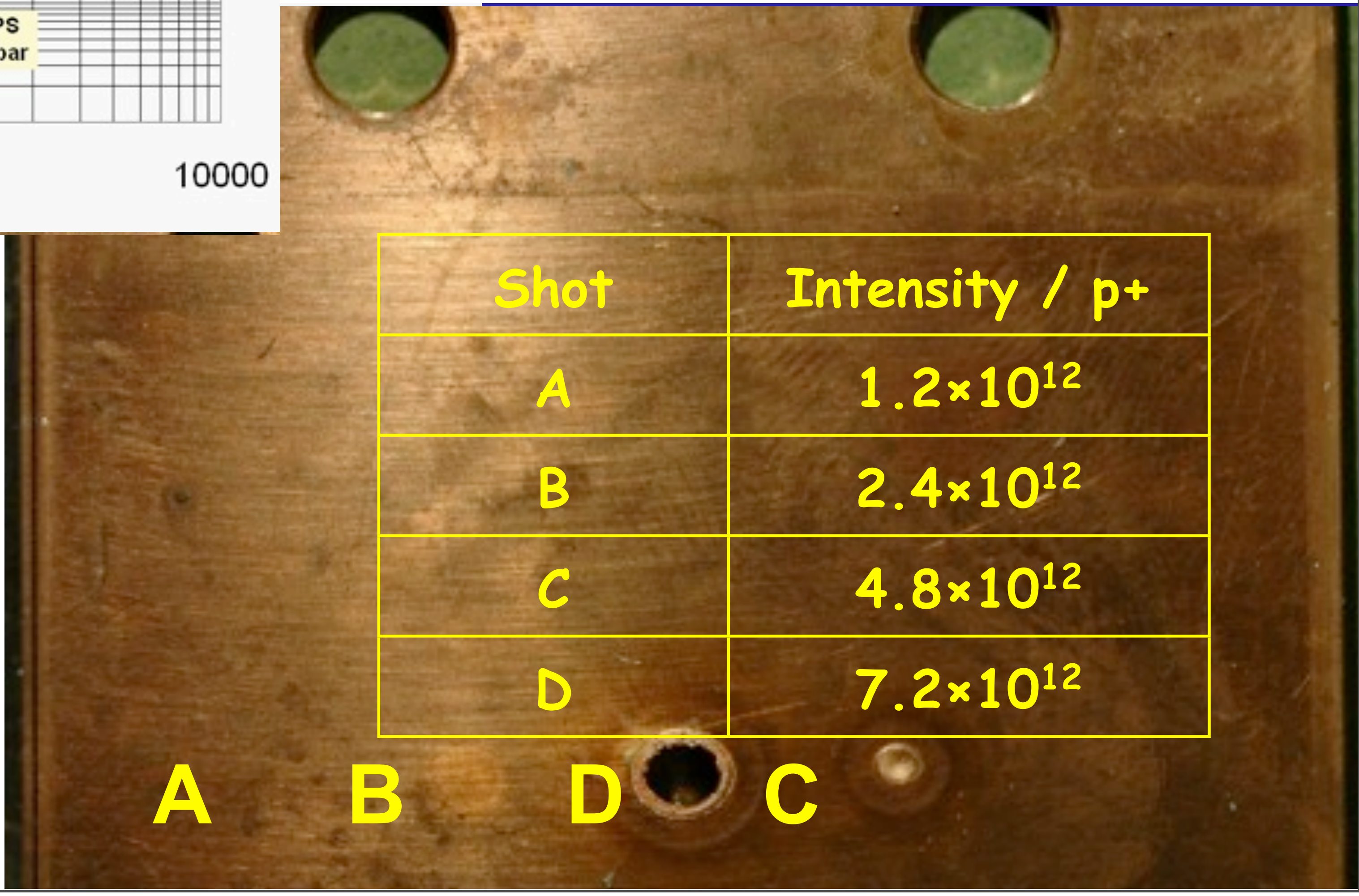
- LHC beams are of unprecedented intensity and damage potential



- A factor 2 in magnetic field
- A factor 7 in beam energy
- A factor 200 in stored energy

- All aspects of beams needed to be checked around the accelerator

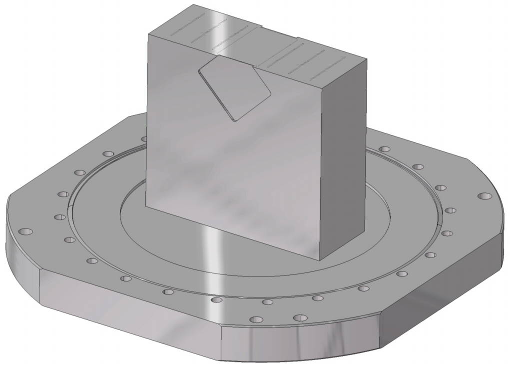
- For the 45m of the CMS cavern, no LHC monitoring
- Need for monitoring by CMS of losses

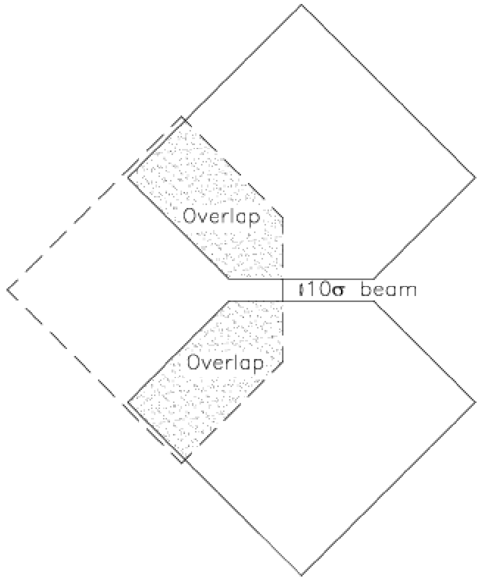


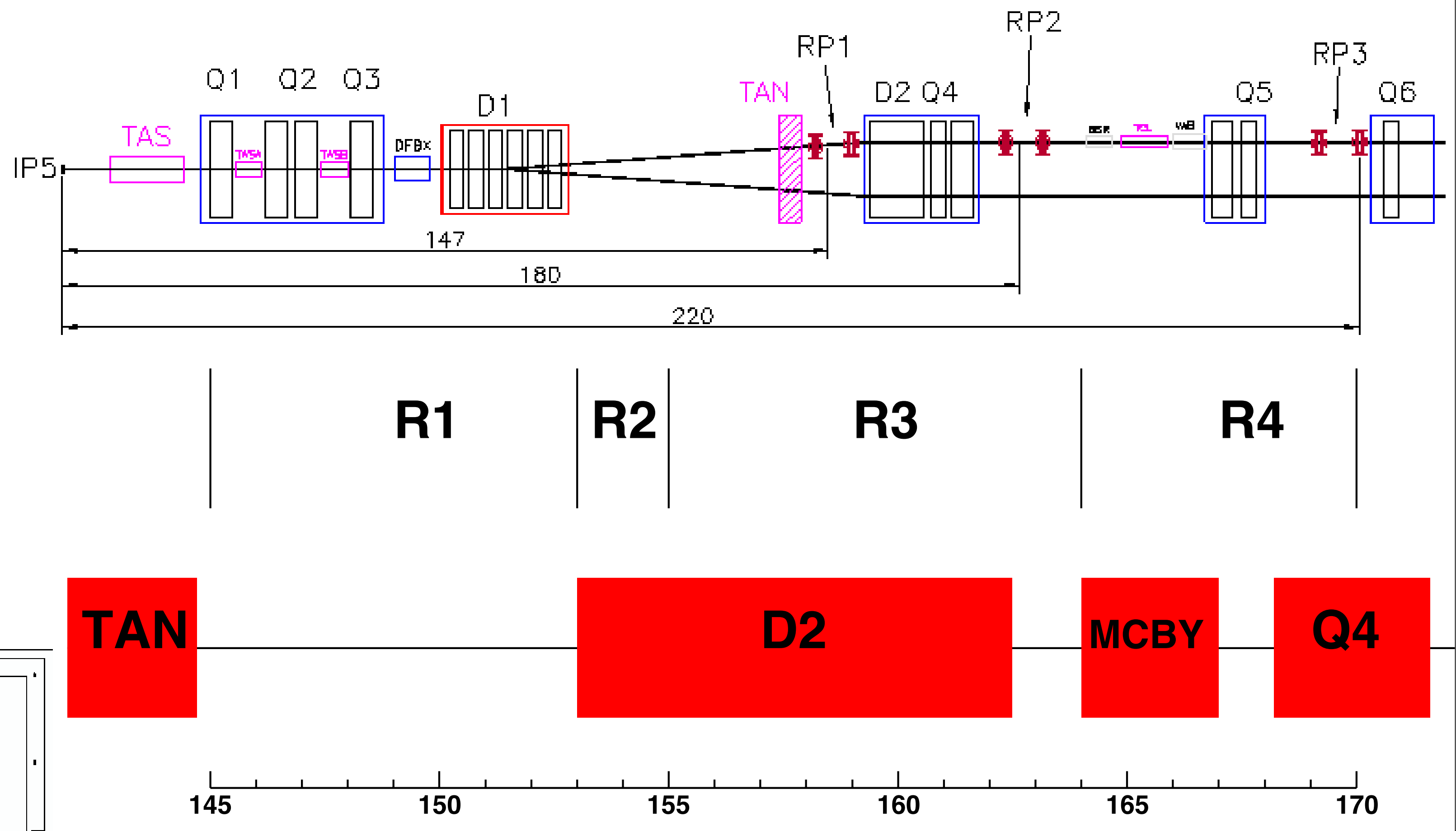
| Shot | Intensity / p+ |
|---|---|
| A | $1.2\times10^{12}$ |
| B | $2.4\times10^{12}$ |
| C | $4.8\times10^{12}$ |
| D | $7.2\times10^{12}$ |

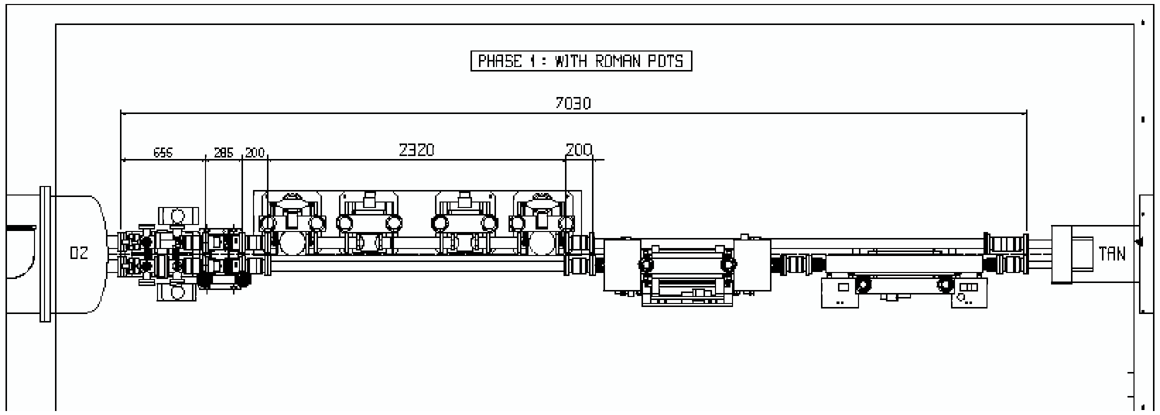
# Large Hadron Collidor: Detectors in the Beam

