Radiation damage and GSO luminosity monitor at the LHC

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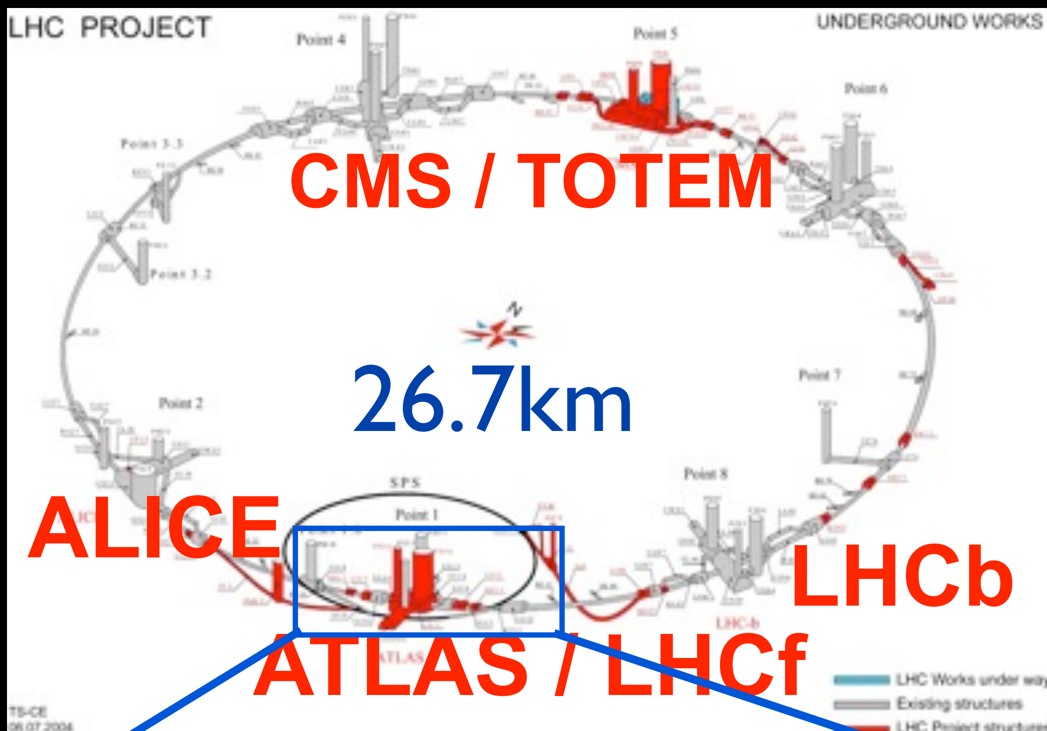
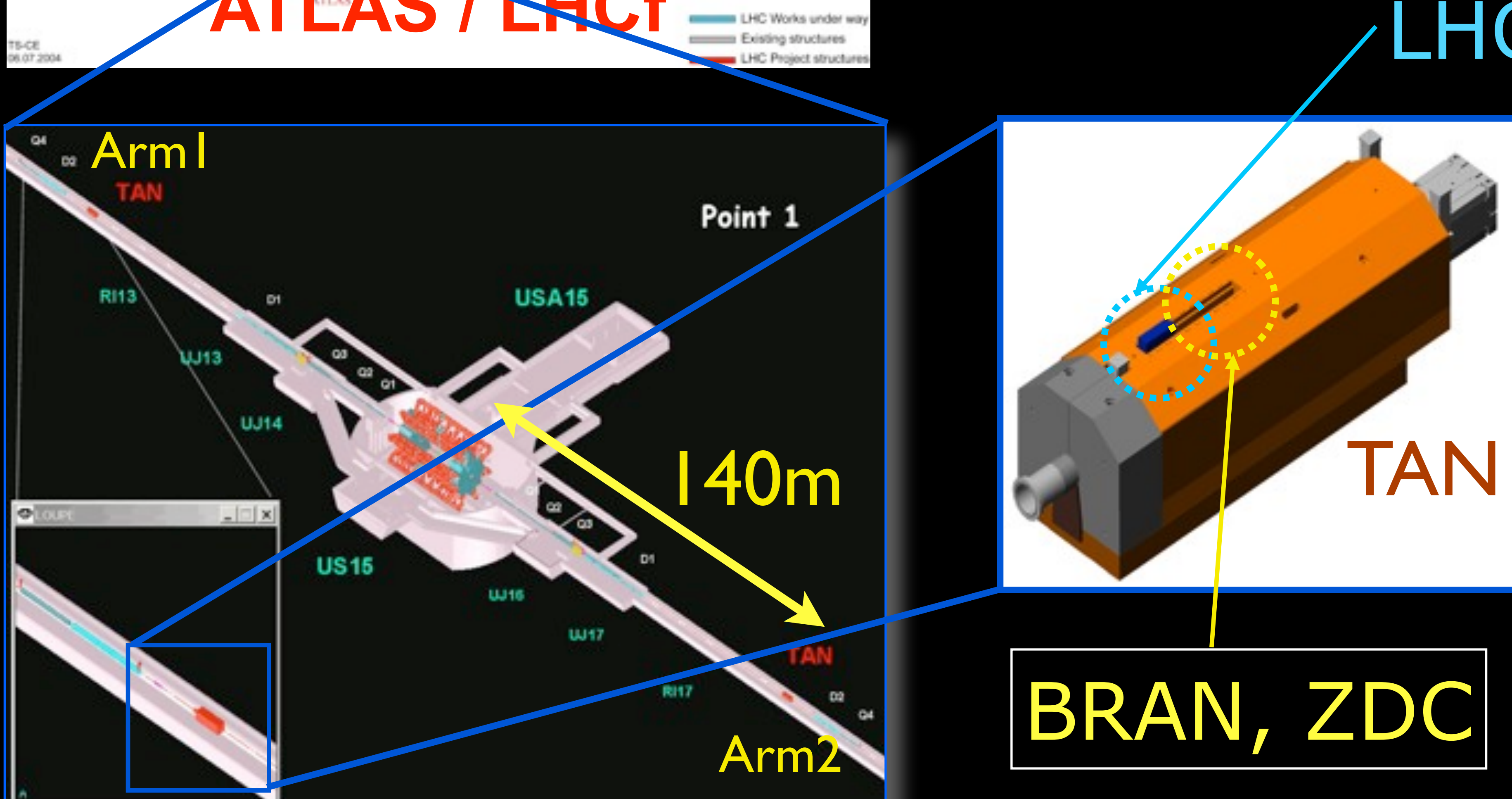
- Introduction and motivation
- Projects and Status
  - Radiation measurements at the LHC
  - Testing GSO scintillators
  - GSO luminosity monitor
- Conclusions

