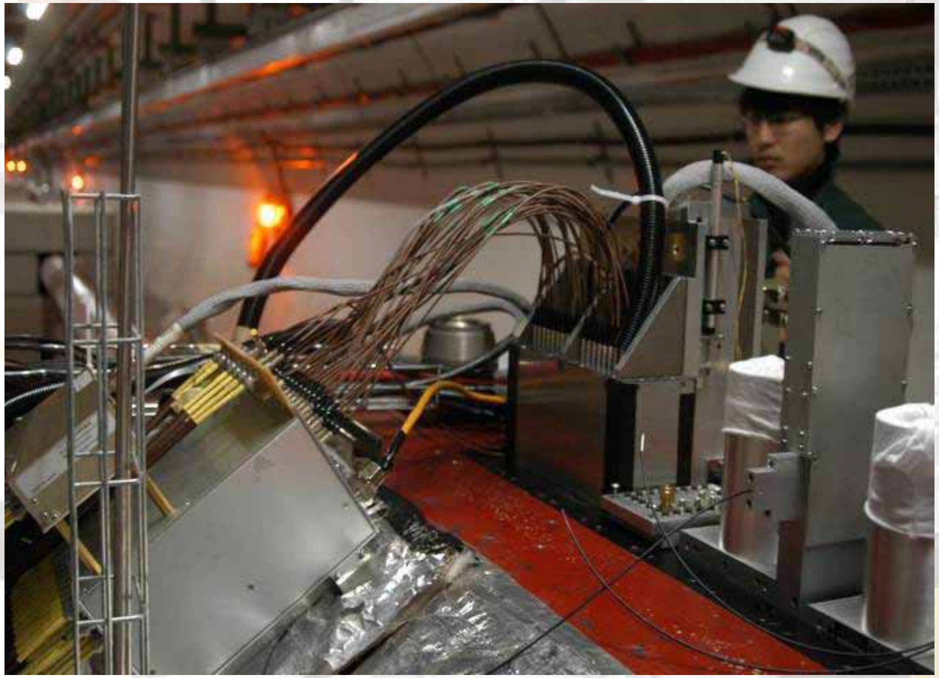
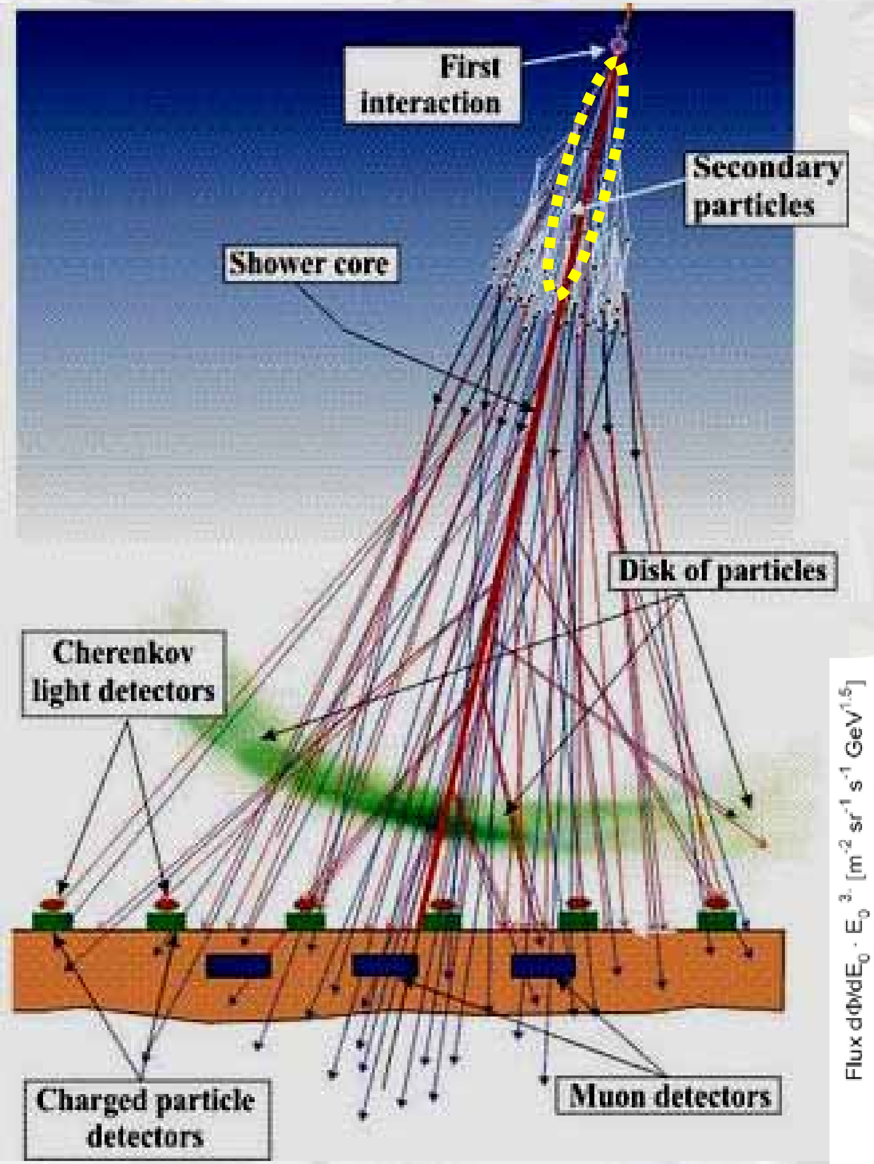
LHCf Status Report

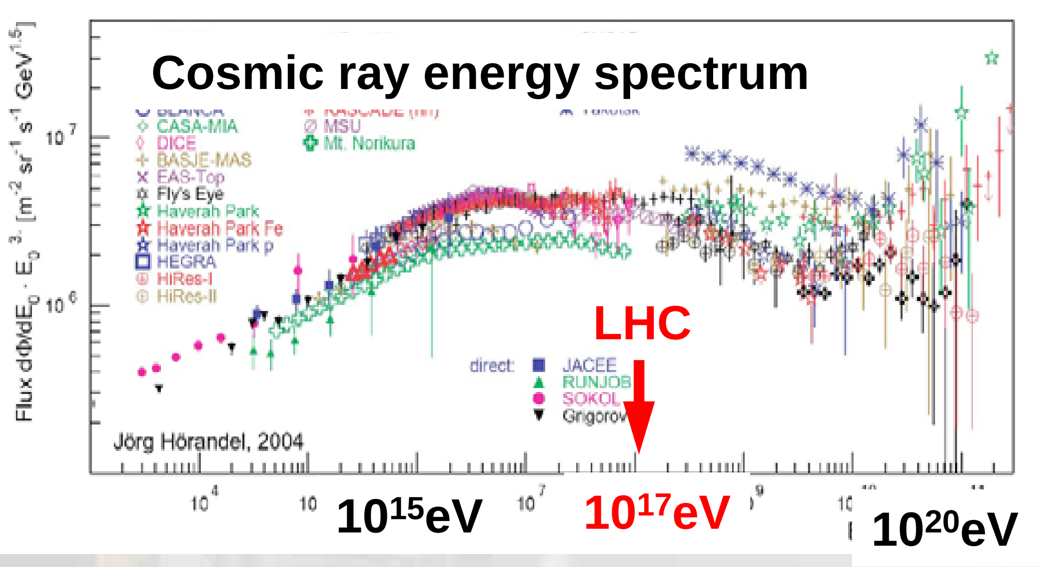


Yoshitaka Itow
Solar-Terrestrial Environment Laboratory
Nagoya University
for the LHCf collaboration

LHCf physics motivation



- Verify cosmic ray interaction models at LHC energy ($E_{CR}=10^{17}$eV)
- Precise measurement of π^0,γ ,n at very forward, which is relevant to air shower development of UHECR.