steel

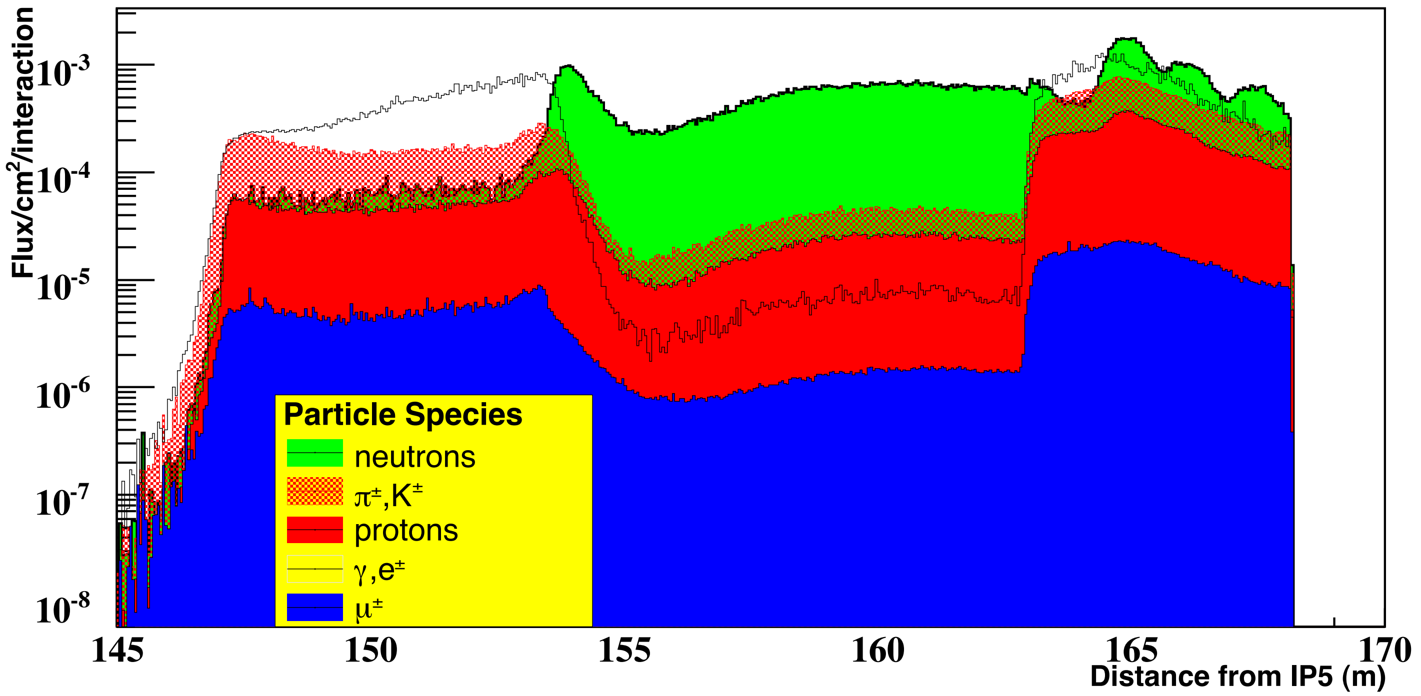




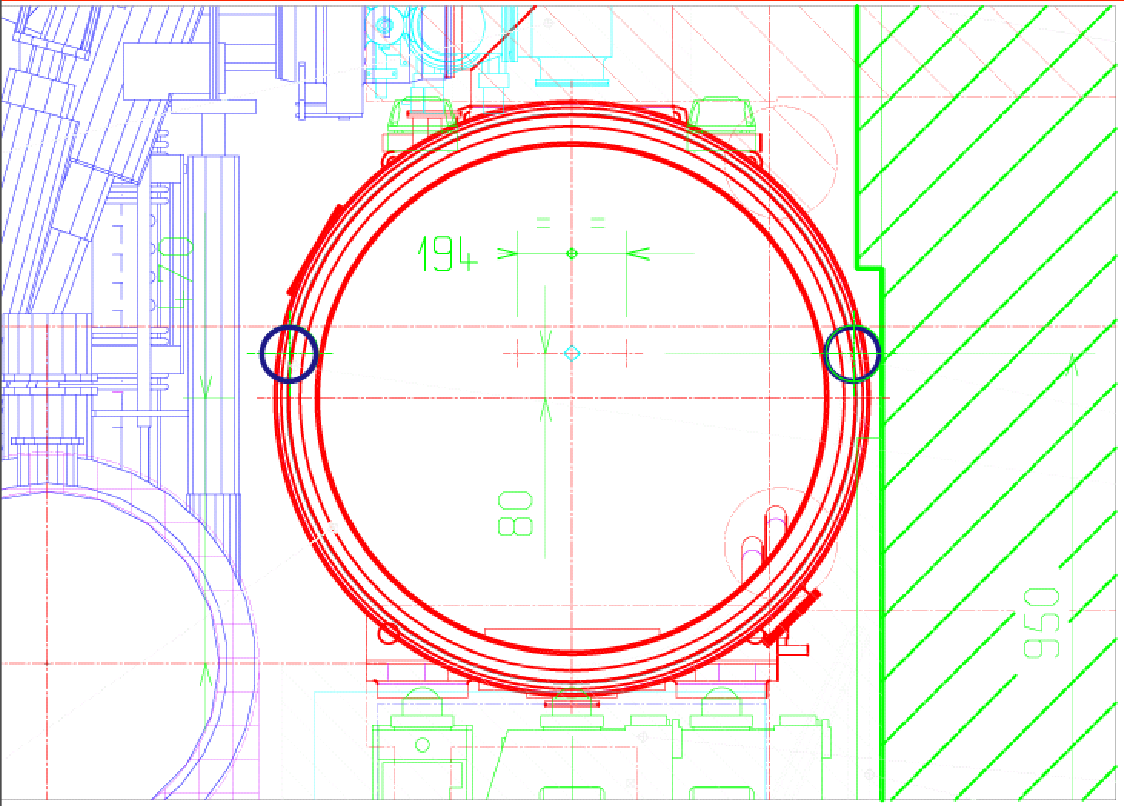


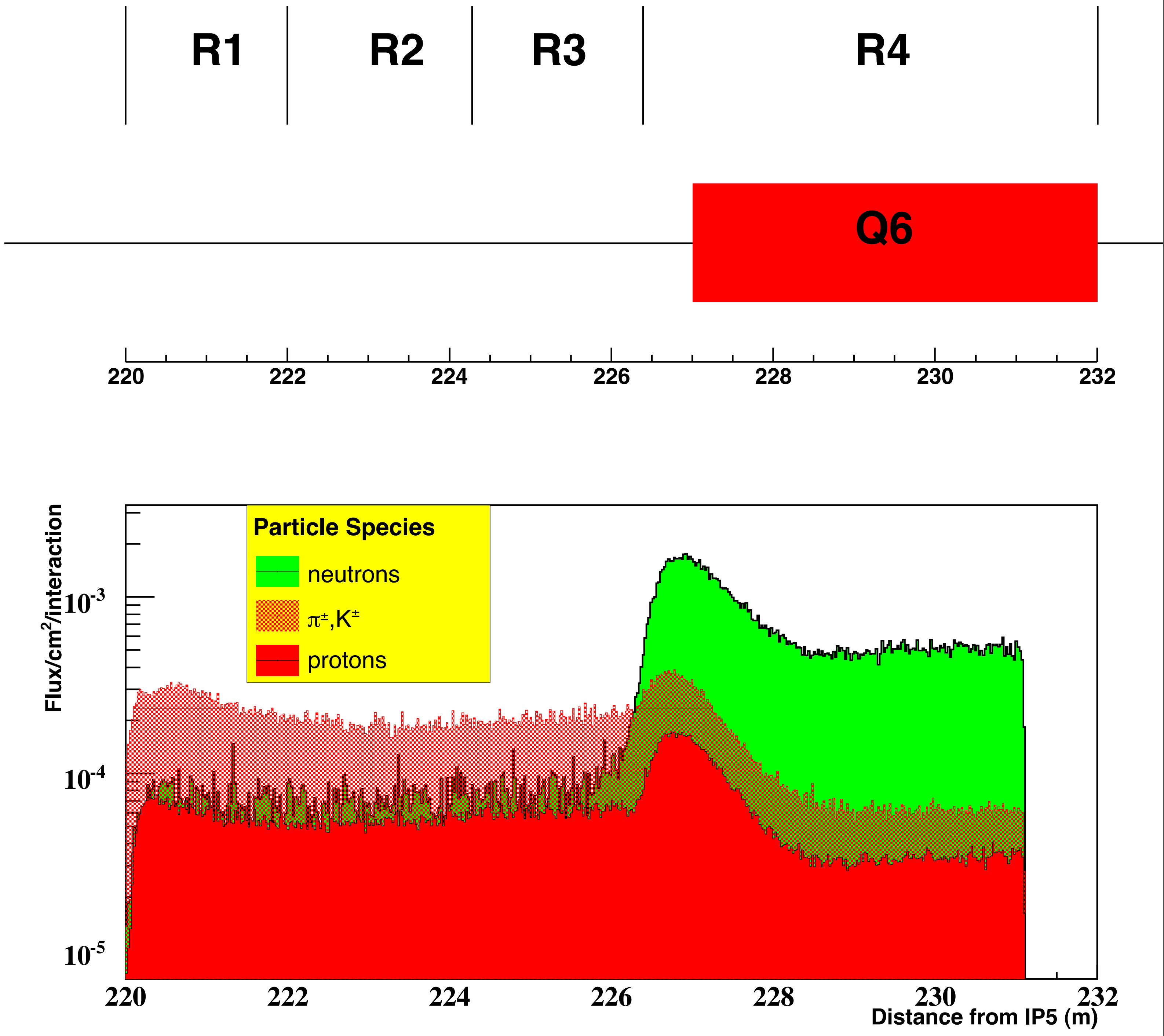


- Same message as you have heard from Nataliya and Kelly:
  - “Shielding” may cause backgrounds to go up before coming down
  - Particle species mix will change also