New Hadron workshop
RIKEN, Mar. 1st, 2011

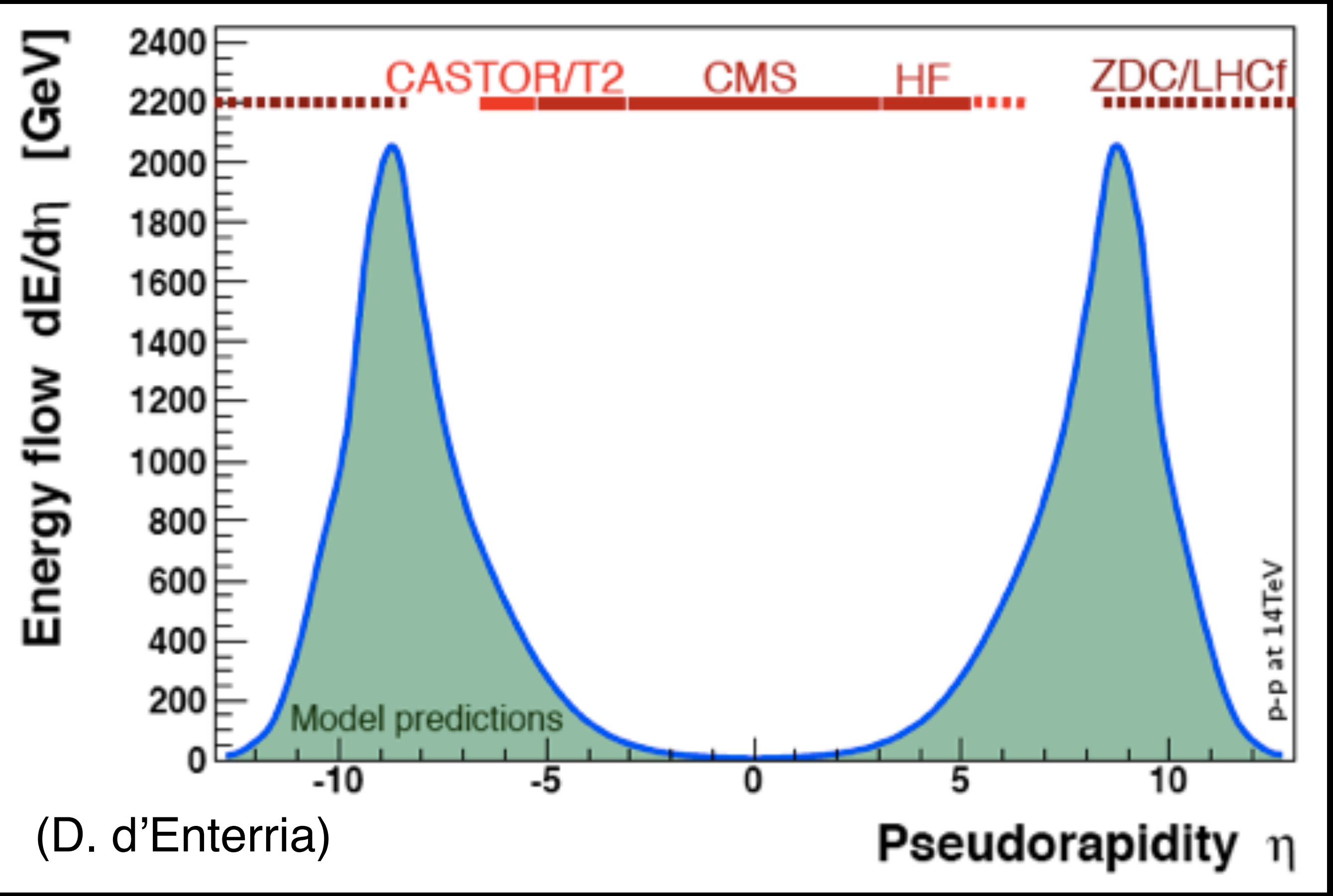
Forward region



- Zero degree instrumentation slot at 140m away from IP1(ATLAS).
- Only neutral particles achieves TAN through a dipole magnet.
- Luminosity monitor and ZDC are located as well as the LHCf detectors.
- Pseudo-rapidity covers above ~8.



Energy flow at forward region



Absorbed dose

$$\mathrm{Dose(Gy)} \equiv \frac{\mathrm{J}}{\mathrm{kg}} \propto \mathrm{Energy} \times \mathrm{L}$$

Significant at high luminosity operation and <u>especially in forward region</u> where luminosity monitor is placed.

Estimated dose at the LHCf location(MC simulation)

$\sqrt{s}$	Gy/hr@L=10^{29}	100Gy@L=10^{29}	Gy/hr@L=10^{31}	100Gy@L=10^{31}
900GeV	4.1×10^{-4}Gy	1.0×10^{4} days	4.1×10^{-2}Gy	100 days
7TeV	1.9×10^{-1}Gy	22 days	1.9×10^{1}Gy	2.2×10^{-1} days
14TeV	1.5Gy	2.7 days	1.5×10^{2}Gy	2.7×10^{-2} days

(K. Kawade)

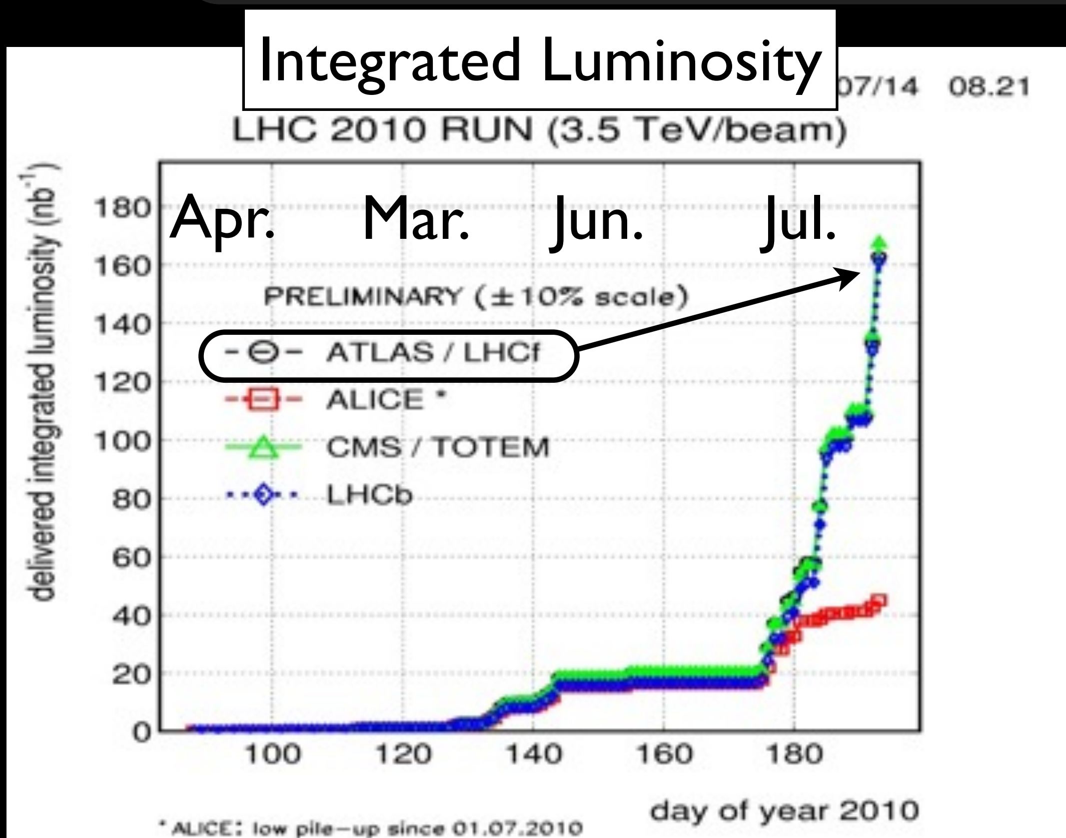
<u>Good opportunity to understand a radiation in forward region.</u>