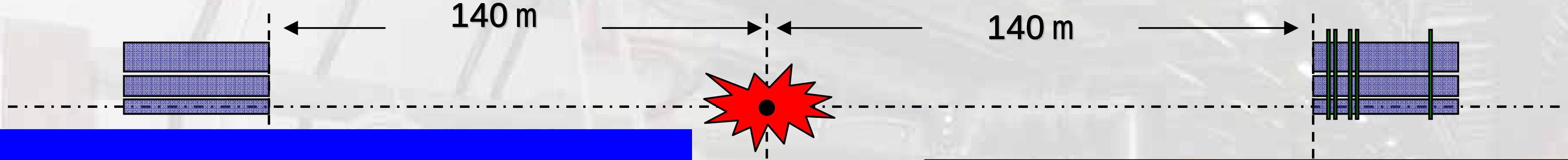
LHCf: location and detector layout

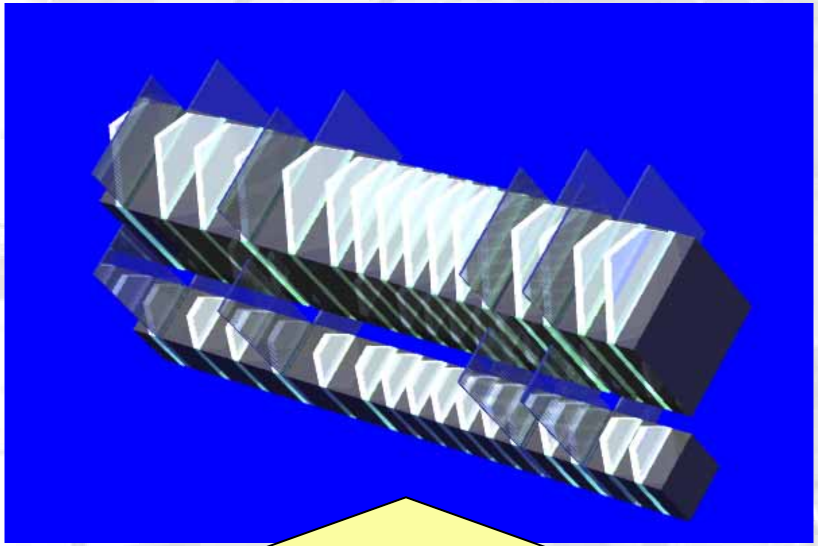
Detector I
Tungsten
Scintillator
Scintillating fibers

INTERACTION POINT

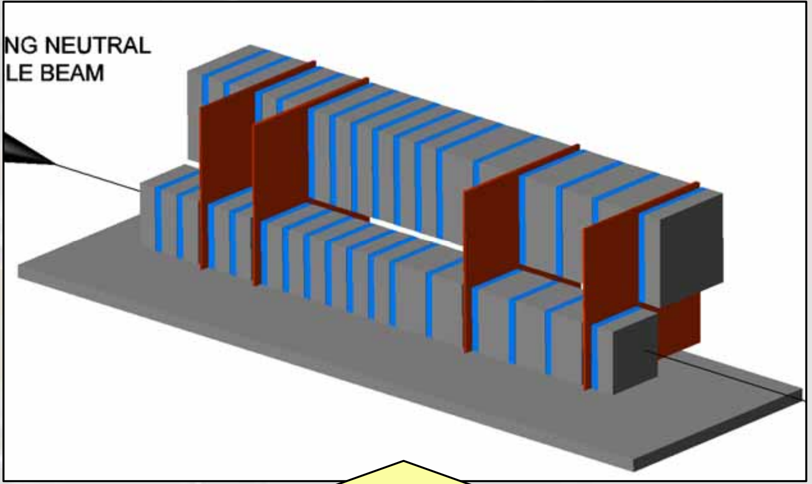
IP1 (ATLAS)

Detector II
Tungsten
Scintillator
Silicon μstrips





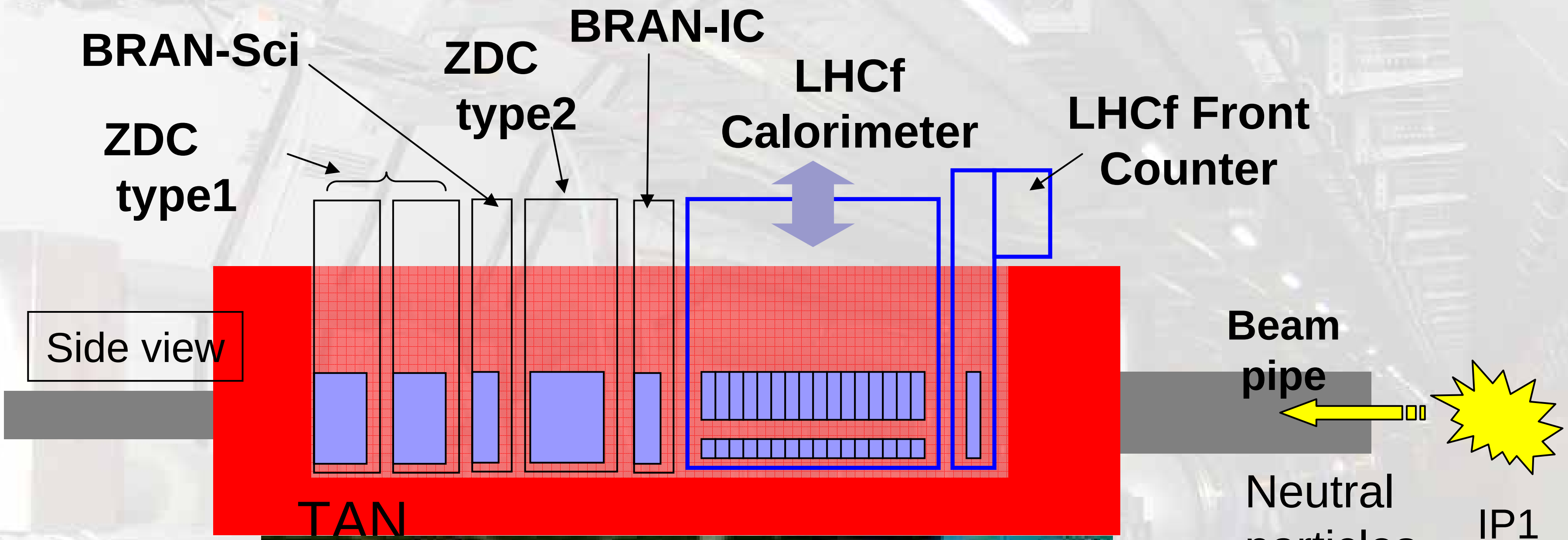
$44X_0$,
$1.6\ \lambda_{int}$



Arm#1 Detector
20mmx20mm+40mmx40mm
4 SciFi tracking layers

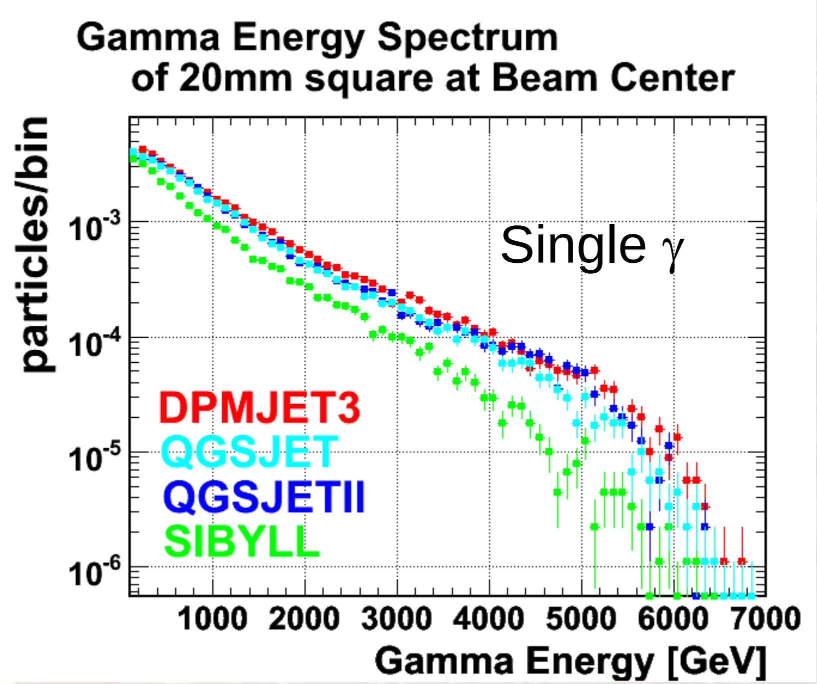
Arm#2 Detector
25mmx25mm+32mmx32mm
4 Silicon strip tracking layers