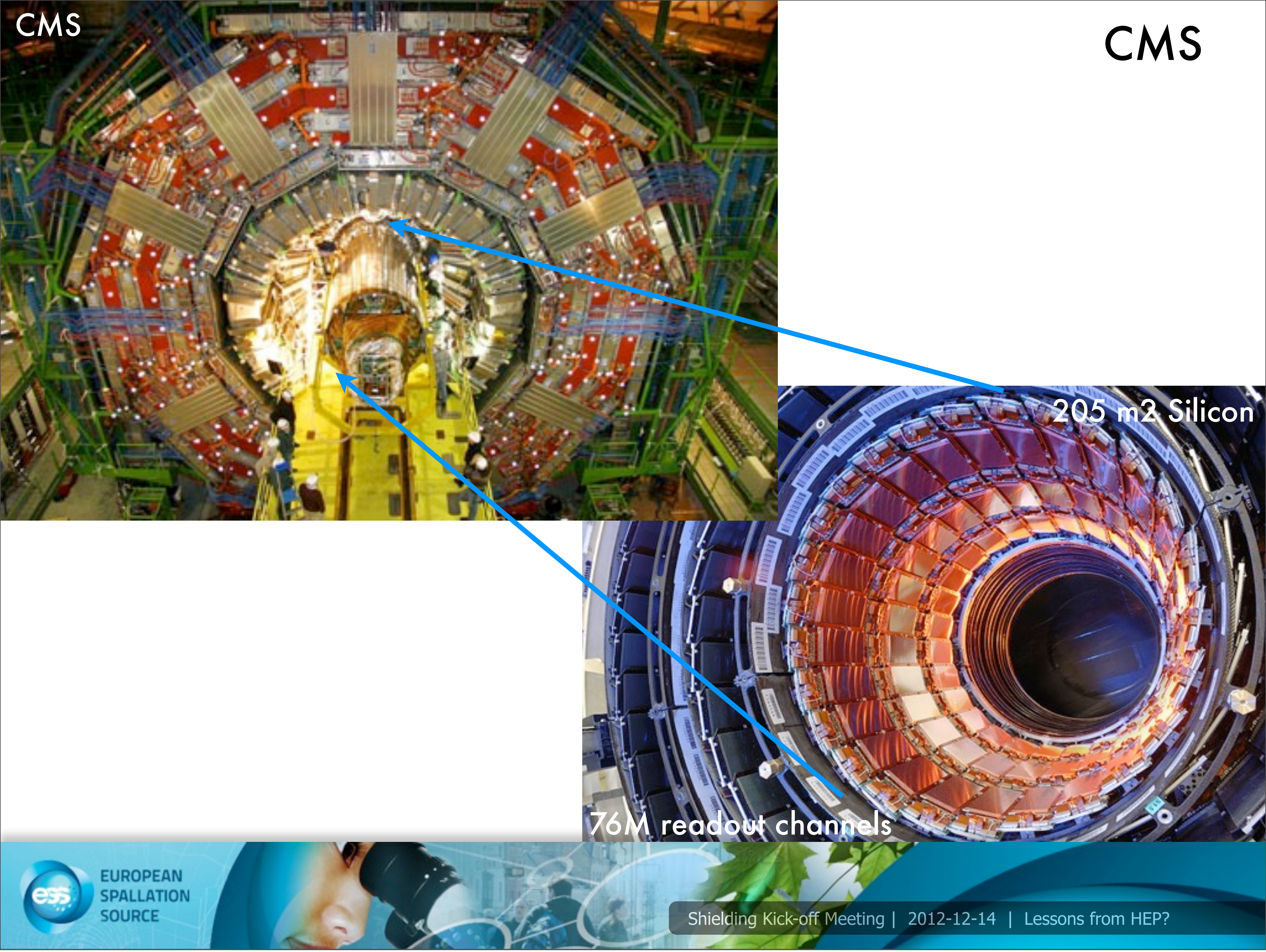
# Large Hadron Collidor





# CMS Experiment@LHC

# CMS



205 m2 Silicon

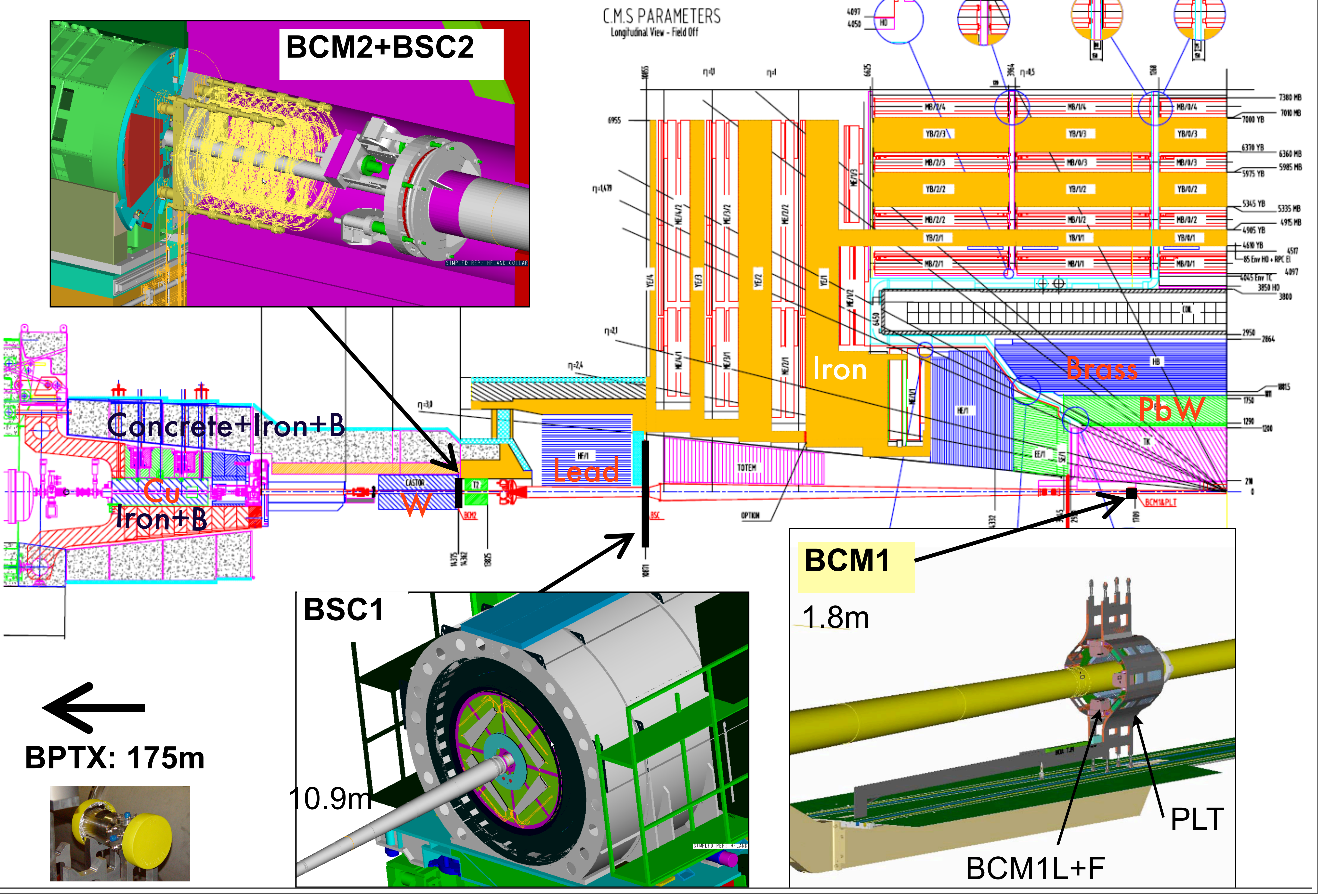
76M readout channels

# Overview of the CMS Beam and Radiation Monitoring

**RADMON: 18 monitors around UXC**

**PASSIVES: Everywhere**

Neutron Camera x 5

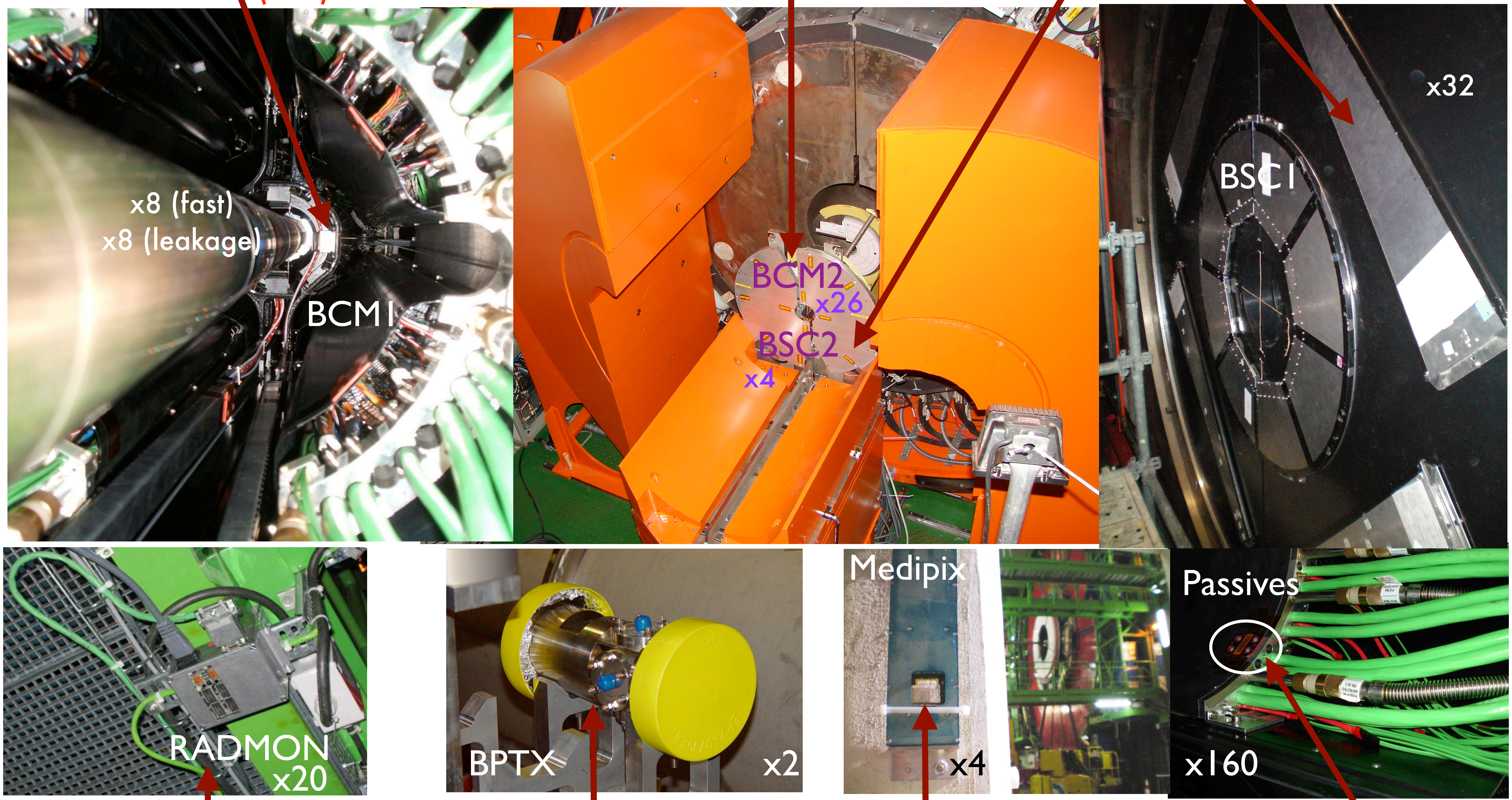


# … and the reality …

single and polycrystalline CVD diamond (8+8)

polycrystalline CVD diamond (24)