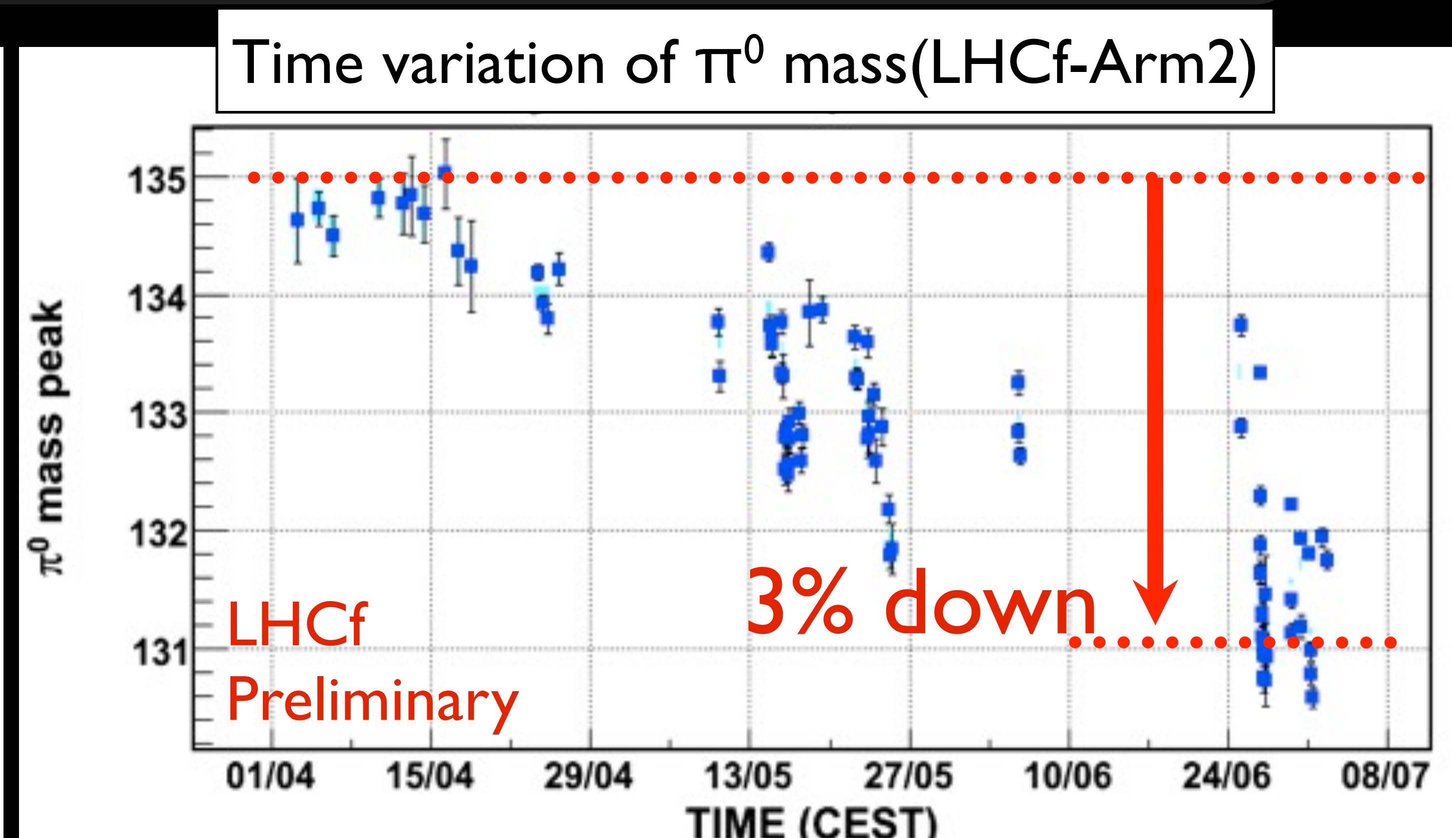
Projects

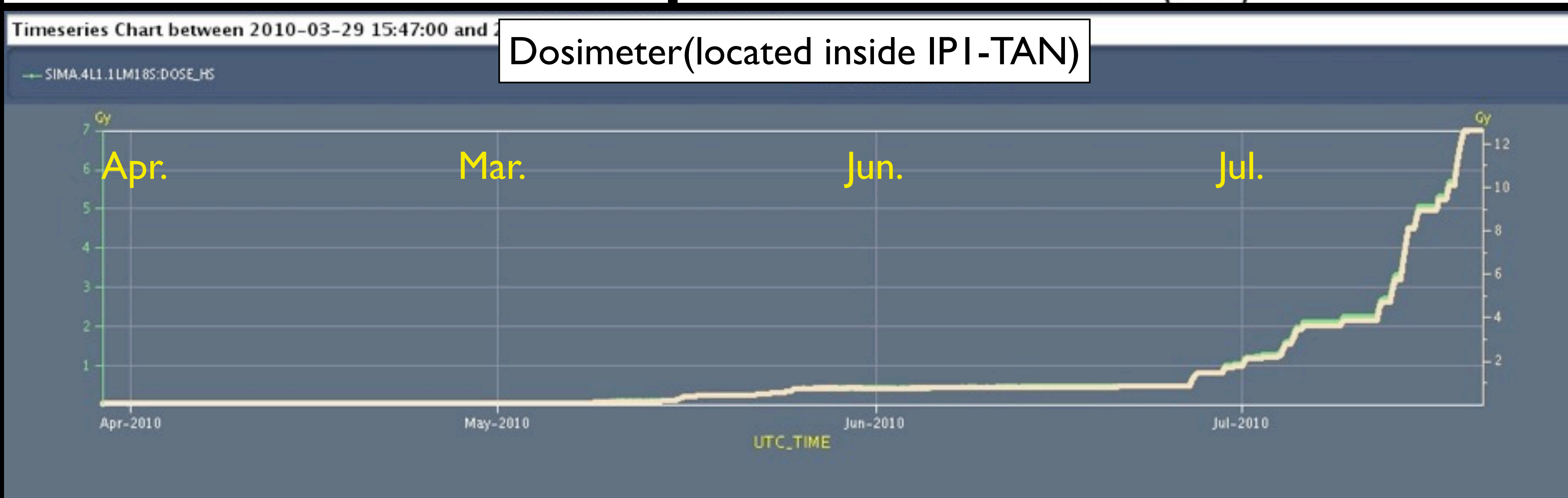
- Measurements of radiation at the forward region.
  - LHCf data at $\sqrt{s}$=7TeV and 14TeV
  - dosimeter in TAN
- Testing GSO(Gd_2SiO_5) radiation hardness
  - @HIMAC, Chiba
  - will be tested by LHCf in 2014 at the LHC
- Luminosity monitor with GSO scintillator