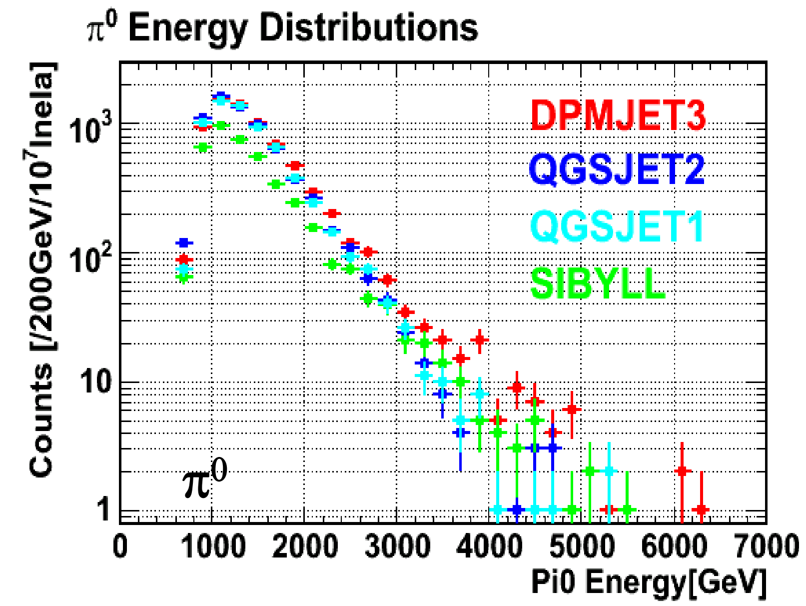
Current setup in IP1-TAN (side view)

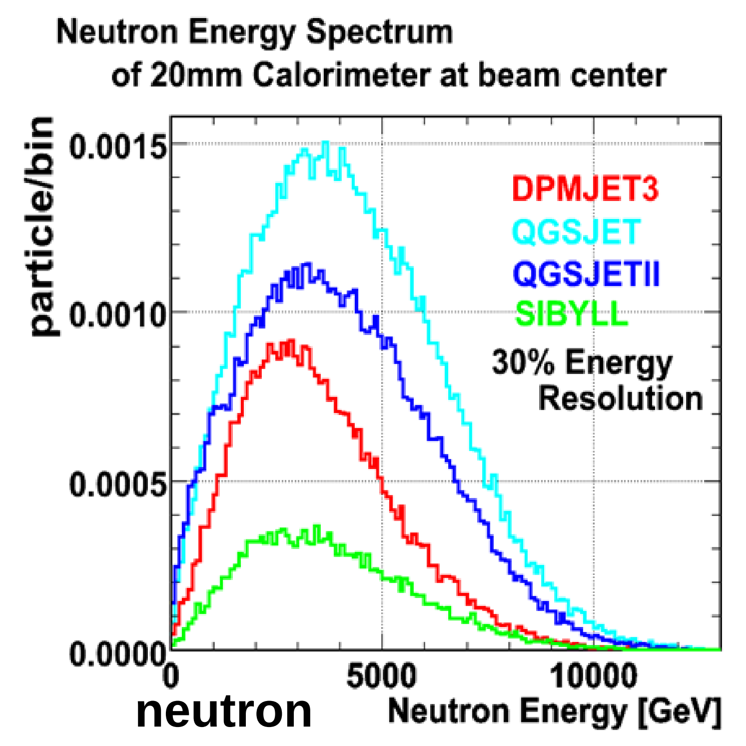


Model dependence of forward energy spectra

- Discriminate a good model
- Input data for model building

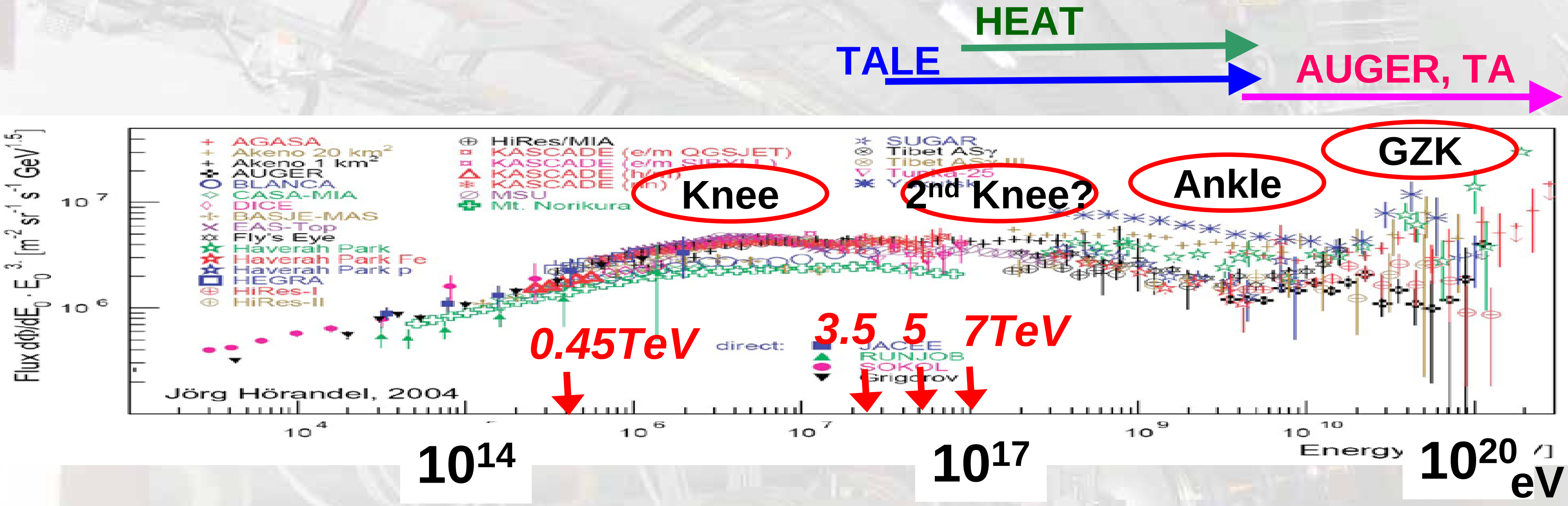






Various distributions at 7TeV

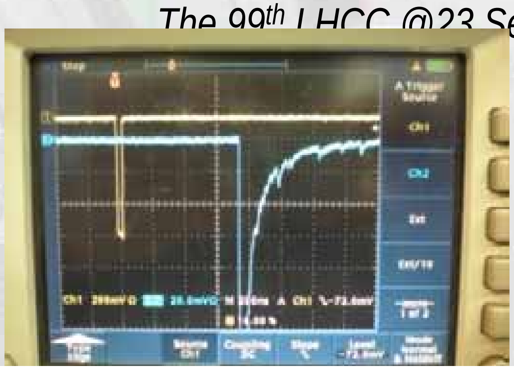
Why interest in data at different energies ?



- Energy evolution is important for extrapolation to much higher energy and inputs for tuning of hadron models.
- Closer reference to the “knee” regions, another important feature of CR.