plastic scintillator + PMTs

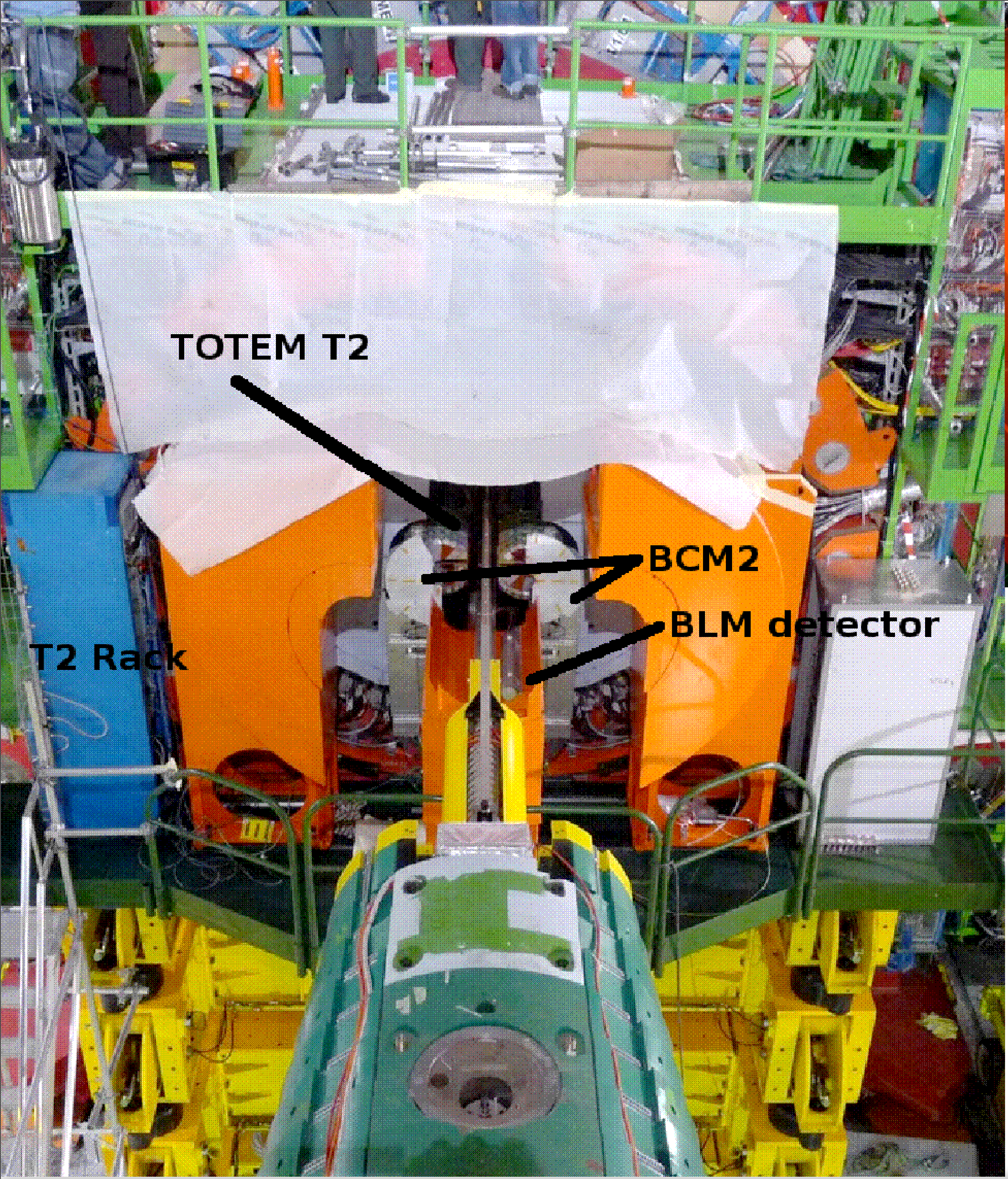


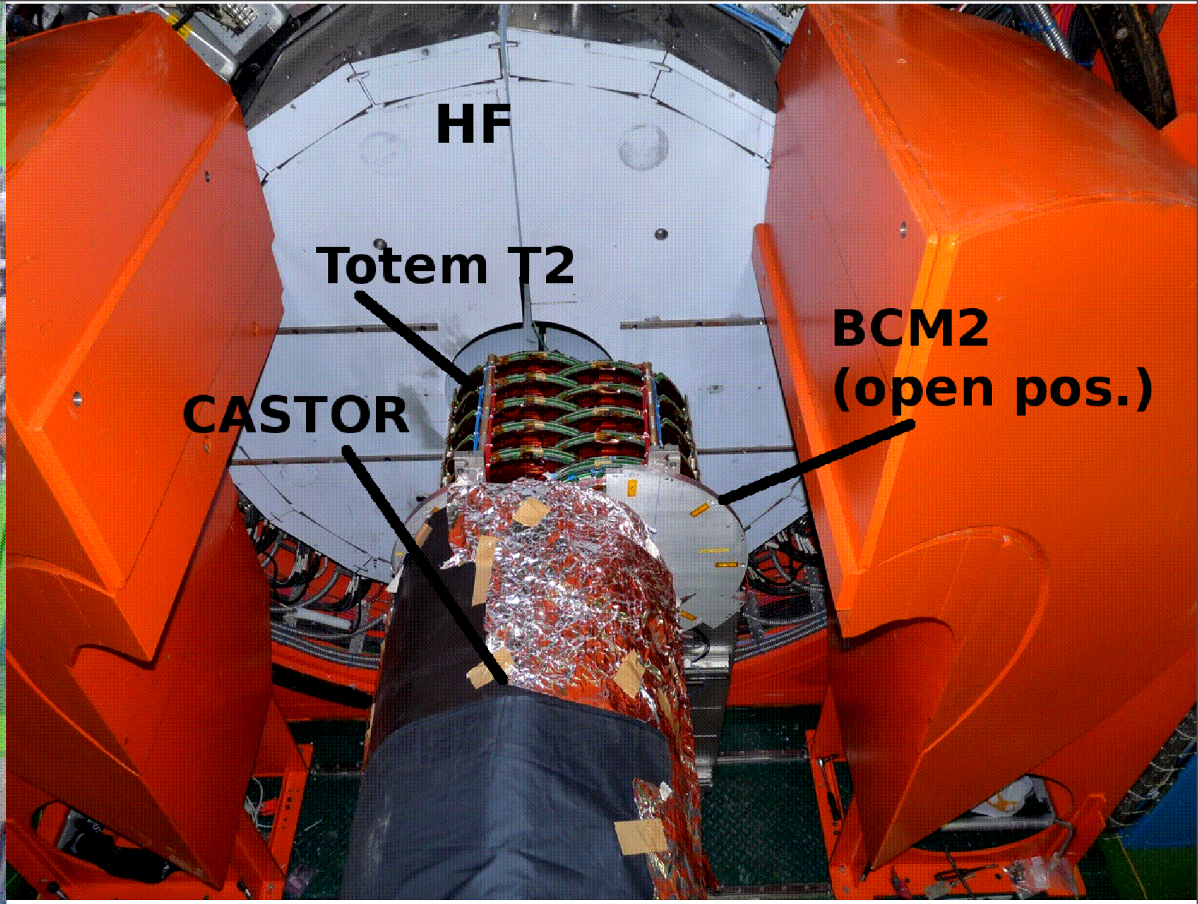
RADFET, Pin diode, SRAM

button monitor

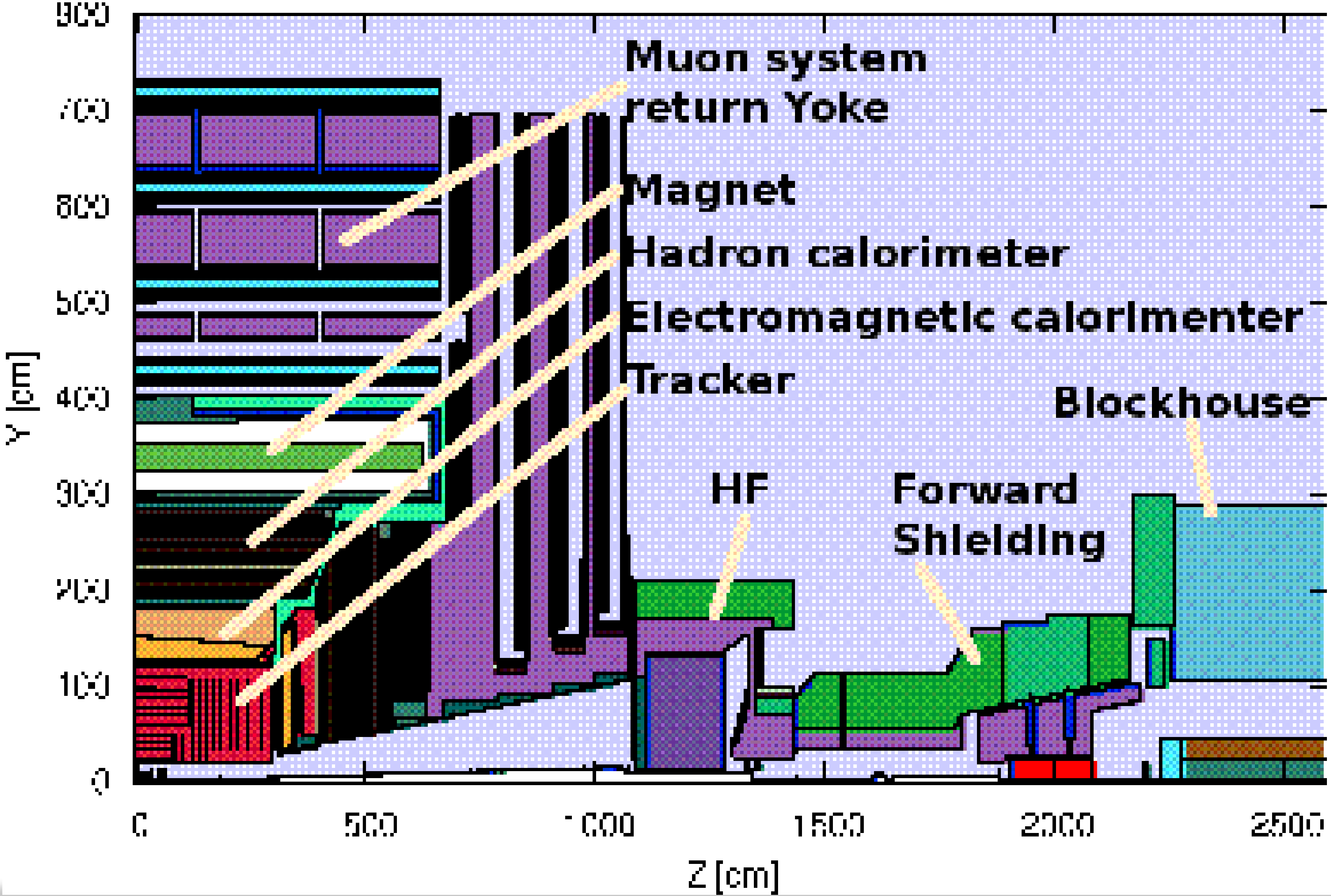
Silicon pixel detector

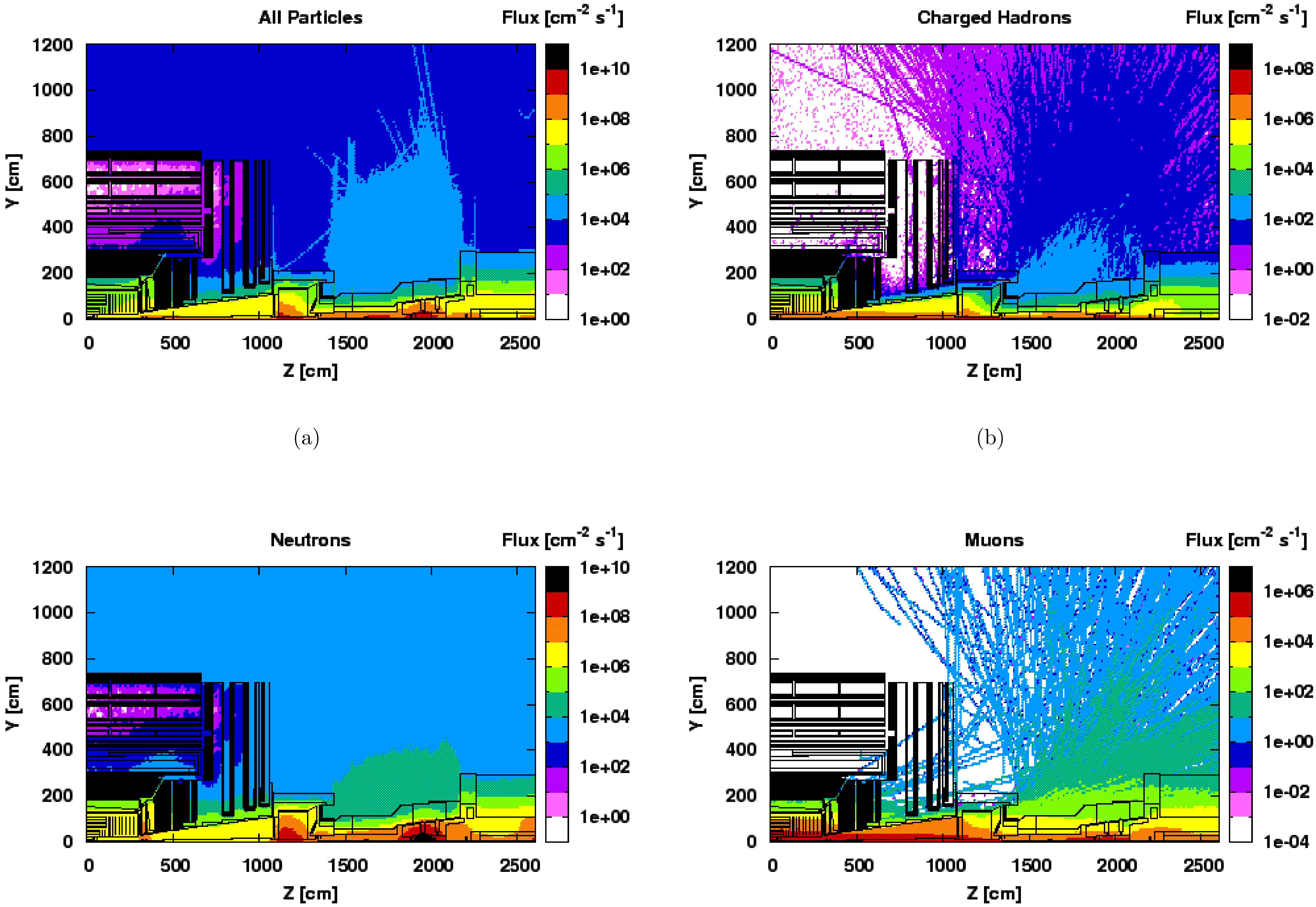
TLDs


TOTEM T2
BCM2
BLM detector
T2 Rack


HF
Totem T2
BCM2
(open pos.)
CASTOR

# geometry as implemented in FLUKA





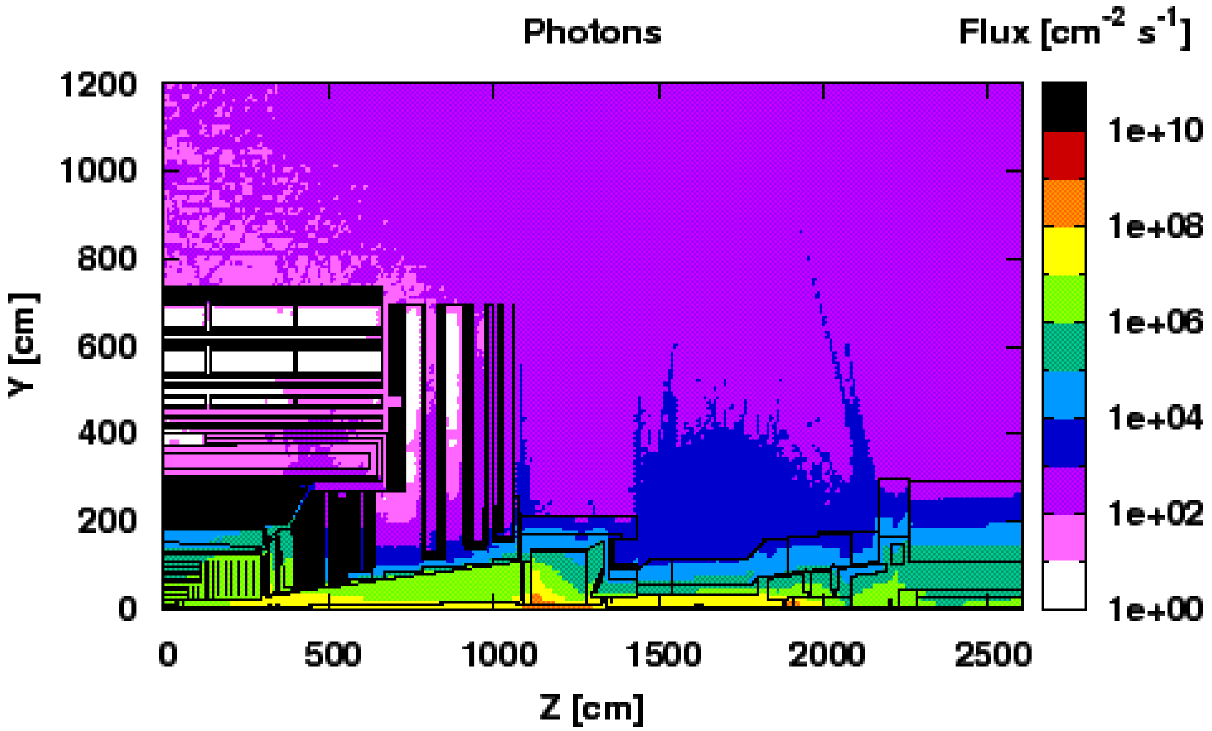
(a)

(b)

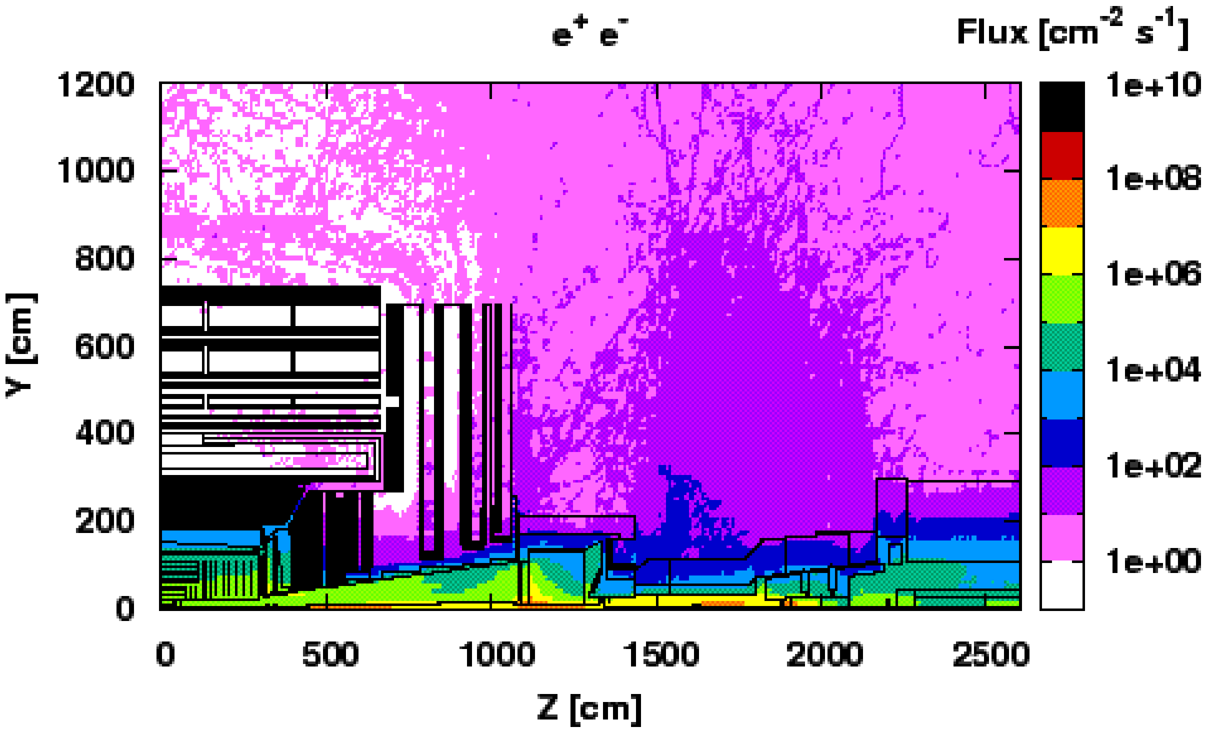
(c)