Measurements of radiation at the LHC

Radiation at the forward region





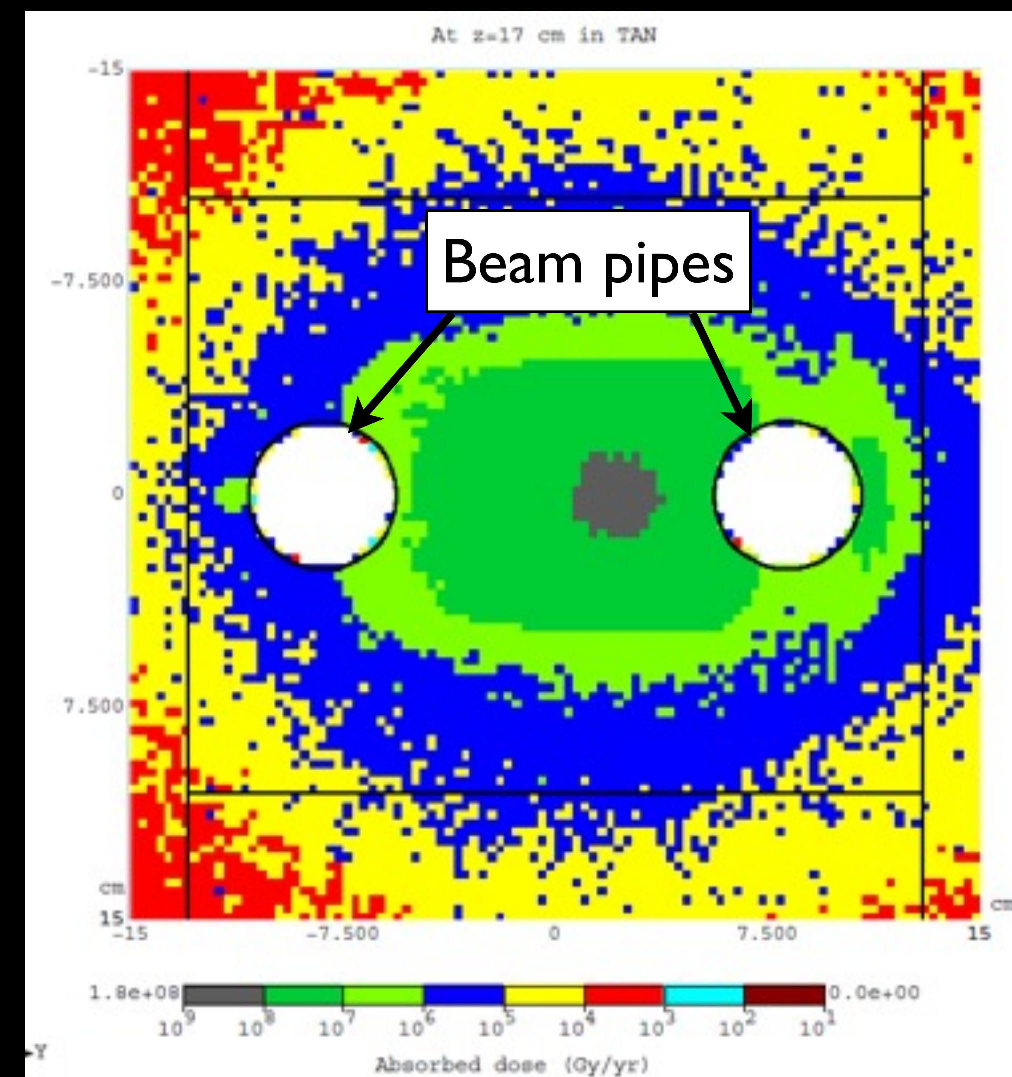


Comparisons

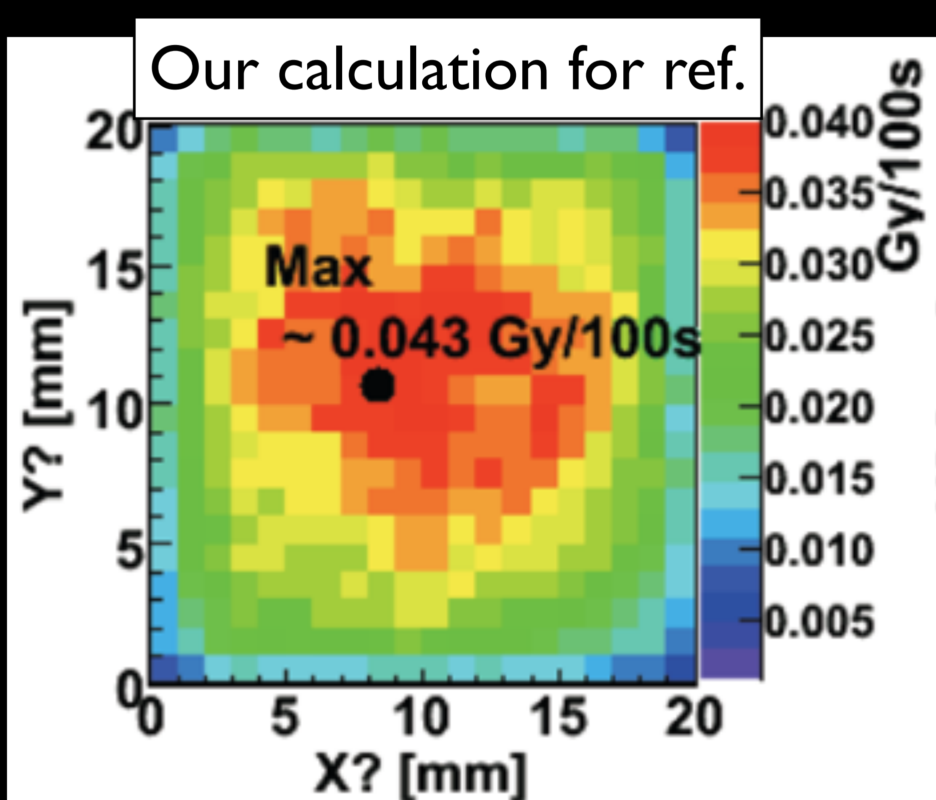
For example IP1-TAN at $\sqrt{s}$=14TeV,

- Calculation by Mokov(based on MARS) indicates
  - 1.8×10^{8}Gy/y@L=10^{34}
  - 5.0Gy/d(0.2Gy/h)@L=10^{29}
- while our calculation based on the Epics MC library shows different estimation
  - 1.4Gy/h@L=10^{29}
- , but configuration(material etc.) has a slight difference between each calculation and it affects a few of factor.

Absorbed dose in TAN



(Mokov et al, LHC Project Report 633, (2003))

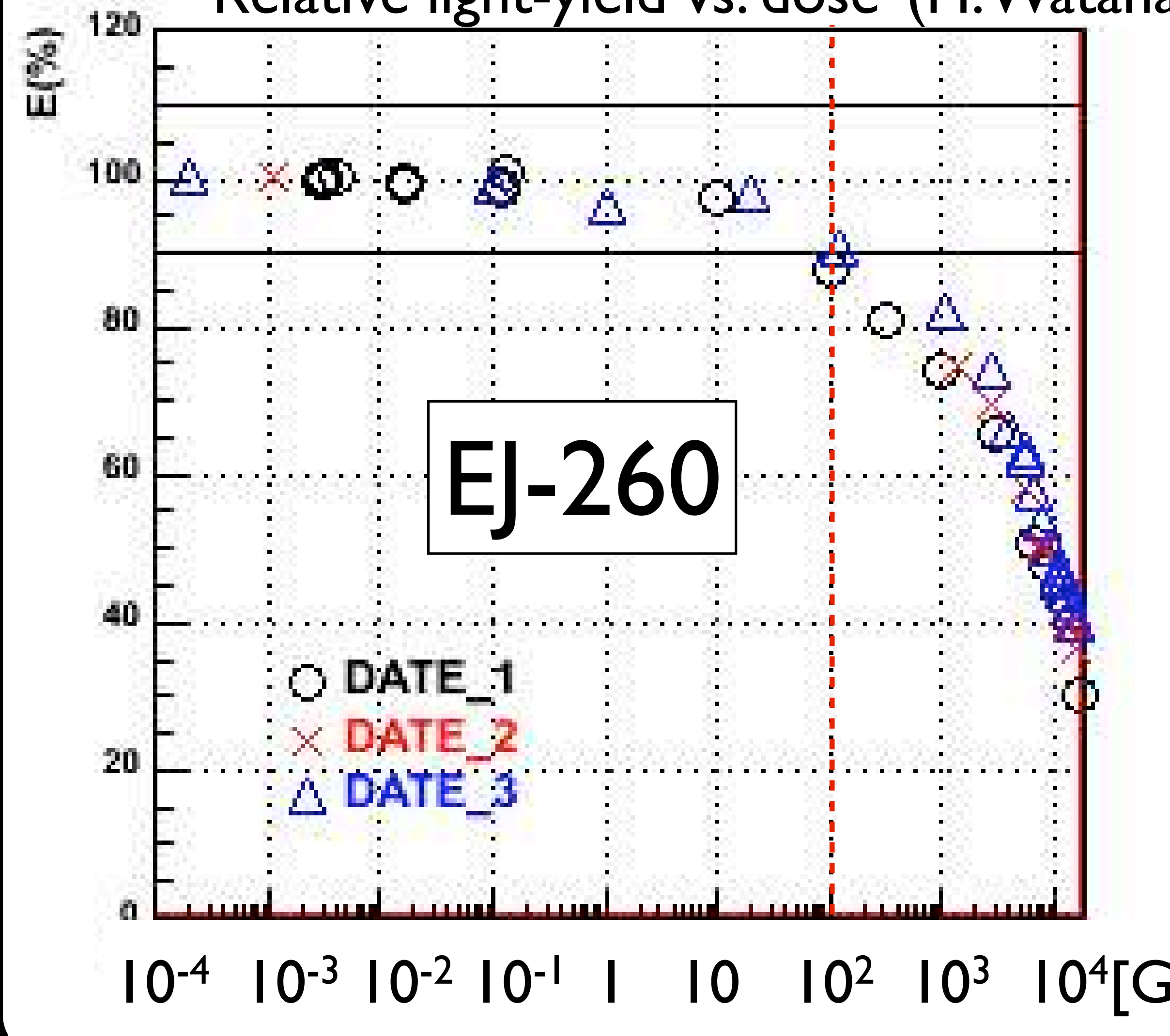


Detailed analysis is ongoing.