A "silver lining" for cosmic ray physics

Status in 2008-2009

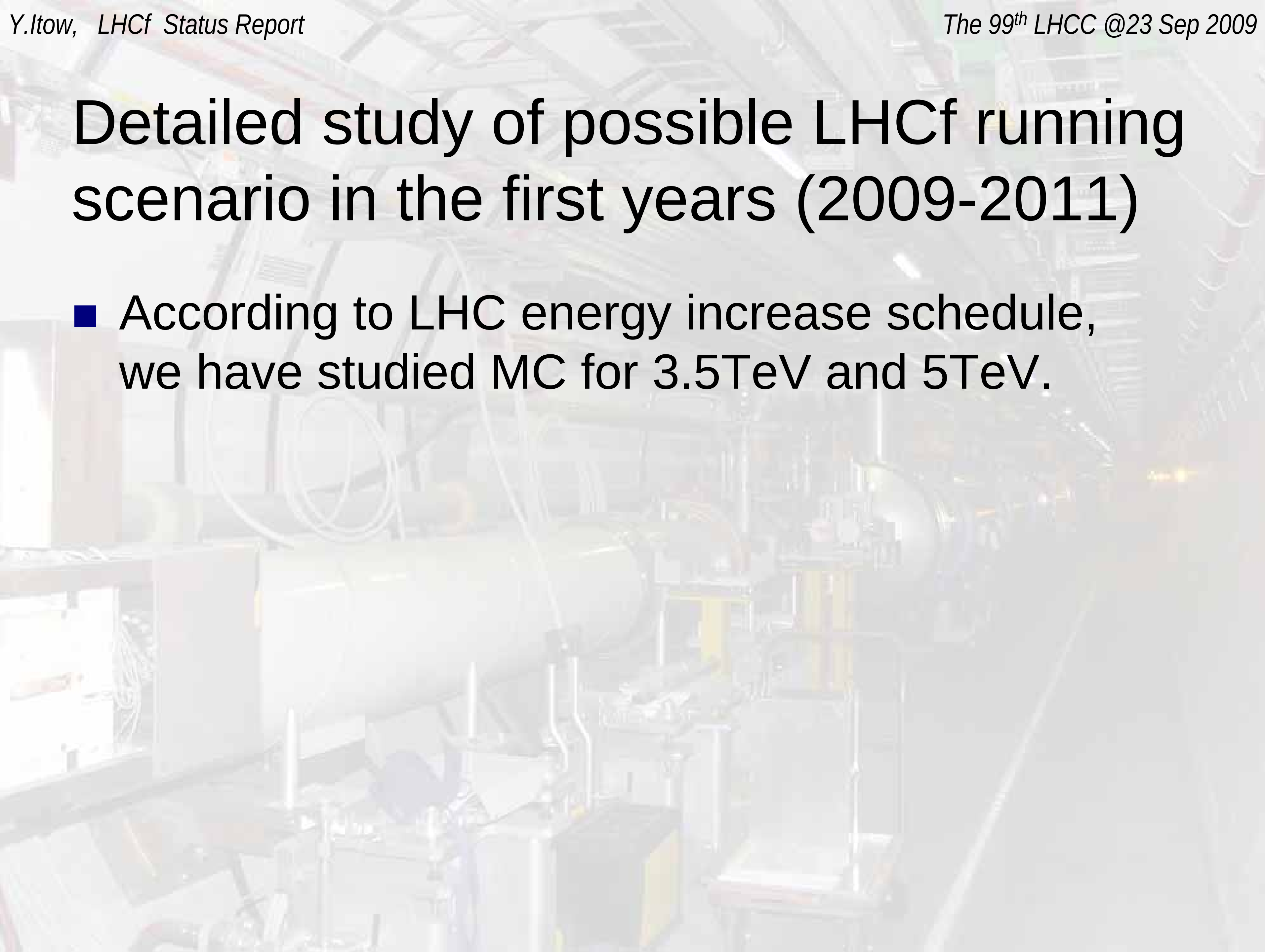


The first signal on Sep10th,2008

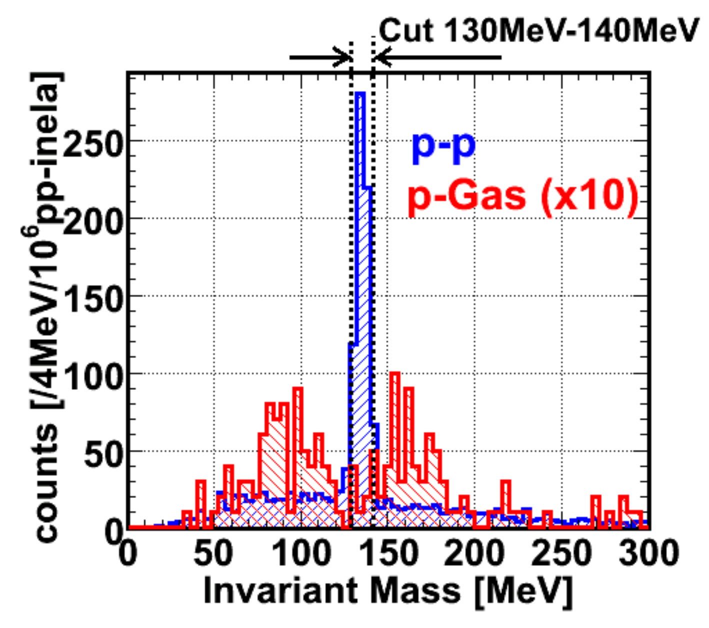
- Since 2008 the detectors have been installed and fully commissioned. We are ready to take data since Apr 2008.
- Many improvement works and software study are done
  - DAQ, calibration system, slow control, dosimeter, etc…
  - Prepare analysis tools, detail MC studies, etc..
  - Remote handling system (Not only for LHCf).
- According to LHC energy increase schedule, we have studied the LHCf physics potentials, radiation dose and the influence of LHCf on the BRAN response at reduced center of energy by our custom MC code “EPICS”.
  - Send memo to LHCC(Nov,08) for 5TeV run and revisit for 7TeV run.
  - Send a short report to LHCC(Aug,09) for lower energy data taking.
- Based on these studies we have studied detailed running scenario in “the first years” with discussion of relevant people, LHC, BRAN, ATLAS, LTEX, LPC…..

Detailed study of possible LHCf running scenario in the first years (2009-2011)

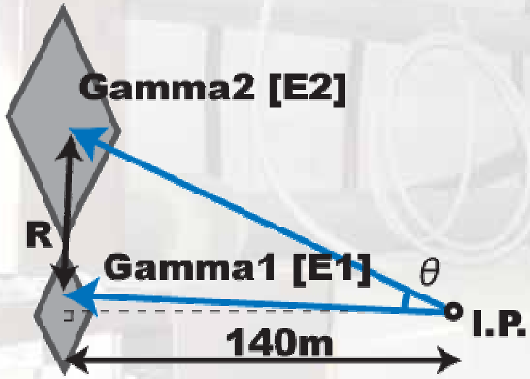
- According to LHC energy increase schedule, we have studied MC for 3.5TeV and 5TeV.



The basic sample ; π^0



- A clean sample against beam-gas background.
- Energy scale can be checked by data itself



- ~10^4 π^0 for typical 1 run
  - ☐ at 3 detector positions(N, M, L)
  - ☐ with 2 different PMT HV (High, Low)
  - ☐ with 2 different trigger threshold
  - ☐ Several runs for systemic check (Scifi HV, etc.)

~ 36 runs

- π^0 is ~1/100 of single γ
  - ☐ pre-scaled single shower trigger
    + double shower (π^0) trigger for higher lumi.

Note: Max DAQ rate is 1kHz, single γ rate is also 1kHz@L=10^{29}

Expected dose,π^0,and γ yields

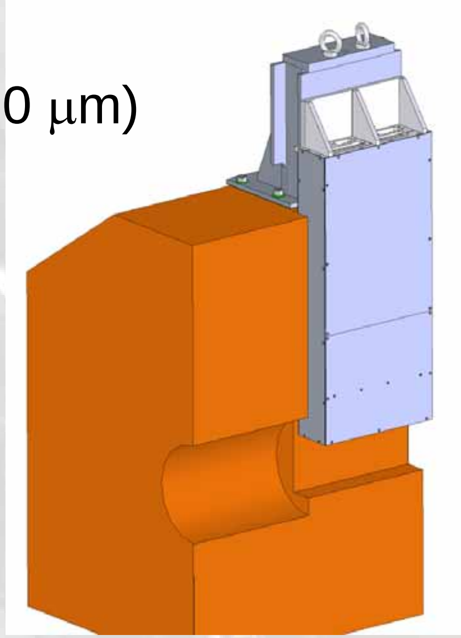
$L=10^{29}cm^{-2}s^{-1} = 0.0001nb^{-1}/s=0.36nb^{-1}/h$

E(TeV)	Dose rate		Intg Lumi. for dose	π^0 rate	Intg Lumi	
					π^0	γ
	Gy/h @$L=10^{29}$	Gy/ nb^{-1}	nb^{-1} for 100 Gy	π^0/sec @$L=10^{29}$	nb^{-1} for 10^4 π^0	nb^{-1} for 10^4 γ
0.45	0.00041	0.0011	88,000	------	------	0.77
3.5	0.19	0.53	190	2.0	0.5	0.0069
5	0.61	1.7	59	4.2	0.24	0.0028
7	1.5	4.2	23	7.0	0.14	0.0017

At the Arm1 calorimeter with nominal position, 100GeV threshold,
σ_{pp}= 100mb assumed, DAQ dead time not included
(Peak value in the detector for dose estimation)