(d)

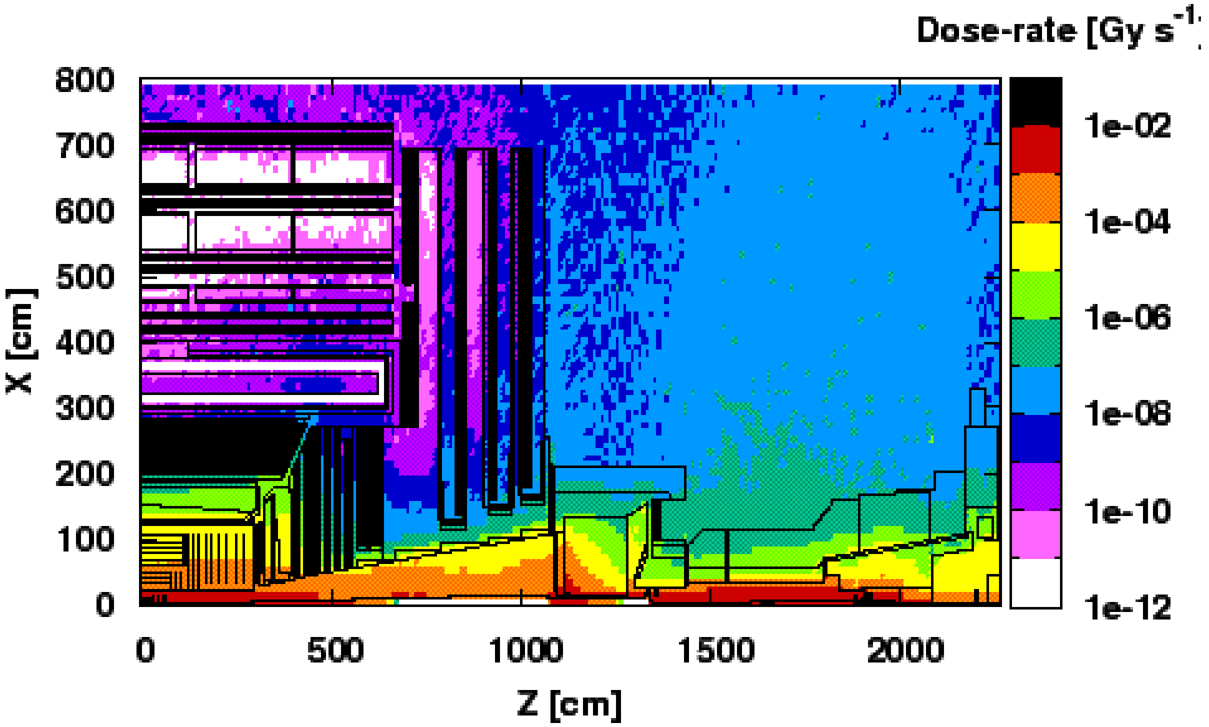
Figure 9.6: Fluxes for 7TeV collisions in the CMS cavern.

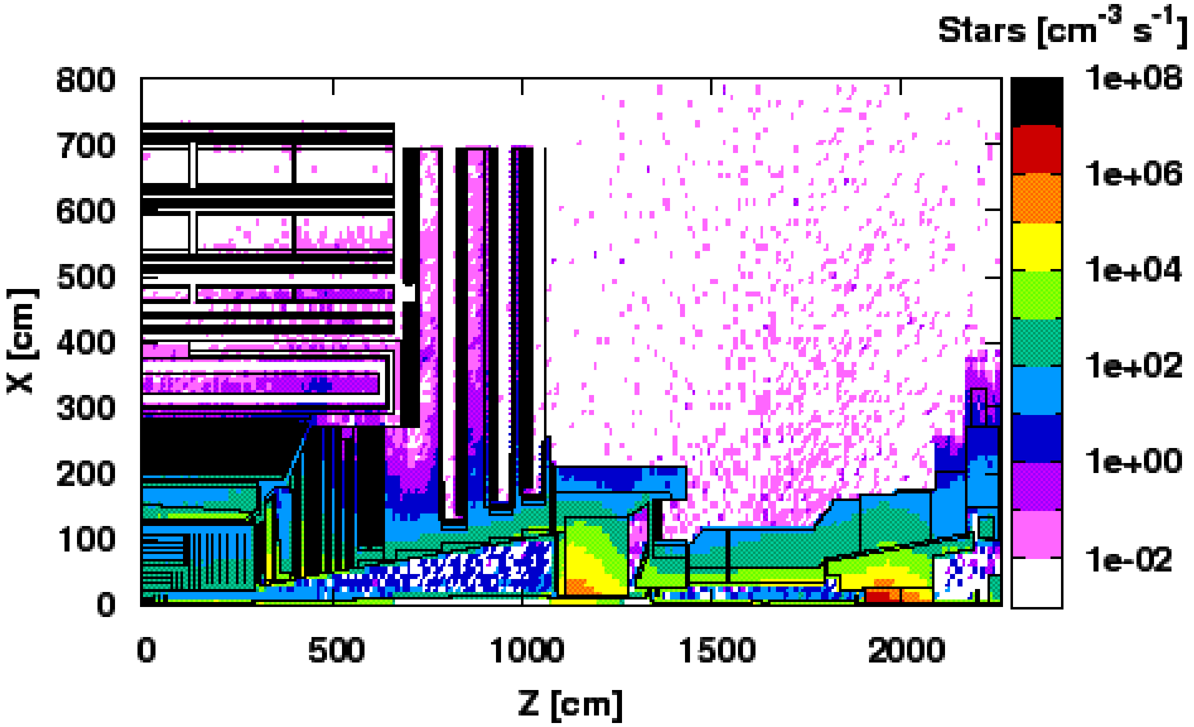

Photons
Flux [cm$^{-2}$ s$^{-1}$]
1200
1000
800
600
400
200
0
Y [cm]
0
500
1000
1500
2000
2500
Z [cm]
1e+10
1e+08
1e+06
1e+04
1e+02
1e+00

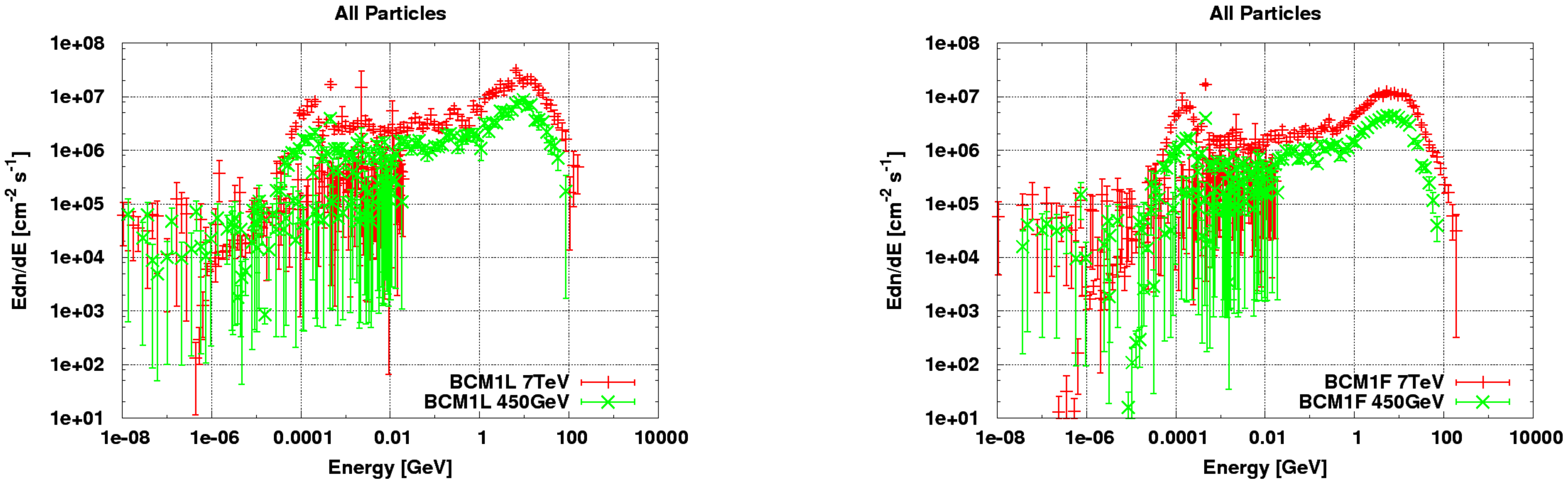
(a)


e$^{+}$ e$^{-}$
Flux [cm$^{-2}$ s$^{-1}$]
1200
1000
800
600
400
200
0
Y [cm]
0
500
1000
1500
2000
2500
Z [cm]
1e+10
1e+08
1e+06
1e+04
1e+02
1e+00

(b)


Dose-rate [Gy s$^{-1}$]
800
700
600
500
400
300
200
100
0
X [cm]
0
500
1000
1500
2000
Z [cm]
1e-02
1e-04
1e-06
1e-08
1e-10
1e-12


Stars [cm$^{-3}$ s$^{-1}$]
800
700
600
500
400
300
200
100
0
X [cm]
0
500
1000
1500
2000
Z [cm]
1e+08
1e+06
1e+04
1e+02
1e+00
1e-02

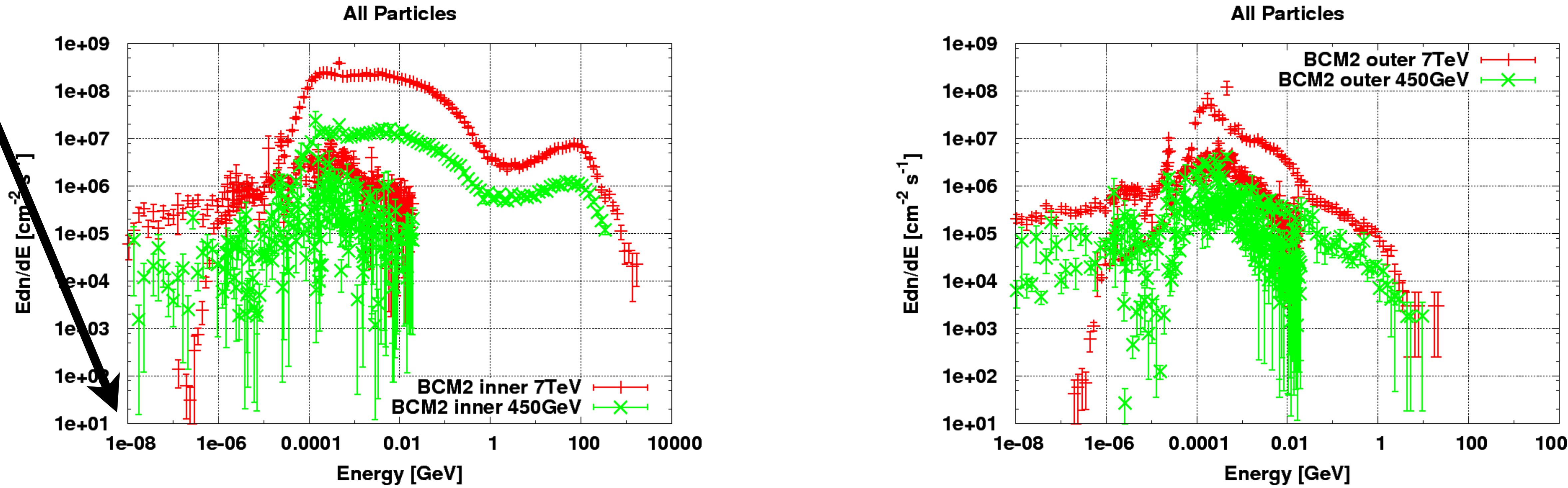


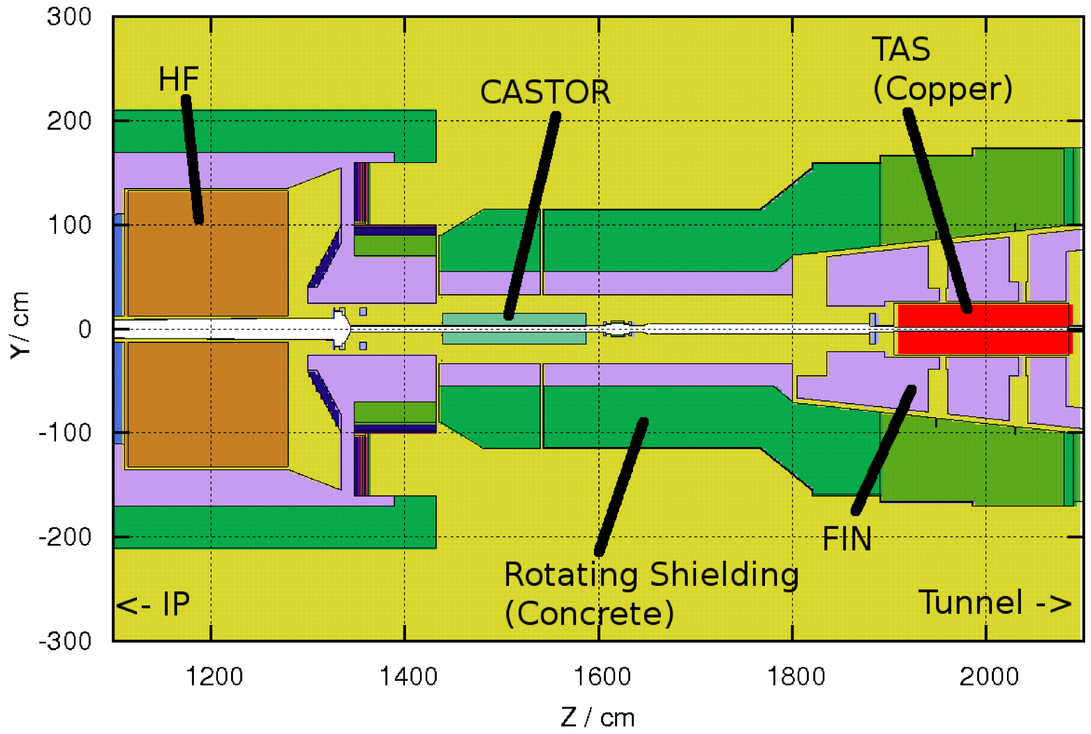
spectra will change with location ...