Performance test of GSO scintillator

What and why is GSO?

Relative light-yield vs. dose (H.Watanabe)



Damaged by [12]C beam@HIMAC, where data has been taken with different beam intensities(DATE_1-3).

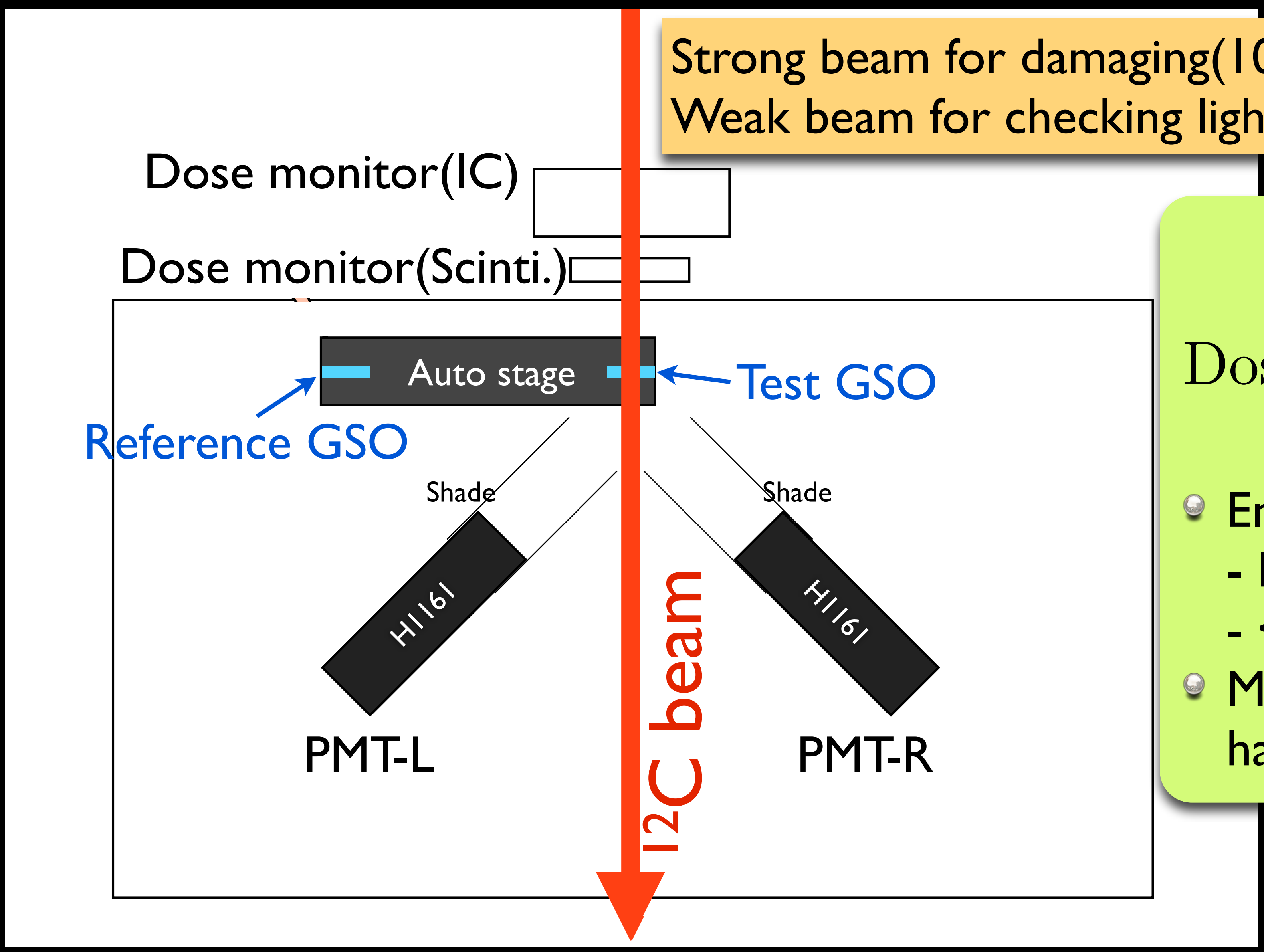
- Plastic scintillator(e.g. EJ-260) highly suffers from radiation damage.
  - 10% down at 10^2Gy (~45min@14TeV&L=10^{31}).
- GSO is strong to radiation damage. Degrade of light yield less than 10% even at 10^4Gy.
- GSO is the best solution considering other similar properties to plastic scintillator.

Properties of scintillators

	GSO	EJ-260	BGO	PWO	CeF3
density(g/cm3)	6.71	1.023	7.13	8.28	6.16
r.l.(cm)	1.38	14.2	1.12	0.92	1.68
decay time(ns)	30-60	9.6	300	2,7,26	5,15
Fluorescence(NaI=100)	20	19.6	12	0.26	7
λem(nm)	430	490	480	430	305
Refractive(@λem)	1.85	—	2.15	2.16	1.68
tolerance(Gy)	10^6	100	10^4	10^4	10^4
melting point(℃)	1950	—	1050	930	1460

Testing GSO w/ ^{12}C beam

- Artificially damaged by ^{12}C beam@HIMAC
  - monitoring light yield until 10^6Gy
  - 2 GSOs are prepared for test and reference