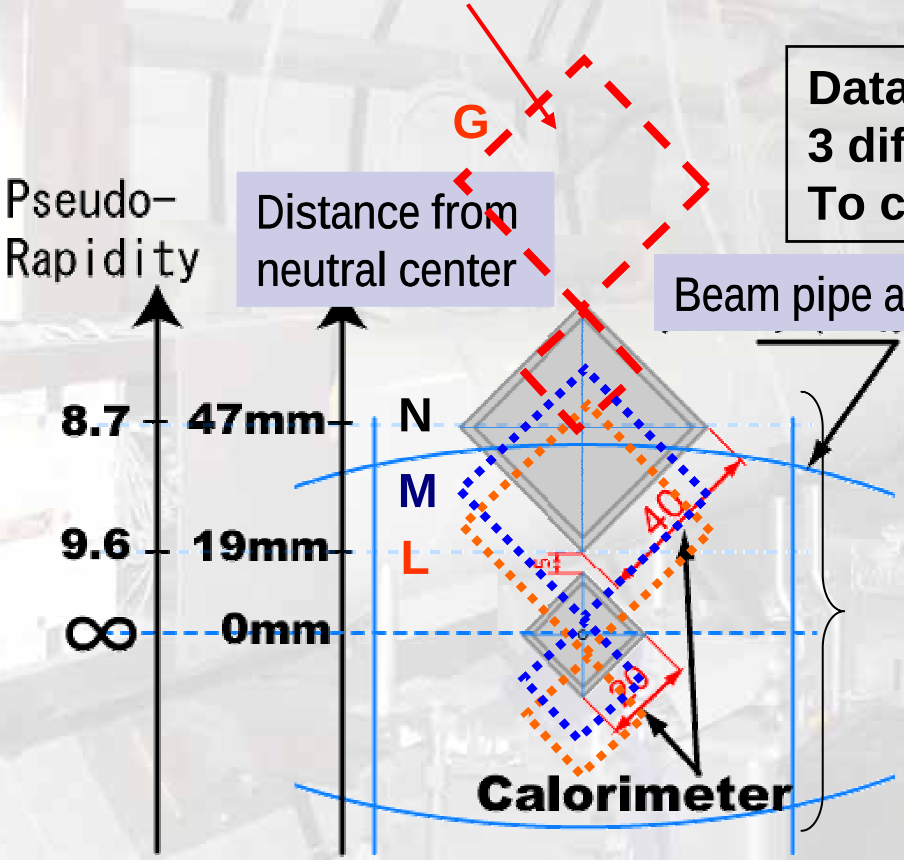
Detector vertical position

- Remotely changed by a manipulator(w/ accuracy 50 μm)



Garage position when beam tune
To prevent unnecessary dose
(10^{-3} of data taking mode)

Data taking mode
3 different position
To cover P_T gap

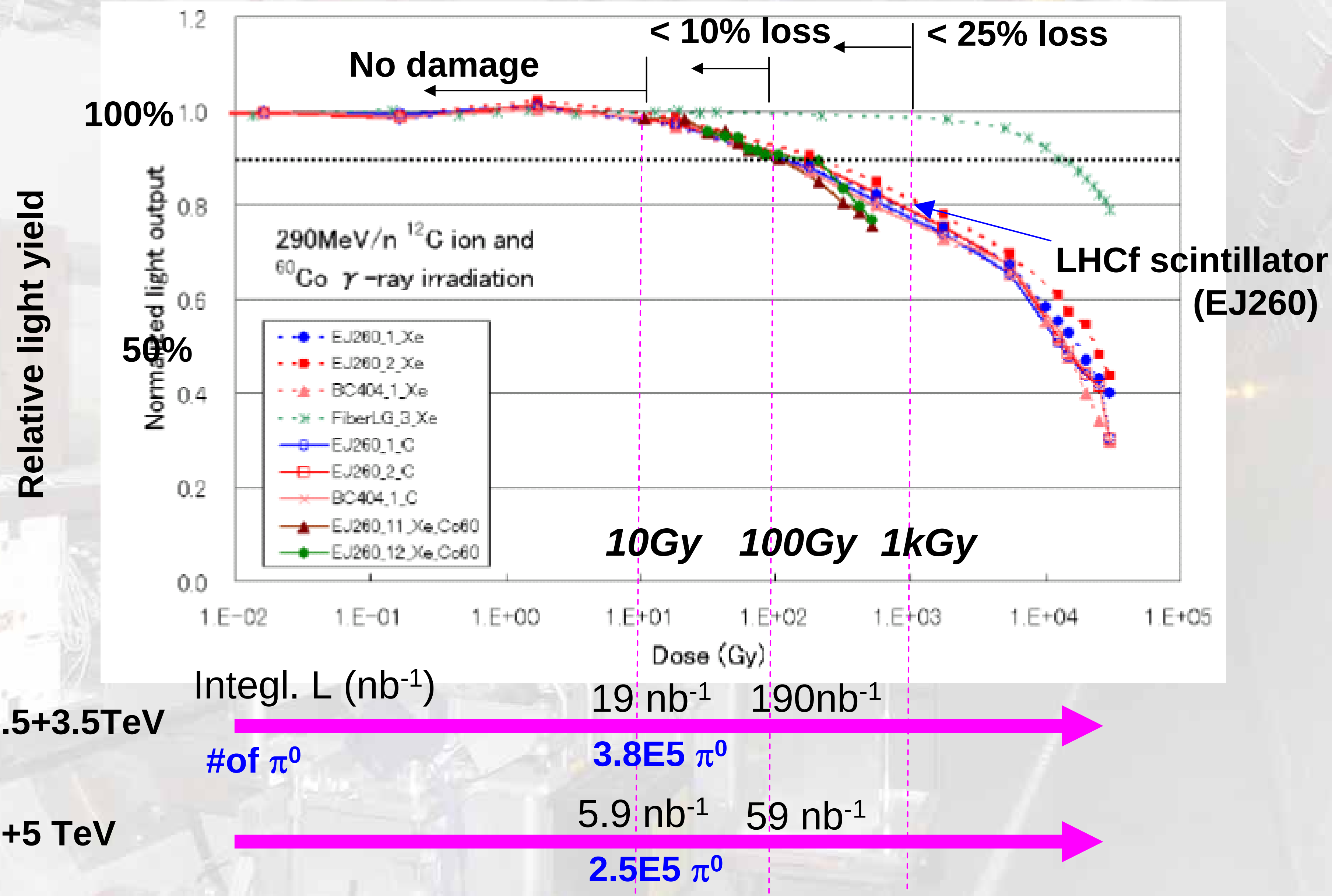


Vertical setting for minimum π^0 sample

	Y(mm)	# runs (10^4 π^0)	Integ L (nb^{-1})
N	0.0	~12	6
M	-16.6	~12	6(*)
L	-21.6	~12	6(*)

(*) tentative

Expected dose and degradation of plastic scintillators



No damage

< 10% loss

< 25% loss

100%

50%

Relative light yield

LHCf scintillator (EJ260)

10Gy

100Gy

1kGy

Integl. L (nb^{-1})

3.5+3.5TeV

19 nb^{-1}

190nb^{-1}

#of π^0

3.8E5 π^0

5+5 TeV

5.9 nb^{-1}

59 nb^{-1}

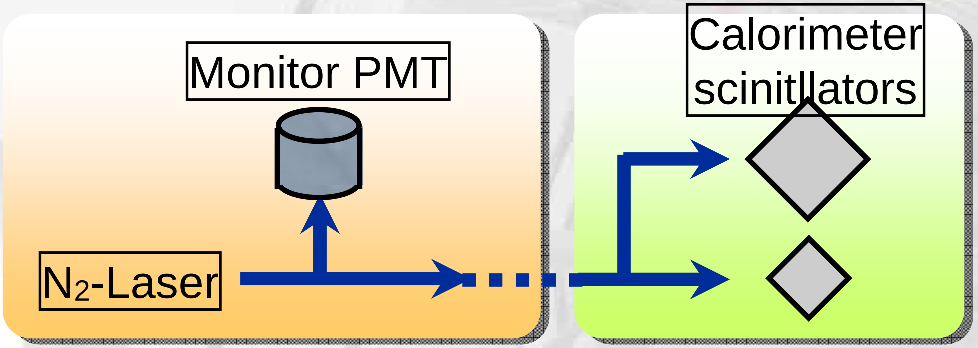
2.5E5 π^0

Possible running scenario in “the first years”

- During beam tuning, the LHCf detector is retracted to the “garage” position until stable beam operation (to prevent unnecessary dose)
- Dose<10Gy, LHCf will take “clean” minimum data sets with no degradation of scintillators.
- 10Gy < Dose < 1kGy (~20% loss), LHCf will extend data taking for higher statistics as much as possible until luminosity gets too high($L>\sim10^{31}cm^{-2}s^{-1}$)
  - To study various systematics (i.e. position dependence, etc..)
  - For advanced phyics targets (for ex. π^0/η ratio, etc.)
  - Dose and radiation damage will be monitored in-situ.