(a) (b)

(oops ... forgot about thermal neutrons)

don’t blindly trust the simulation - especially energy cutoffs





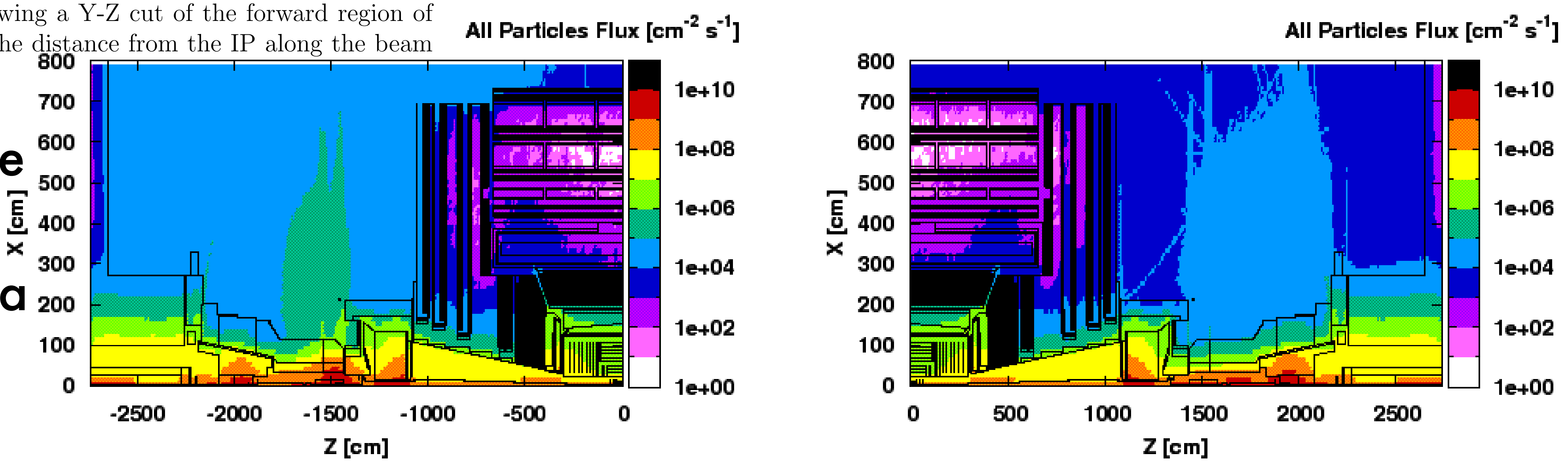
| End | Energy deposition 7 TeV Beam[$\frac{GeV}{g\,s}$] | Dose-rate [$\frac{\mu Gy}{s}$] | Time to reach 500 Gy [LHC years (1 ×$10^7$ s)] |
|---|---|---|---|
| +Z (without CASTOR) | 2.45 | 0.393±0.05 | 127 |
| -Z (with CASTOR) | 28.9 | 4.63±0.17 | 10.8 |

Table 9.9: Energy deposition in a Silicon scoring volume to represent BCM2 readout electronics. All numbers refer to nominal luminosity, dose is given in GeV per gram per second of nominal luminosity and in Gray. The impact of CASTOR is roughly a factor of ten.

Lifetime electronics reduced by factor 10

Figure 9.42: Detail of the FLUKA geometry showing a Y-Z cut of the forward region of CMS. Relevant parts are indicated. Z indicates the distance from the IP along the beam axis, Y is the vertical axis.

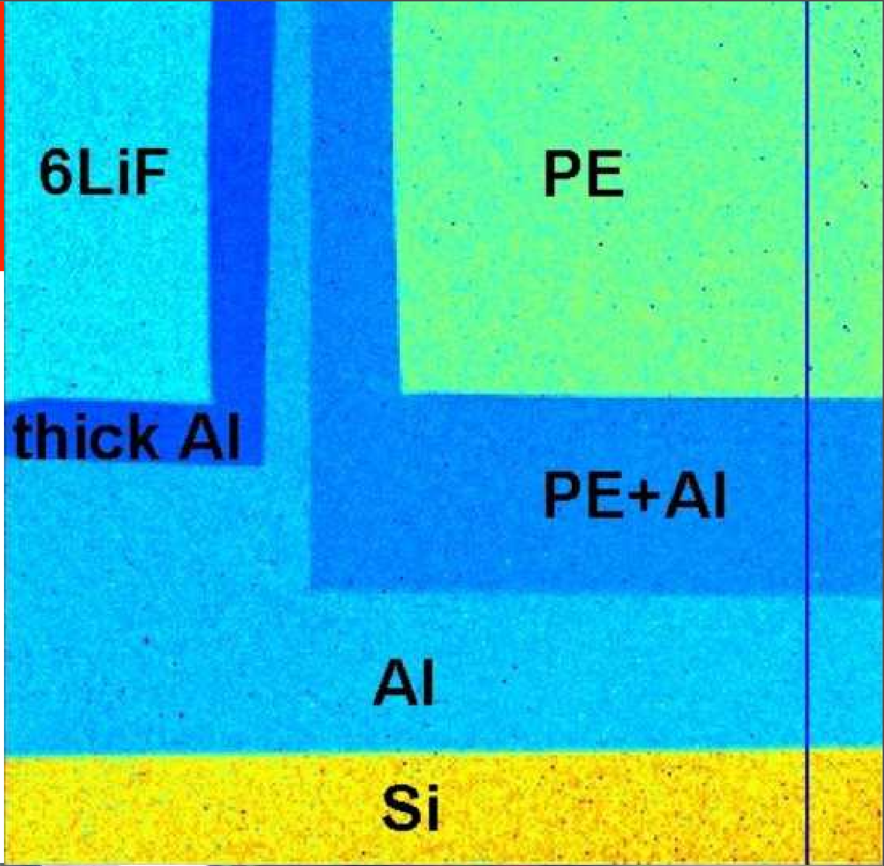
- Order and admixture of shielding critical
- Later verified by data
- (However thermal neutrons were forgotten)



(a) (b)

Figure 9.41: Full CMS detector simulation with 7 TeV beams showing the dose-rate over all the cavern. The impact of CASTOR, which is only installed at Z≈-1500 cm and R<30 cm is clearly visible in Figure 9.41(a). The particle flux at the +Z side is about 10 times less near the HF region.

# Semiconductor Detectors - "Neutron Camera"



- Medipix Neutron Cameras are pixelated silicon devices which have several conversion layers applied to have sensitivity to different particle types.
  - 6LiF and Polyethylene layers to convert thermal (1%) and fast neutrons (0.2%)
  - Total flux in agreement with simulation during beam times
  - From deposit shapes, can "see" the particle type

| Particle | Measured Flux $\left[\frac{particles}{cm^2\ s} / \frac{10^{30}}{cm^2\ s}\right]$ | Simulated Flux (7 TeV) $\left[\frac{particles}{cm^2\ s} / \frac{10^{30}}{cm^2\ s}\right]$ | $\frac{\text{Measured Flux}}{\text{Simulated Flux}}$ [%] |
|---|---|---|---|
| neutrons (< 100 keV) | 0.11 | 0.1017(14) | 108 |
| neutrons (100 keV - 20 MeV) | 0.068 | 0.0659(07) | 103 |
| neutrons (> 20 MeV) | - | 0.0181(03) | - |
| neutrons (all without neutrons > 20 MeV) | 0.178 | 0.1858(12) | 96 |
| charged hadrons | - | 0.000378(44) | - |
| electron | 0.0021 | 0.0023(01) | 91 |
| photon | 0.14 | 0.1354(19) | 103 |
| all (without neutrons > 20 MeV) | 0.32 | 0.3240(23) | 99 |

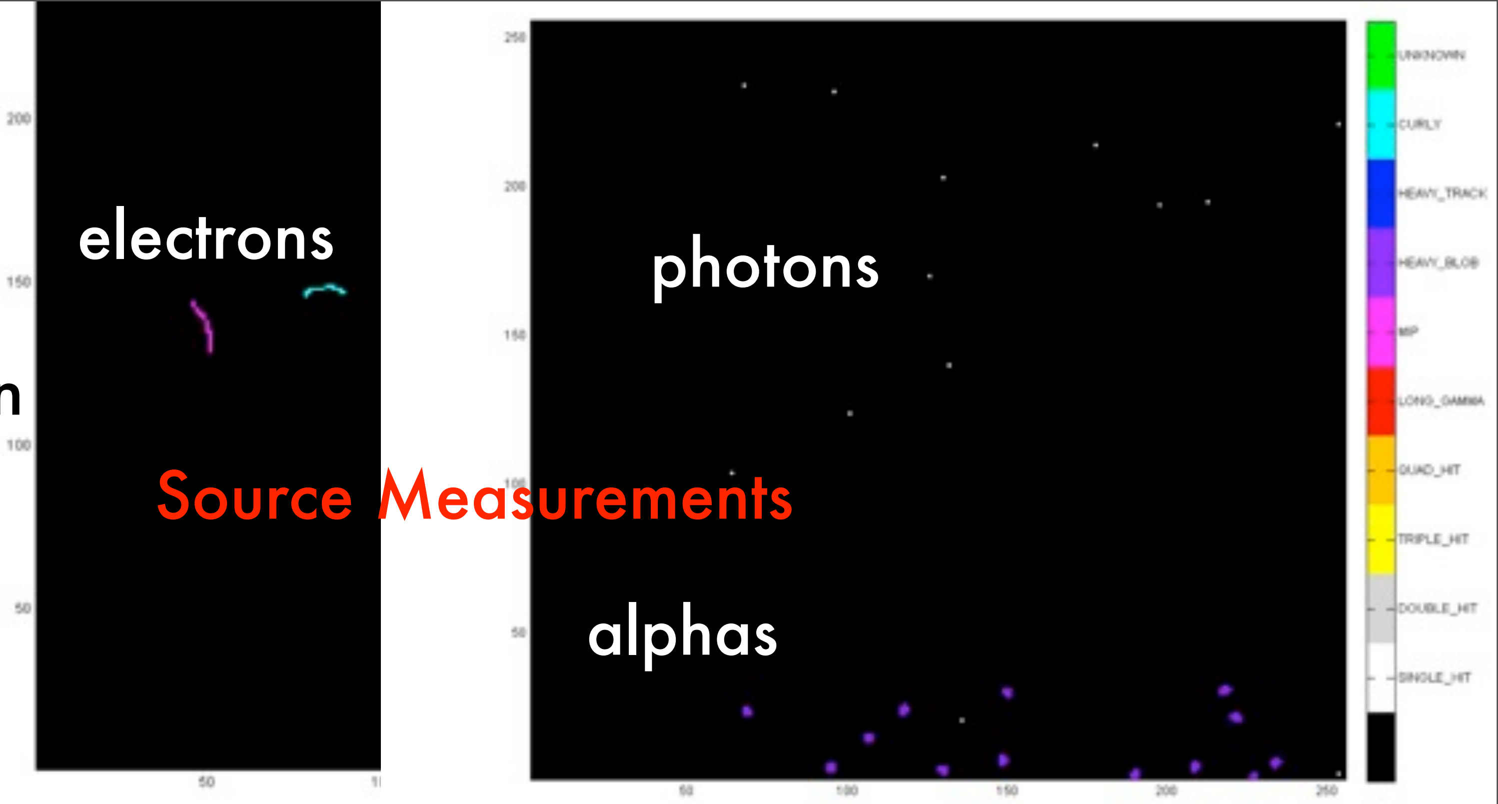
**Table 5.** Comparison of particle fluxes as measured with the Medipix detector inside the CMS cavern with FLUKA simulations.