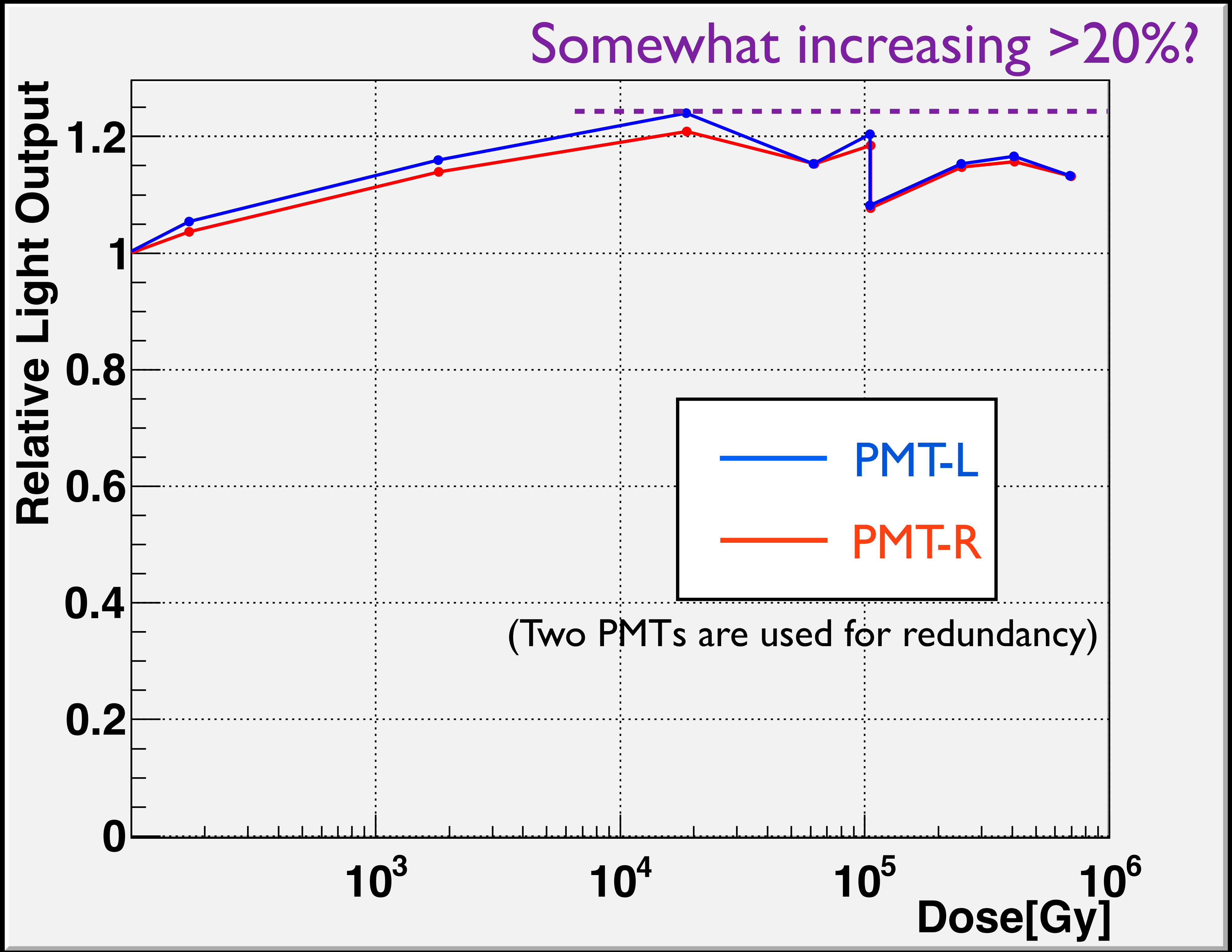
Estimation of absorbed dose

$$\mathrm{Dose(Gy)} = \frac{\mathrm{Energy\ deposit(J)}}{\mathrm{Mass(kg)}}$$

- Energy deposit = N x <E>.
  - N is counted by IC
  - <E> is estimated by Bethe-Bloch
- Mass is calculated by beam size which has been controlled by collimator.

(1.5% Ce is doped to GSOs)

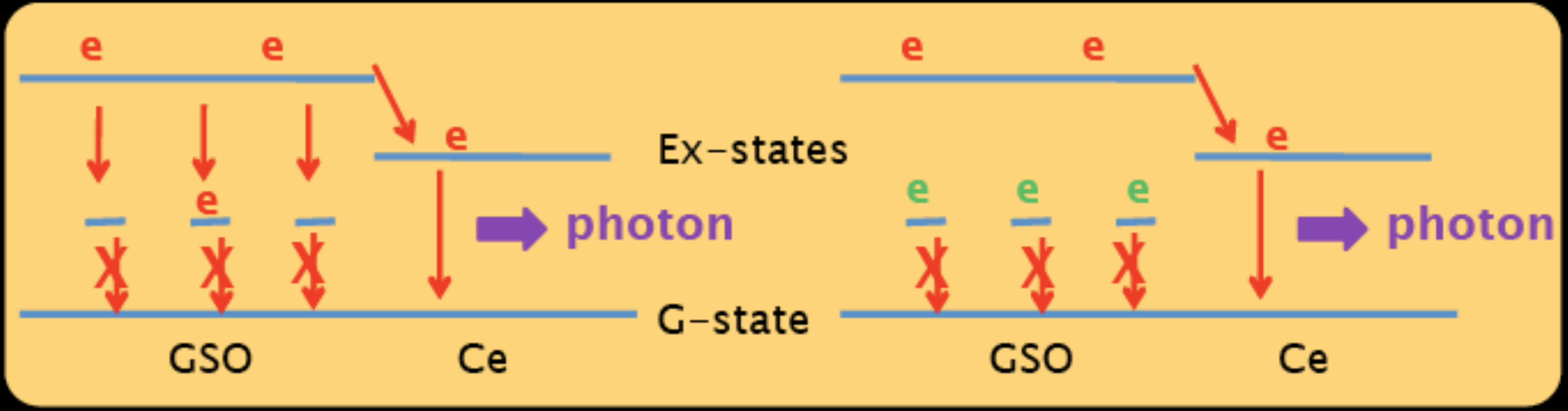
Testing GSO w/ ^{12}C beam



Discussions

- No decrease of light-yield until ~7x10^5Gy, rather it is increased about 20%.
- This mechanism can be understood as follows,