Realtime monitoring of radiation damage

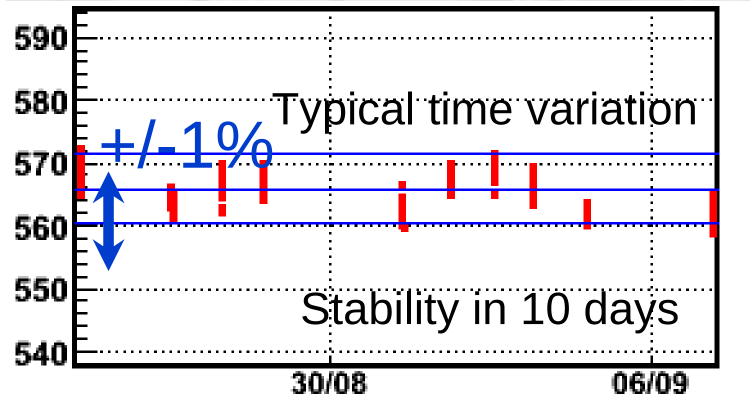
- Real time in-situ monitoring of scintillator response by N_2-laser



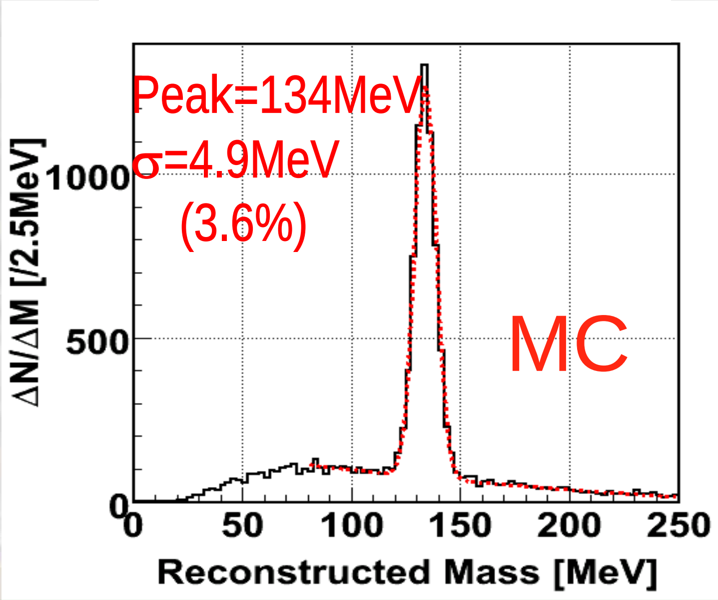
Monitor PMT

Calorimeter scintillators

N_2-Laser

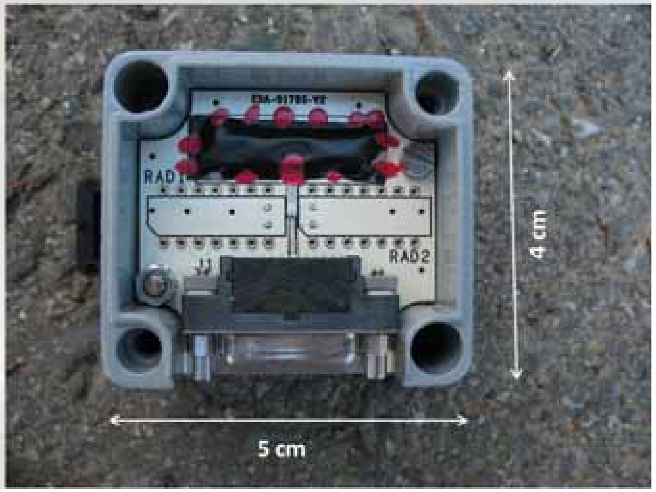


- Absolute energy calibration by π^0 mass peak



- RADMON dosimeter ver5

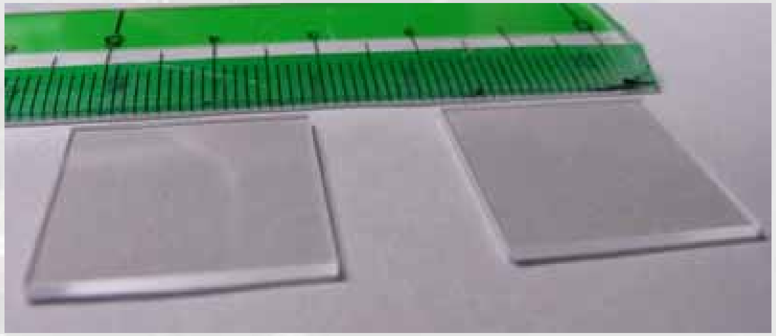
The remote measurement unit will be installed behind the detector in next week.

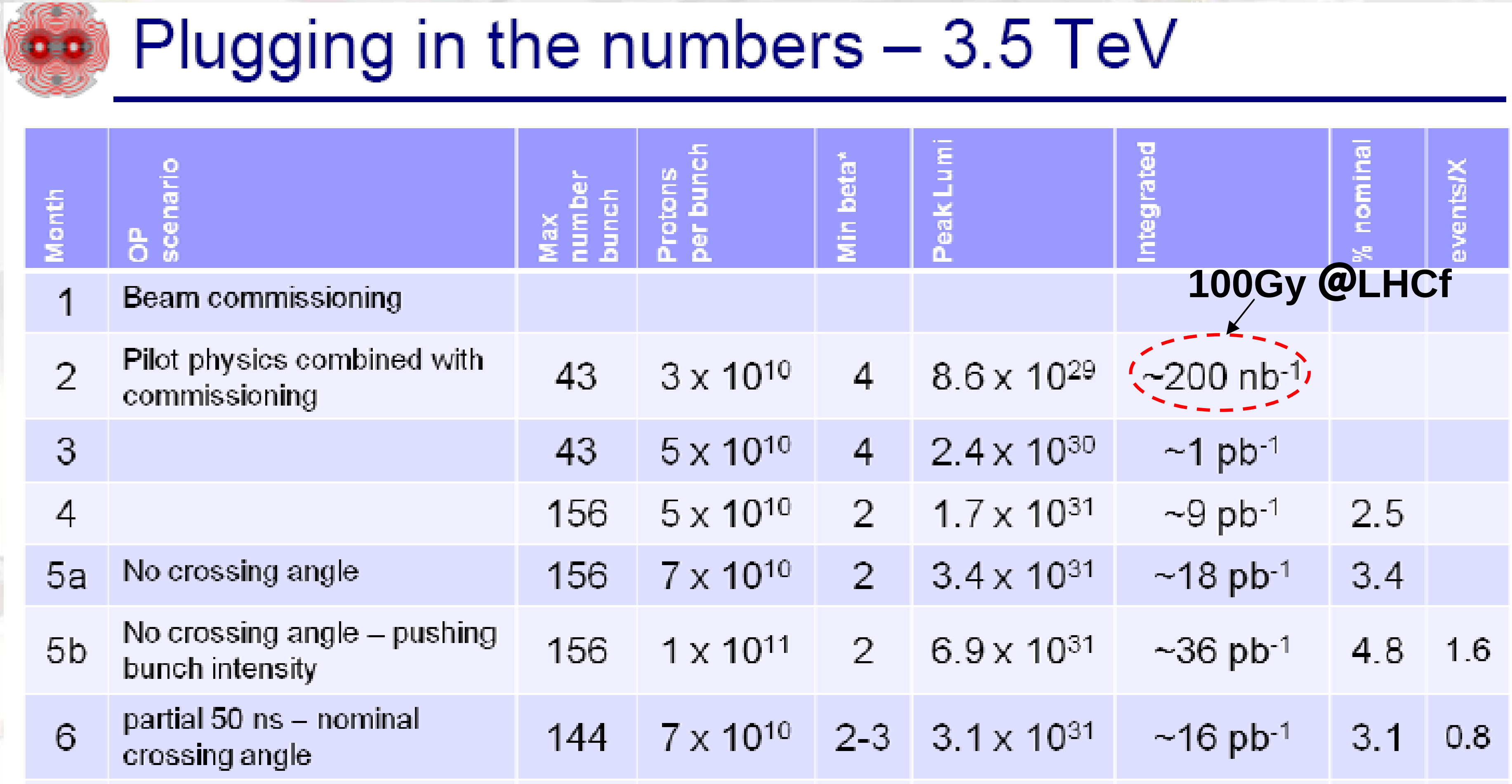


LHCf runs at higher energies

- When luminosity > ~$10^{31,}$ the detector can be removed. (For ex, technical stop) .
- In that case, at the earliest opportunity of next energy increase (i.e. 5TeV, 7TeV), the detector will be installed again to take data at that energy (and removed again for too high luminosity).
- In order to prepare the detectors for the higher energy and higher luminosity runs, we are planning to replace the calorimeter plastic scintillator tiles that could have suffered radiation damage with more rad-hard scintillators. It makes us more flexible for given luminosity condition.
- Possible optimization of Si layers configuration to improve energy measurement.