- Detectors developed by IAEP Prague
- D. Pfeiffer et al., JINST 6 (2011) P08005

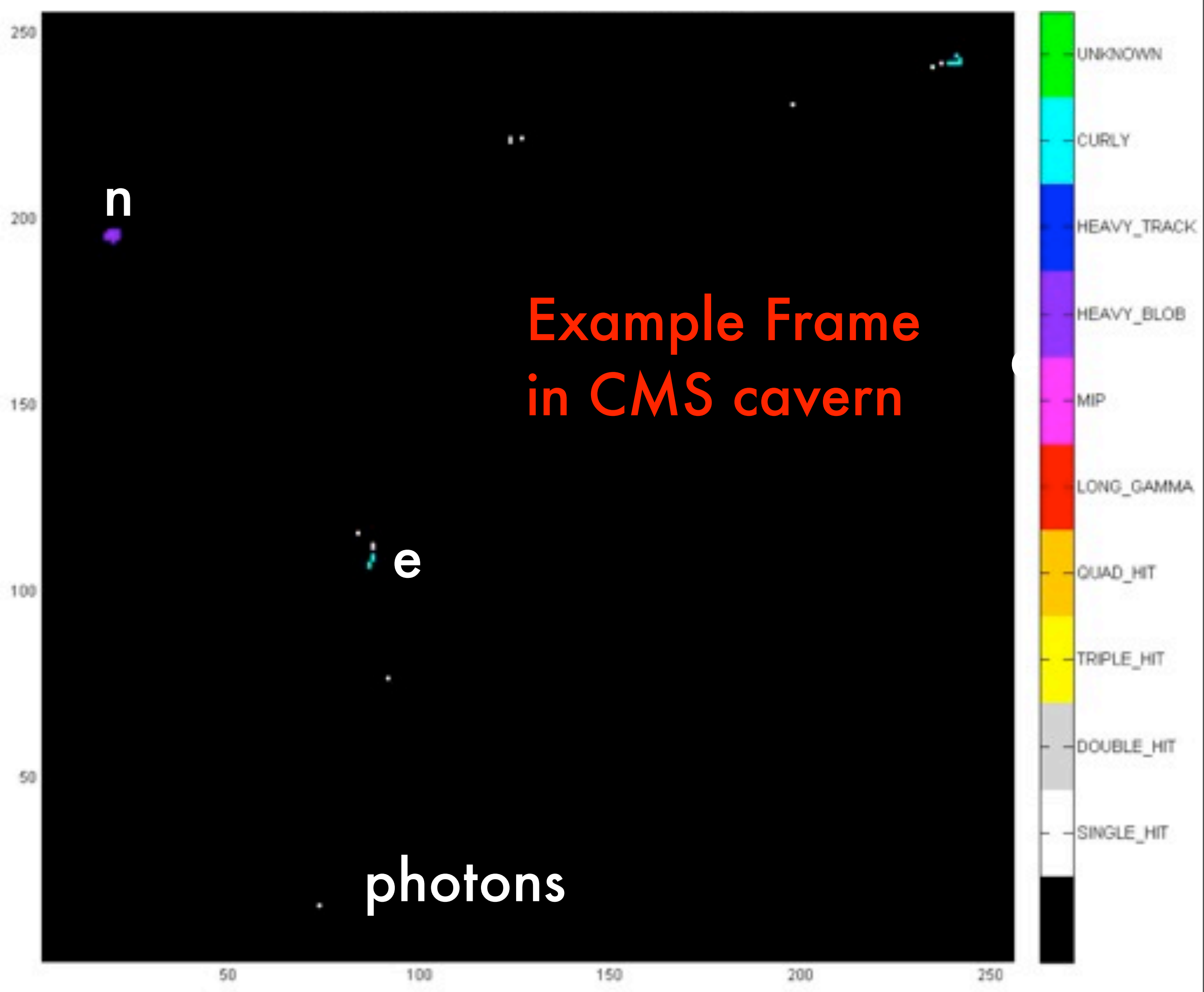
# Neutron Identification in the CMS Cavern

- Neutrons are a major cause of radiation damage and single event upsets
- Single event upsets: >10-20 MeV
- Important to understand the flux within the CMS cavern
- Several pieces of instrumentation installed to do this:
    - LHC-type RADMON
    - Medipix Neutron Cameras
    - Proportional Counters
    - Passive Dosimetry

- From the proportional counters, distribution is described, but magnitude low by factor 2-3



Source Measurements



Example Frame in CMS cavern

# Caveat Emptor

- About to make some suggestions ...

- ... without necessarily understanding the problem ...

- ... based upon a naive view before todays talks ...

- Maybe much of this has already been done ...

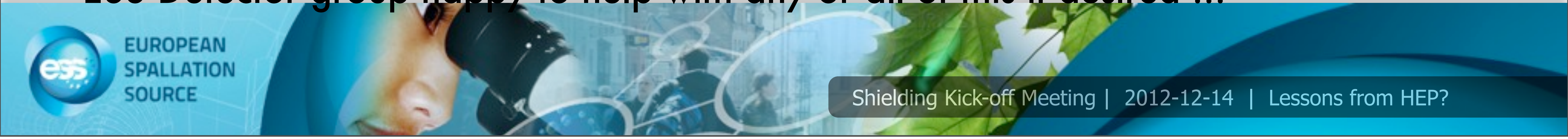
# Some Naive Ideas ...

- Triple approach to the problem - understand it first:
  - (What?) What problems are you seeing in the data? What are your detectors sensitive to?
  - (Data is golden) Add as much (simple)data as possible in terms of maps of fluxes, particle species, energies
  - (Expectation ...) Simulate what you expect to see. Qualify simulation.
- And compare the above 3 ... and iterate ...
- Detectors:
  - Is the sensitivity of detectors to all relevant particle types and energies known and measured?
  - Differences between detector types and what you see is golden information
- Data:
  - Use all existing data you can get your hands on ...
  - In terms of list of possible diagnostic information - see next slide ...
- Simulation:
  - Simulate 1 or 2 instruments in detail
  - Preferably with 2 competitive codes (eg GEANT/FLUKA/MCNP/MARS)
- Remember there may be several problems, not 1 big one ...

# Diagnostic Data

- A list of detector information that may be useful to try ...
  - Flux map from simple handheld h10 electronic domimeters
  - Flux map from simple electronic handheld neutron dosimeters
  - Hand-held gamma spectrometers - what gammas do you see? Where can they come from.
  - Activation map of activated material along guideline - it tells you what material is being activated
  - Flux map of fast neutrons (neutron camera, liquid +plastic scintillator, diamond, He-4)
  - SEU in RAM within instruments, and inside guide shielding? Tells you if there is much neutrons >10-20 MeV
  - Determine particle species where possible (a la Neutron Camera)
  - Map and directionality of muons - indicative of hadronic showers along the guides? Look for loss locations. (2-3 layers plastic scintillator in coincidence, separated by lead)
  - Charged particle concentrations - indicative of unshielded particle showers. (2-3 layers plastic scintillator in coincidence)
  - Try different detector technologies at the instrument locations - do features change?
  - Timing features - fit and see if helpful

  - ESS Detector group happy to help with any or all of this if desired ...



# thank you and any questions ... ?

# Activation

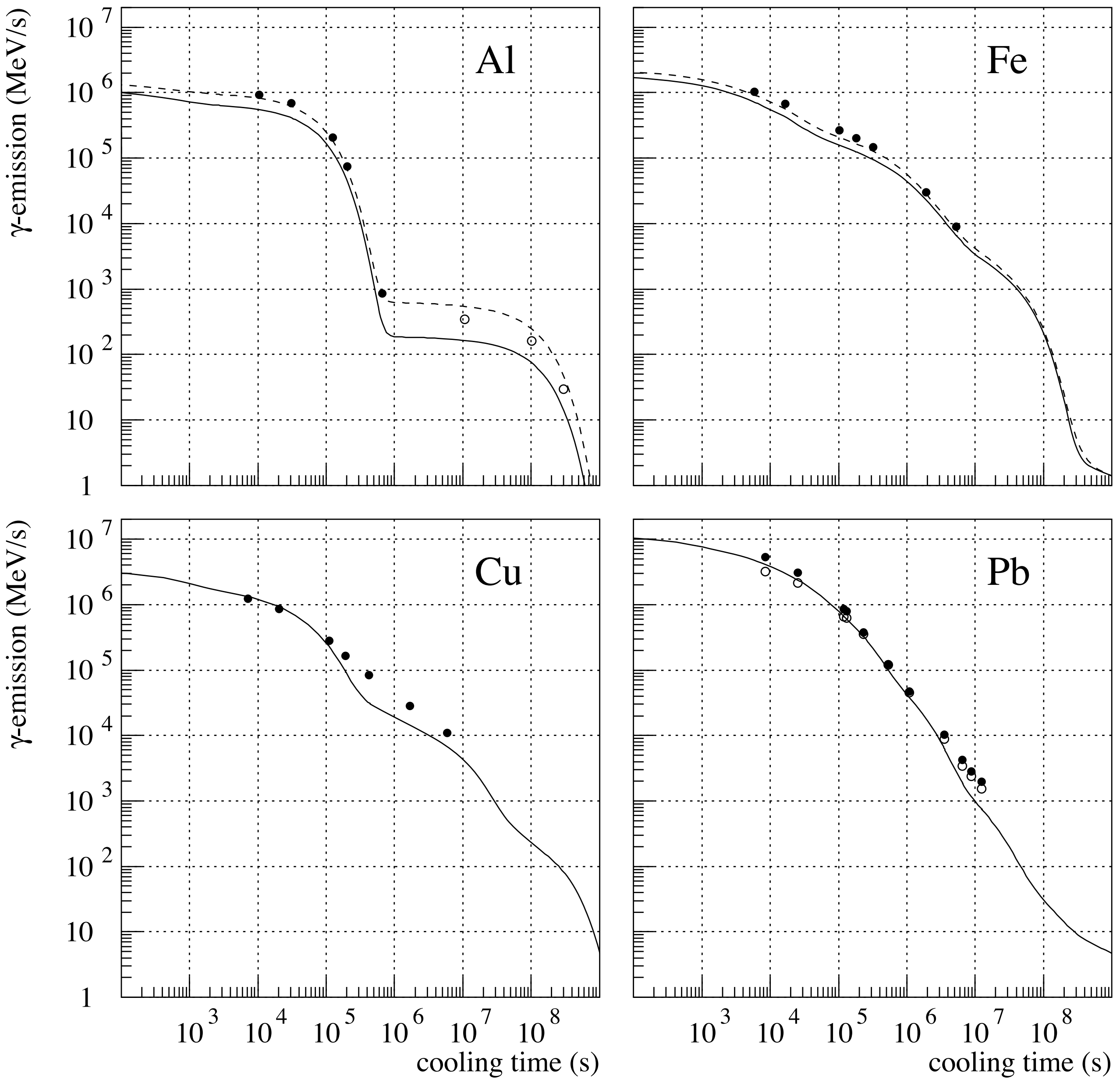
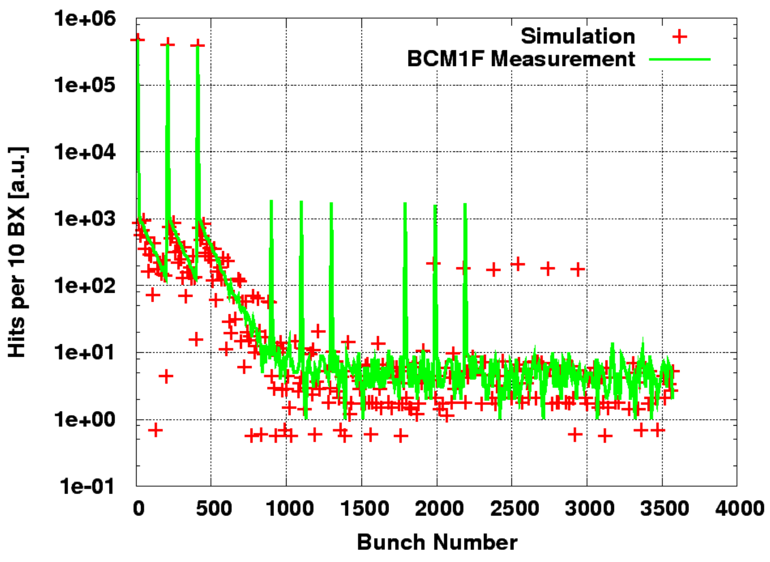
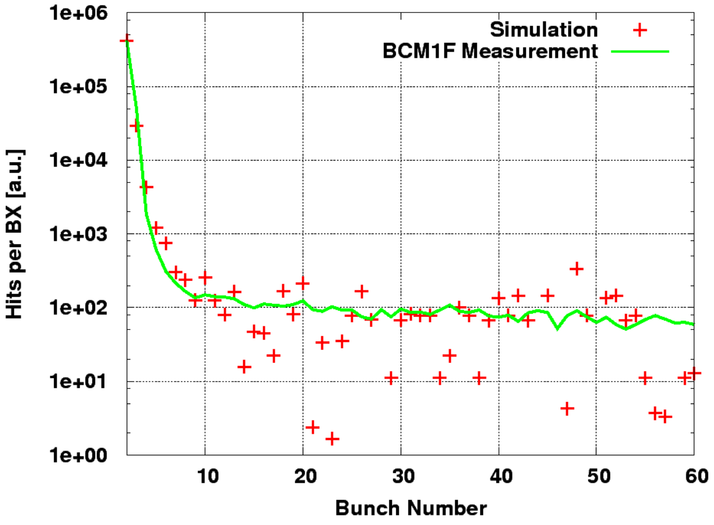


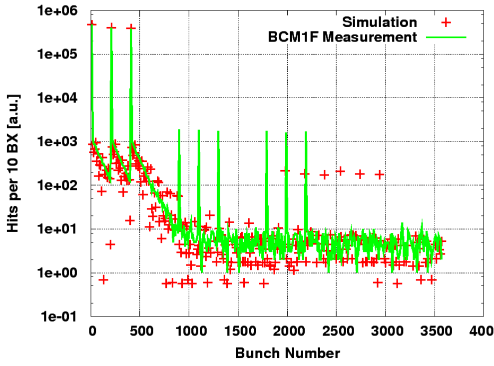
Figure 4: Comparison of calculated (lines) and experimental (dots) total gamma energy emissions from the samples. The solid line shows the FLUKA residual nuclide calculation and the dashed the same complemented with experimental cross section data. The open dots in the Al-comparison show the dose due to $Na^{22}$ calculated from the activity of the last measurement (solid dots). In the Al, Fe and Cu plots the experimental values are based on the photo-peak information. In the Pb-plot the solid dots show the energy from integrating the whole spectrum while the open dots show the dose derived from the photo-peaks found in the spectrum [6].