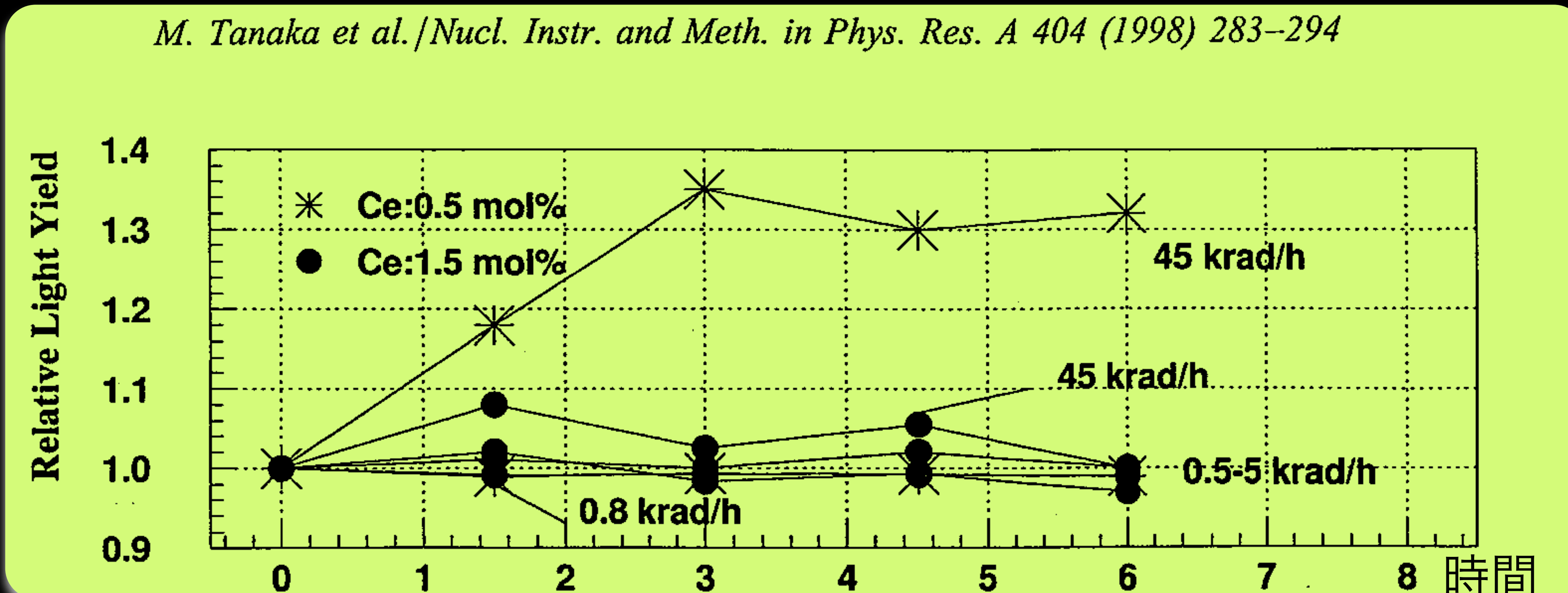
Schematic view of photon emission

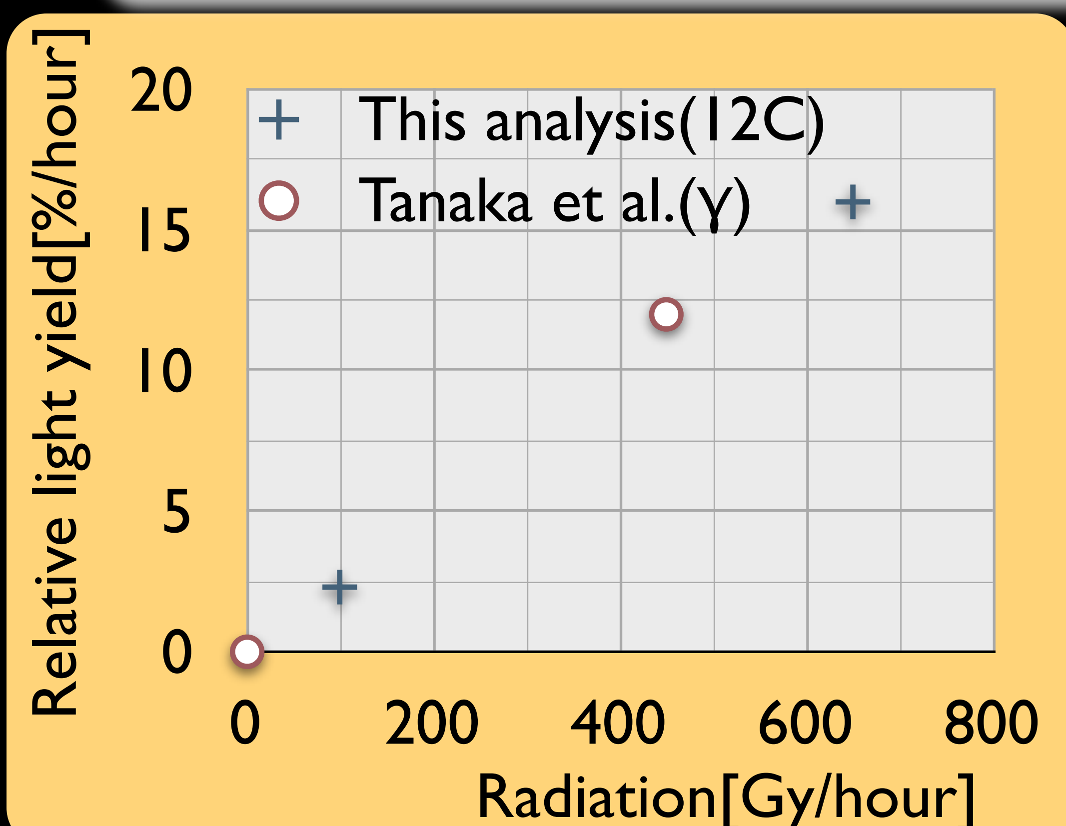


- Originally an energy transfer from GSO-excited to Ce-excited state emits photon.
- No photon can be emitted when de-excited to band gap which restricts scintillation efficiency.
- If band gap is occupied by irradiation, all of electrons must be transferred to Ce excited state which is able to emit photon.
- Thus irradiated GSO cause increase of light yield.

(M. Tanaka et al, NIM A404, 1998, 283)

Comparison



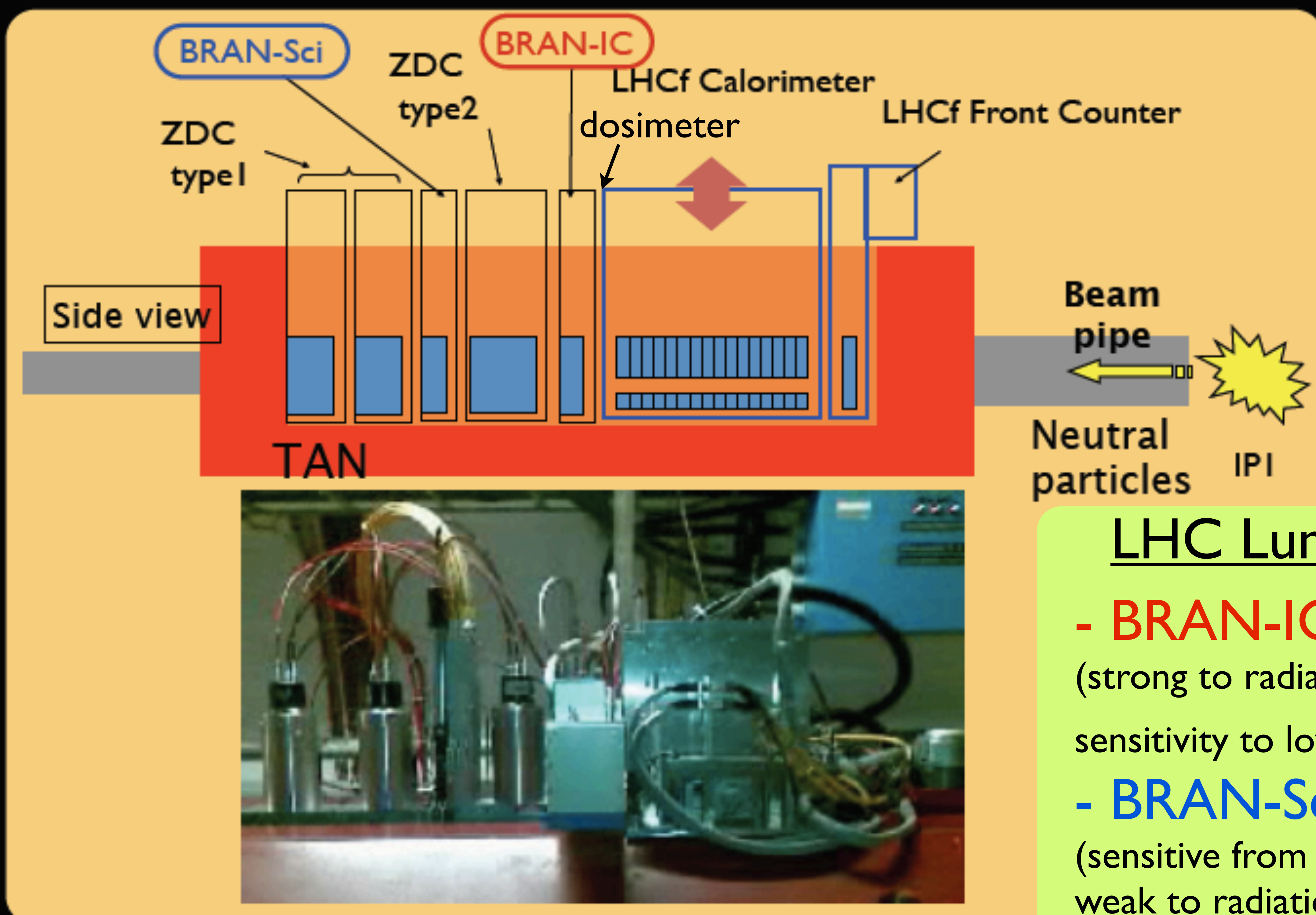


- Increasing yield has been observed in the previous measurements(NIM A404, 1998, 283).
- Light yield increases as depending on "Gy/hour".
- Also it is independent of irradiation source, thus it might be caused by chemical processes.