(We plan only replacement of scintillators, not touching detector structure)





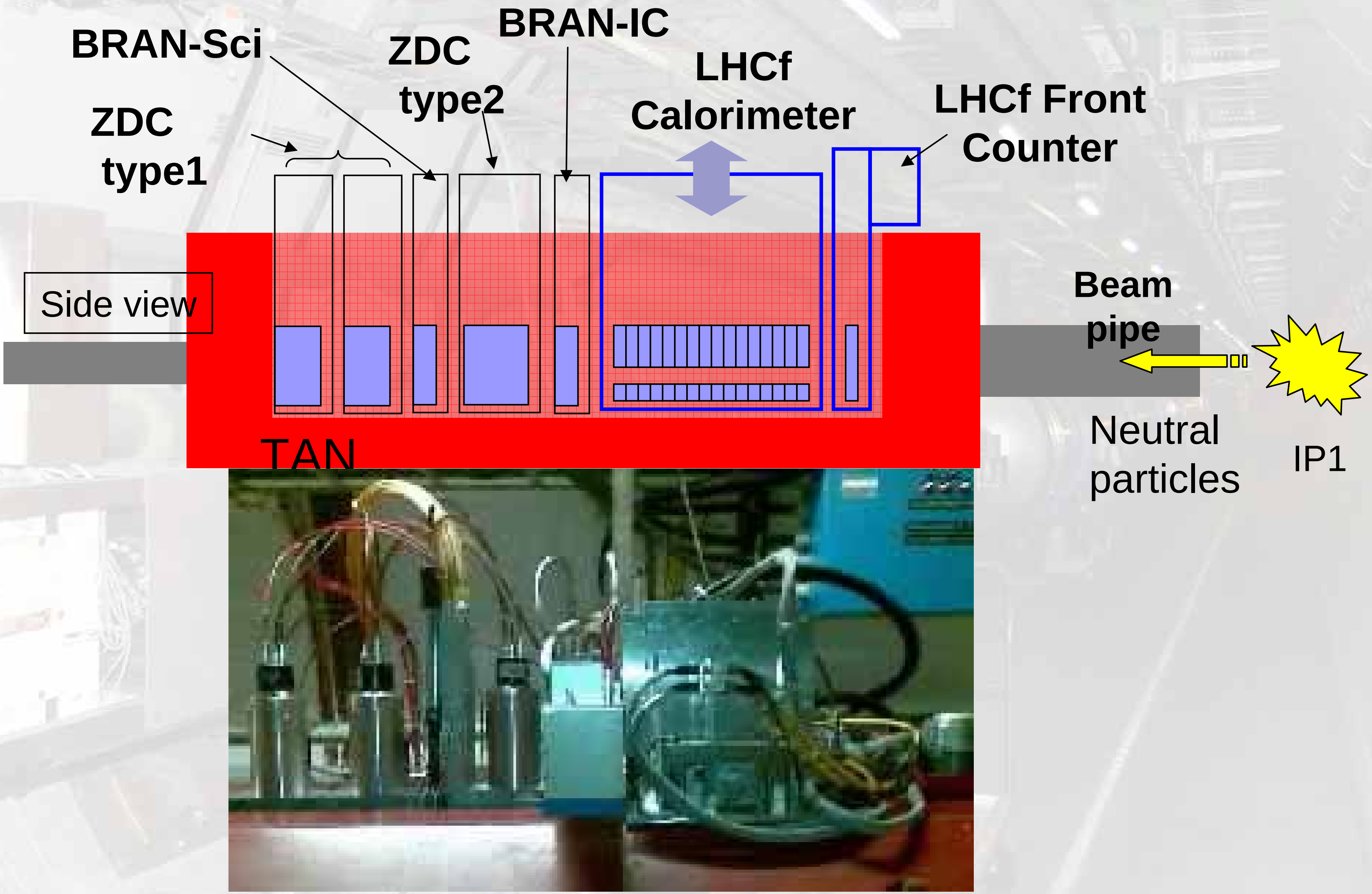
Plugging in the numbers – 3.5 TeV

Month	OP scenario	Max number bunch	Protons per bunch	Min beta*	Peak Lumi	Integrated	% nominal	events/X
1	Beam commissioning							
2	Pilot physics combined with commissioning	43	3 x 10^{10}	4	8.6 x 10^{29}	~200 nb^{-1}		
3		43	5 x 10^{10}	4	2.4 x 10^{30}	~1 pb^{-1}		
4		156	5 x 10^{10}	2	1.7 x 10^{31}	~9 pb^{-1}	2.5	
5a	No crossing angle	156	7 x 10^{10}	2	3.4 x 10^{31}	~18 pb^{-1}	3.4	
5b	No crossing angle – pushing bunch intensity	156	1 x 10^{11}	2	6.9 x 10^{31}	~36 pb^{-1}	4.8	1.6
6	partial 50 ns – nominal crossing angle	144	7 x 10^{10}	2-3	3.1 x 10^{31}	~16 pb^{-1}	3.1	0.8

100Gy @LHCf

From Mike Lamont, LMC 09Sep

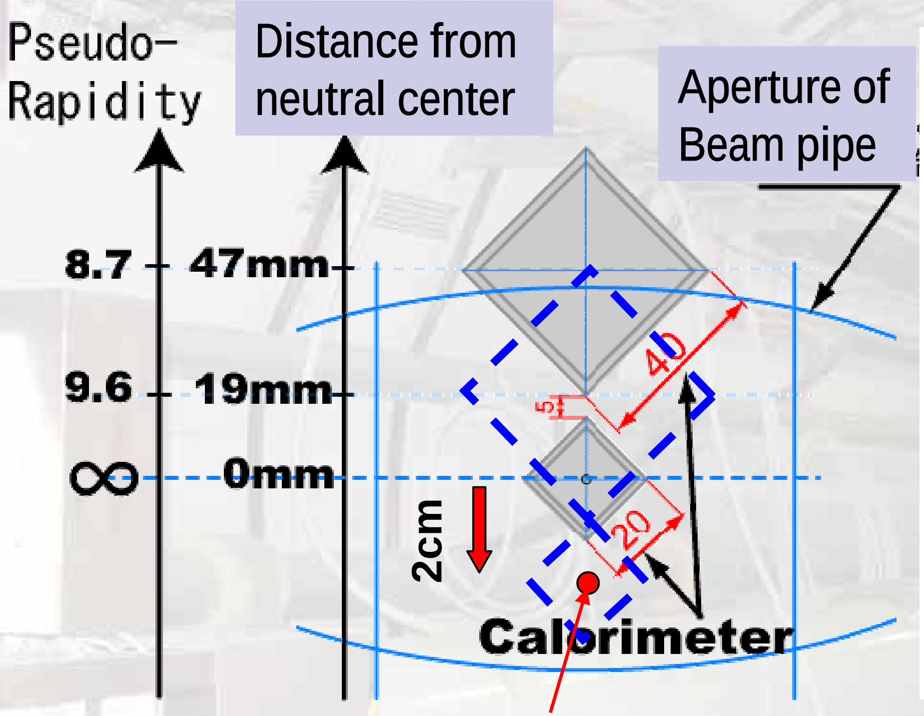
Current setup in IP1-TAN (side view)