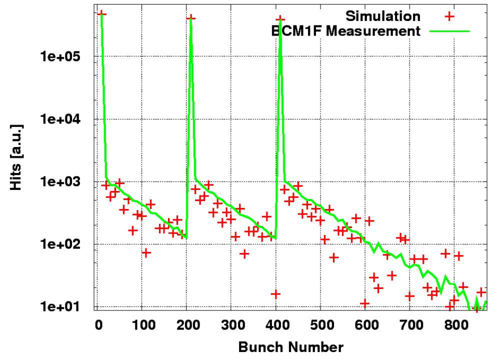
# Timing

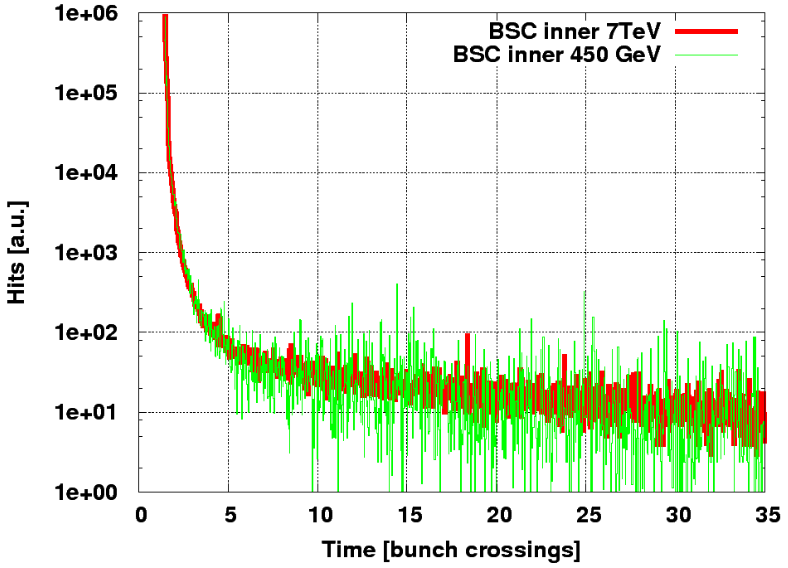

Simulation
BCM1F Measurement
Hits per 10 BX [a.u.]
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
1e-01
0
500
1000
1500
2000
2500
3000
3500
4000
Bunch Number

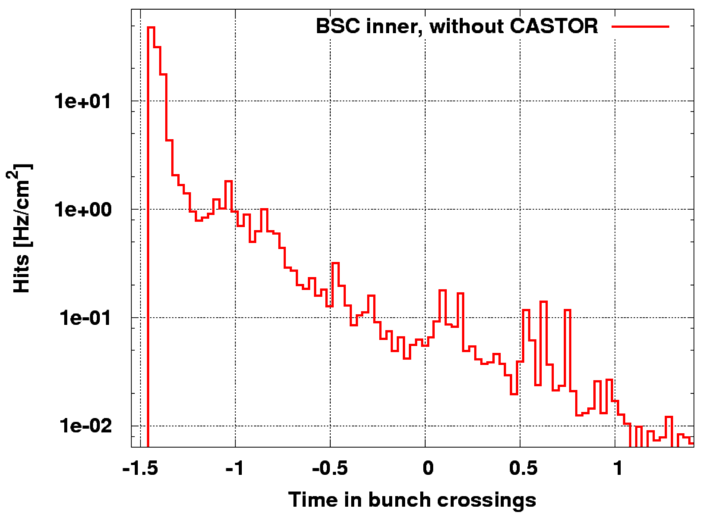
(b)

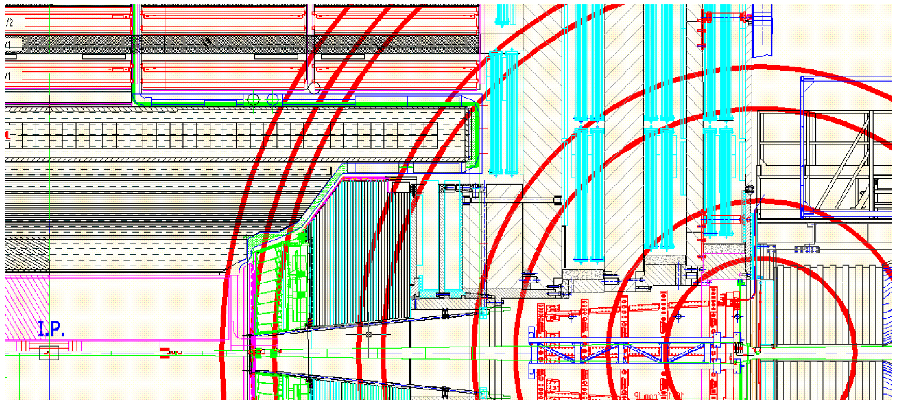

Simulation
BCM1F Measurement
Hits per BX [a.u.]
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
10
20
30
40
50
60
Bunch Number


Simulation
BCM1F Measurement
Hits per 10 BX [a.u.]
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
1e-01
0
500
1000
1500
2000
2500
3000
3500
4000
Bunch Number


Simulation
BCM1F Measurement
Hits [a.u.]
1e+05
1e+04
1e+03
1e+02
1e+01
0
100
200
300
400
500
600
700
800
Bunch Number

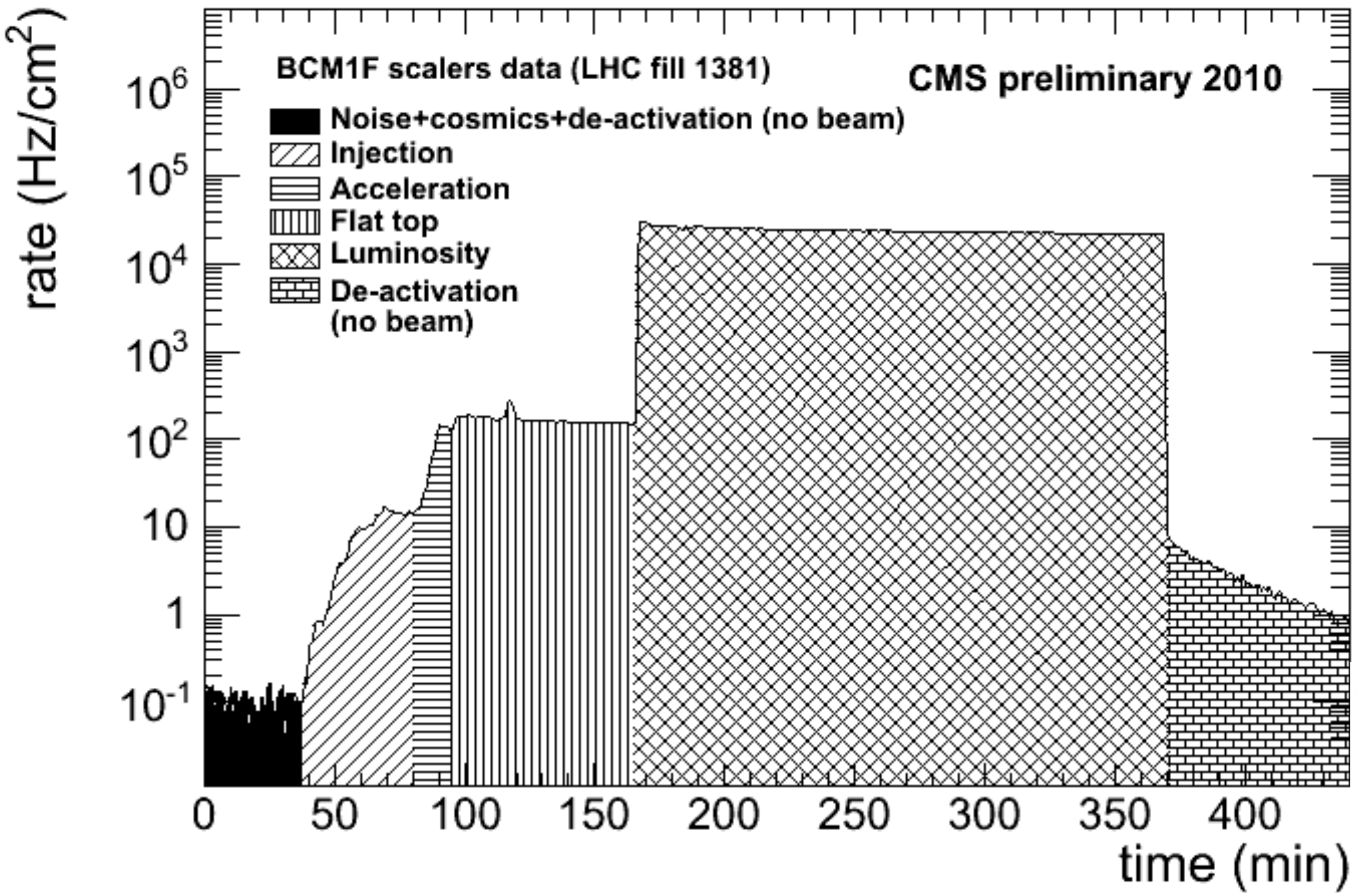

BSC inner 7TeV
BSC inner 450 GeV
Hits [a.u.]
1e+06
1e+05
1e+04
1e+03
1e+02
1e+01
1e+00
0
5
10
15
20
25
30
35
Time [bunch crossings]


BSC inner, without CASTOR
Hits [Hz/cm²]
1e+01
1e+00
1e-01
1e-02
-1.5
-1
-0.5
0
0.5
1
Time in bunch crossings

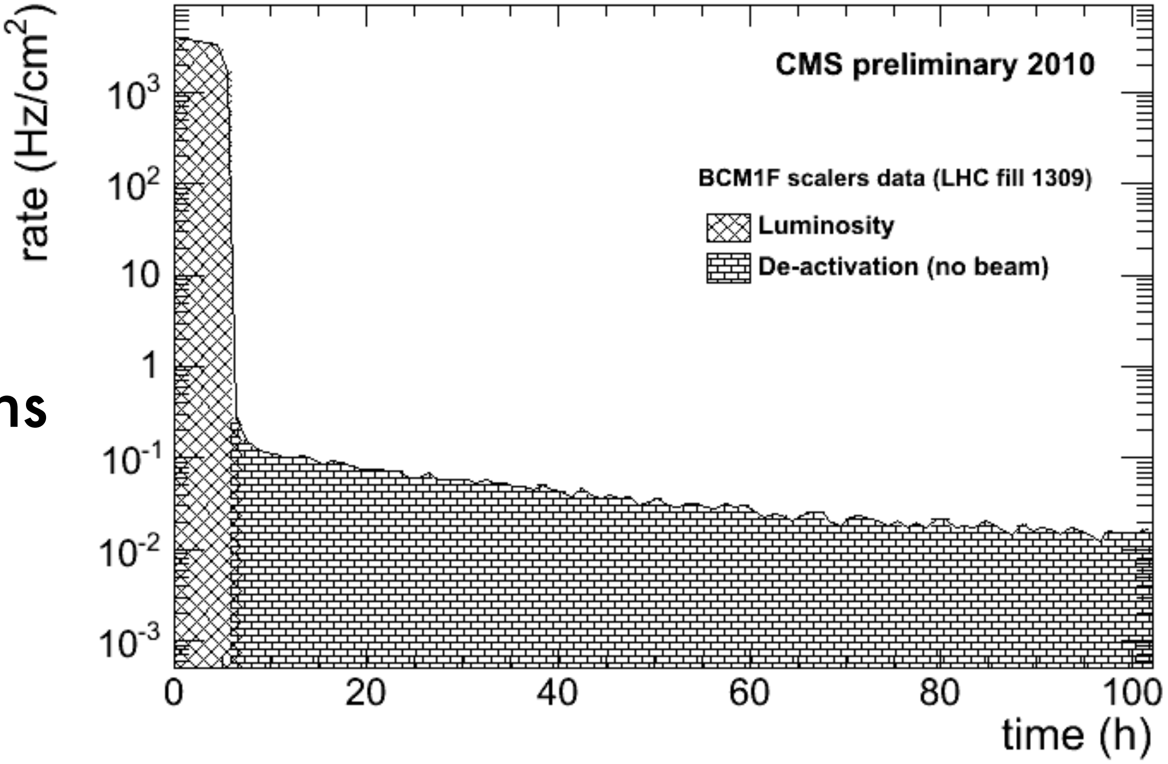

I.P.

(b)

# Timing



- Diamond detector



- Possible to identify timescales ns thru weeks ...
- ... and diagnose activated materials and reflections