GSO luminosity monitor

LHC luminosity monitor

Cross section of the IP1-TAN



LHC Lumi monitor

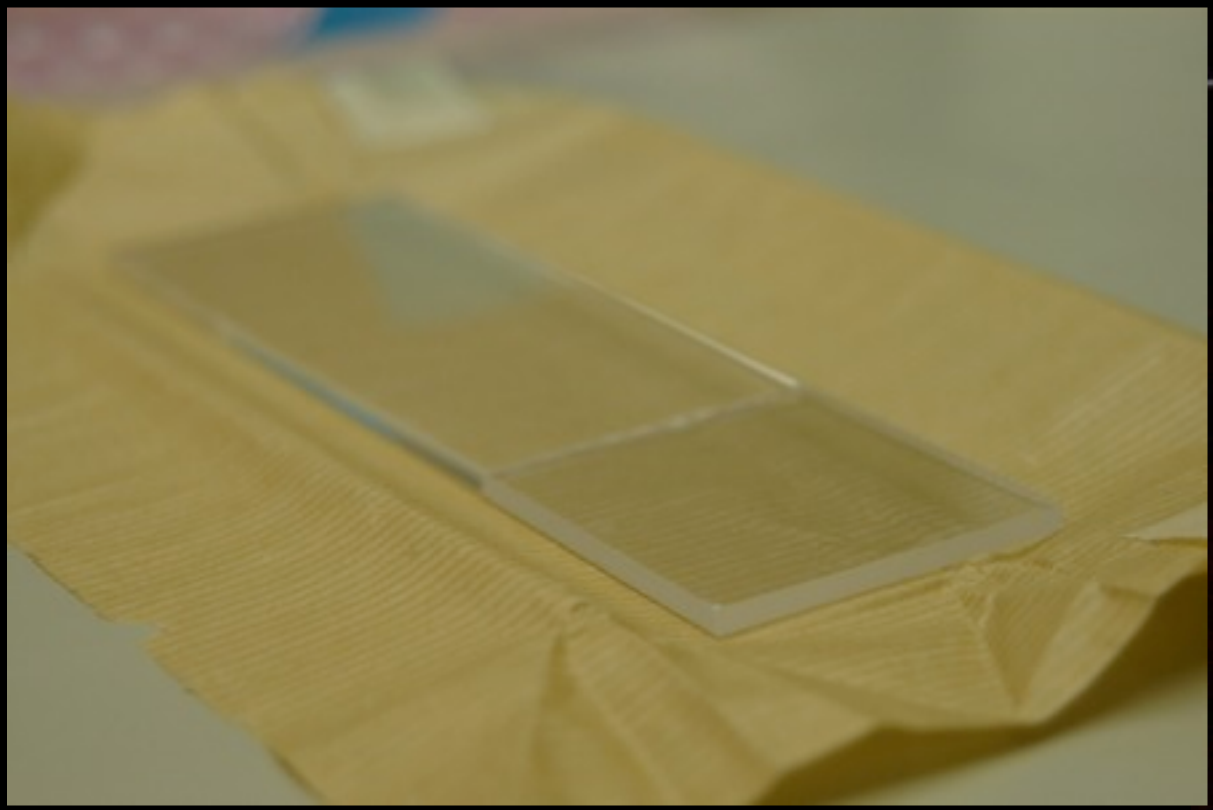
- BRAN-IC(High-L)

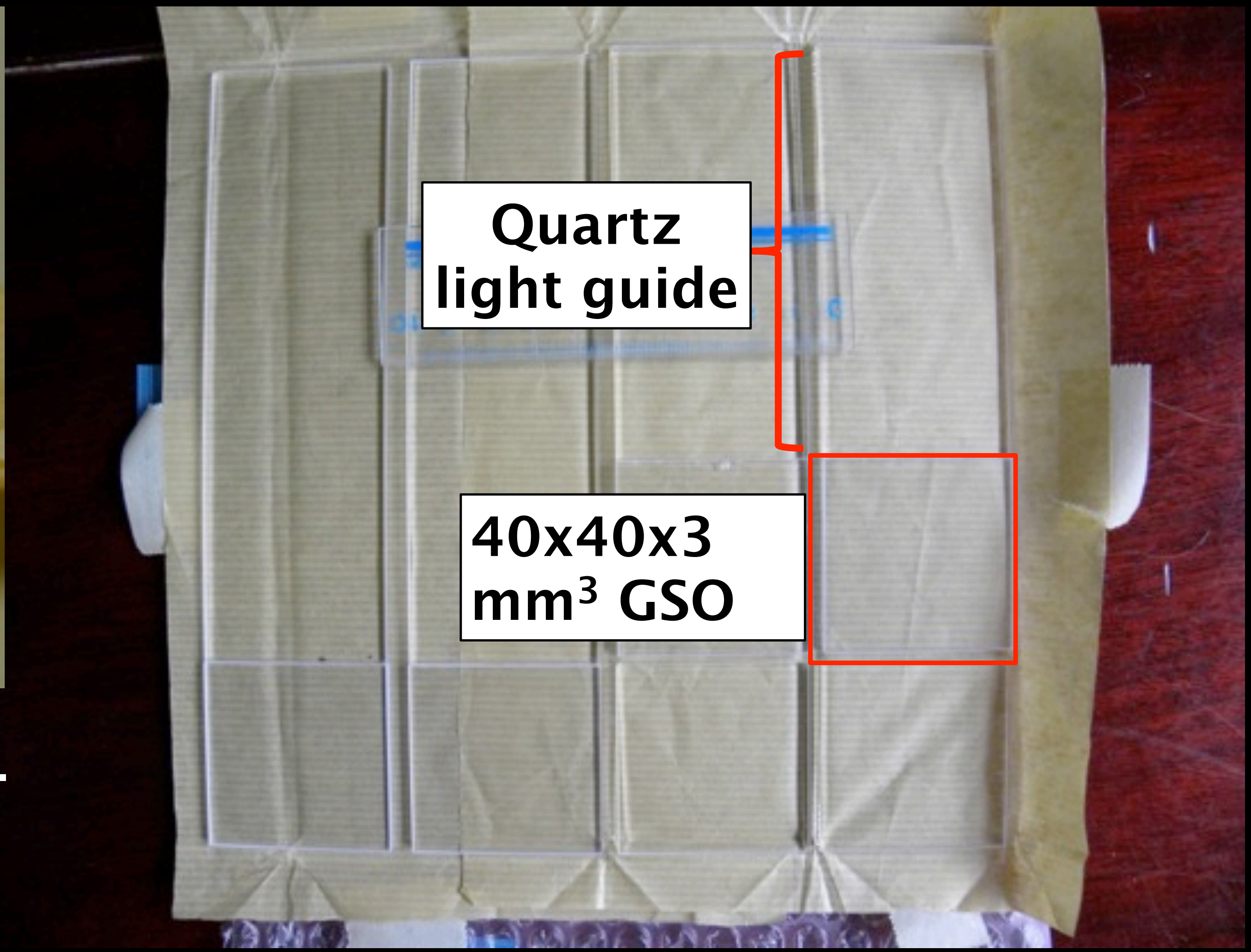
(strong to radiation, but small sensitivity to low energy)

- BRAN-Sci(Low-L)

(sensitive from low energy, but weak to radiation)

GSO luminosity monitor





- Substituted for the "old" scintillators.
- Design and product by Nagoya-U.
- Four 40mmx40mm GSO scintillators cover 80mmx80mm aperture.
- Left/right, Bottom/top separation is able to monitor a position of beam axis, especially in nonzero crossing-angle run.
- GSO scintillator is connected to PMT using quartz guides and optical fibers.

- Assembly and test is ongoing by CERN lumi-team(Enrico Bravis et al.).
- BRAN-Sci will be upgraded soon.

Summary

- We proposed three subjects can be proceeded together with the LHC operation.
  - Measurement of radiation at the LHC
  - Testing GSO scintillator
  - GSO luminosity monitor for the LHC
- They are going well as considering slight delay of the LHC machine.
- New insight to GSO scintillator was obtained.