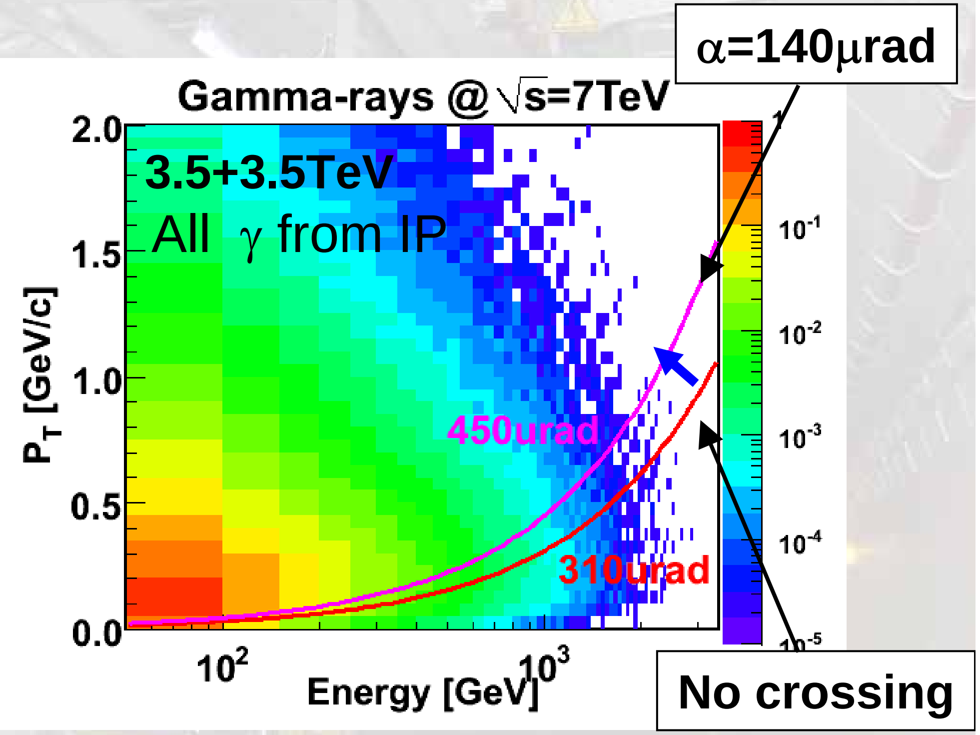


Luminosity monitoring during LHCf run

- At the moment two luminosity monitors are in the TAN
  - □ BRAN-IC (ionization chamber) behind the LHCf(1.6 λ_{int} ,44X_0)
  - □ BRAN-Sci(plastic scintillator) behind the ZDC type2(1.14 $\lambda_{int,}$ 29X_0)
- The BRAN-Sci will be used by the machine operation to safely tune the beam when LHC runs at low energy/low lumi., while BRAN-IC will be used once the flux increases.
- BRAN-Sci is not rad-hard. But it dies mildly by dose (~20% loss @1kGy) as same as LHCf. It could still function for beam tuning.
- The LHCf collaboration will take care of the two spares BRAN-Sci in order to guarantee its good functionality when damage is severe.
- Vertical movement of LHCf (3+garage) changes response of both of the BRANs. They can be calibrated at each position within reasonable time.
- We have already provided MC sample at various energies to BRAN people for these studies.

Crossing angle for LHCf 3.5TeV run

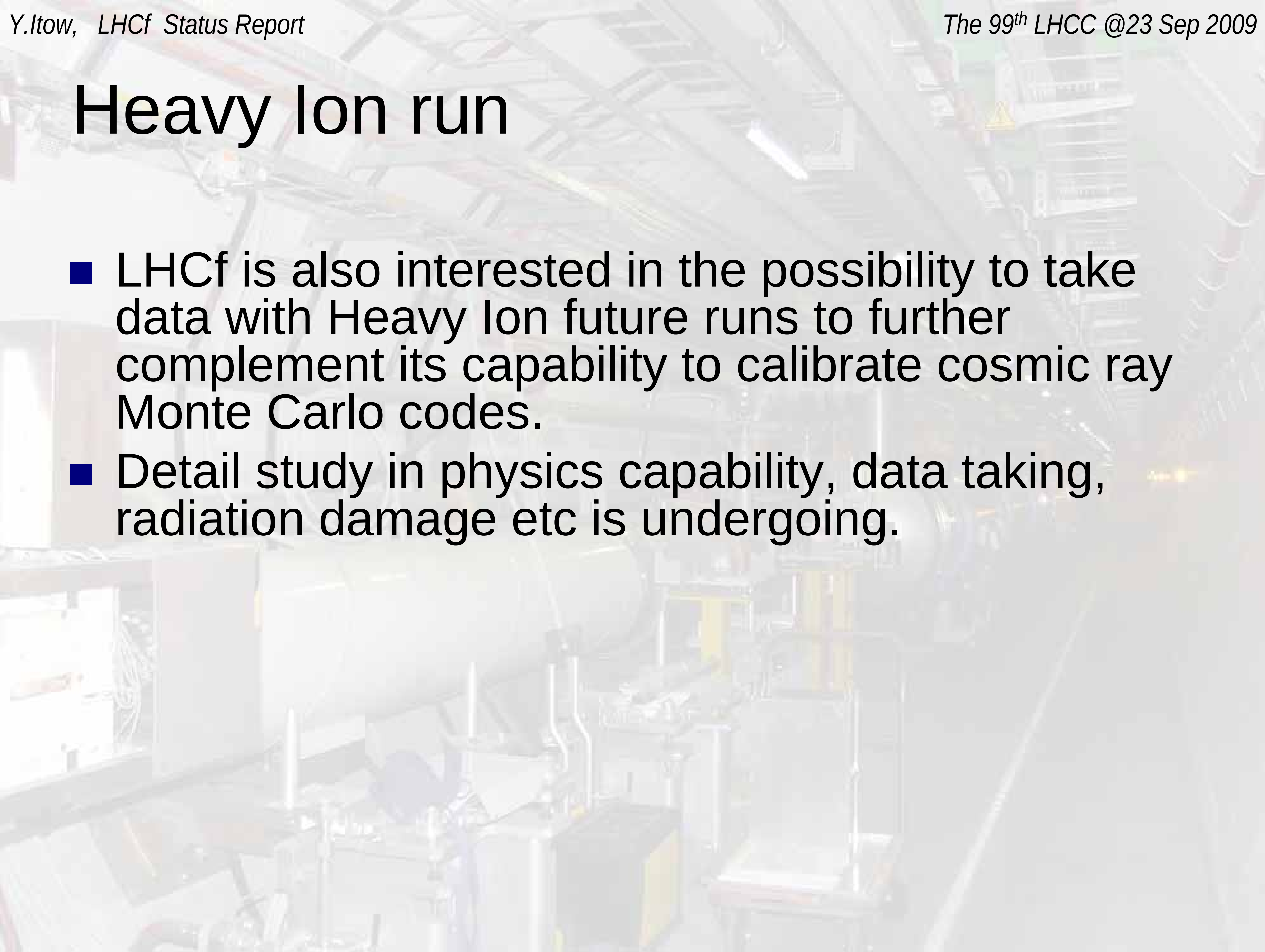




With 140μrad crossing angle,
neutral flux center is lowered by 2cm.
LHCf can enhance its acceptance.

- w/o crossing : 30%acc. @X_f = 0.22
- w/o 140μrad : 50%acc. @X_f = 0.22

- ●If possible, it is nice to have a crossing angle during LHCf run.
- ●LHCf can measure crossing angle by fitting shower center (ΔY~ 1mm for 100sec@L=10^{29}→Δα~7μrad) to be distributed by DIP.



Heavy Ion run

- LHCf is also interested in the possibility to take data with Heavy Ion future runs to further complement its capability to calibrate cosmic ray Monte Carlo codes.
- Detail study in physics capability, data taking, radiation damage etc is undergoing.

Summary

- The LHCf has been installed since 2008 and fully commissioned.
  - Many improvement works in monitoring systems (N_2 laser, dosimeter), analysis tools, etc..
- Data taking at different energies is very important for the LHCf Physics program.
  - MC study at reduced beam energy, 0.45, 3.5, 5 TeV for yields and dose.
- Possible running scenario for the first years (here for 3.5TeV)
  - Clean sample with first $19nb^{-1}$(10Gy), ~4E5π^0 w/o degradation
  - High statistics run upto $1900nb^{-1}$(1kGy), ~4E7π^0 w/ ~20% degradation, until L > ~10^{31}
  - Radiation damage can be monitored and corrected by N_2 laser, π^0 peak and RADMON.
  - Damaged calorimeter scintillator will be replaced for higher energy runs

However proposed scenario will depend on real schedule, technical issue, etc.,etc..
We will be flexible as much as possible to cope with any issue.