γ-ray Induced Light Loss in PWO Crystals

Ren-Yuan Zhu

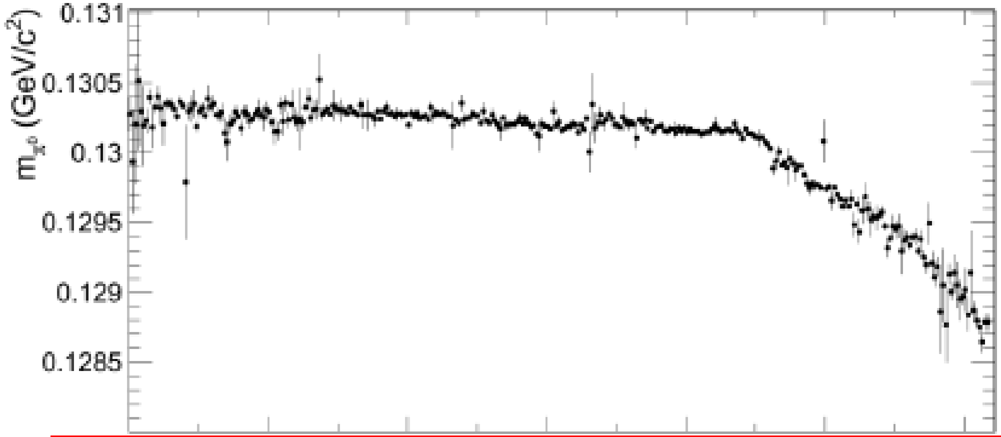
California Institute of Technology

December 9, 2010

Observations *in situ* at LHC

Yong Yang, Talk in CMS ECAL PFG, November 11, 2010

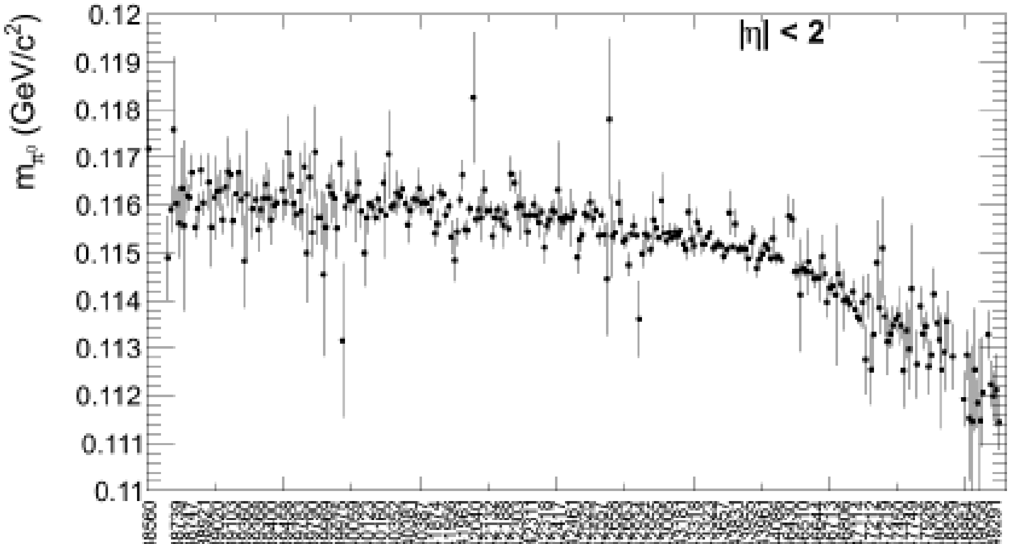
http://indico.cern.ch/getFile.py/access?contribId=4&resId=1&materialId=slides&confId=113597



Barrel:

Mean loss at the end of pp running: **-1.3%**

Reconstructed π^0 mass, indicating significant light loss



Endcap |η| < 2:

Mean loss at the end of pp running: **-3.4%**

Is this Degradation Understood?

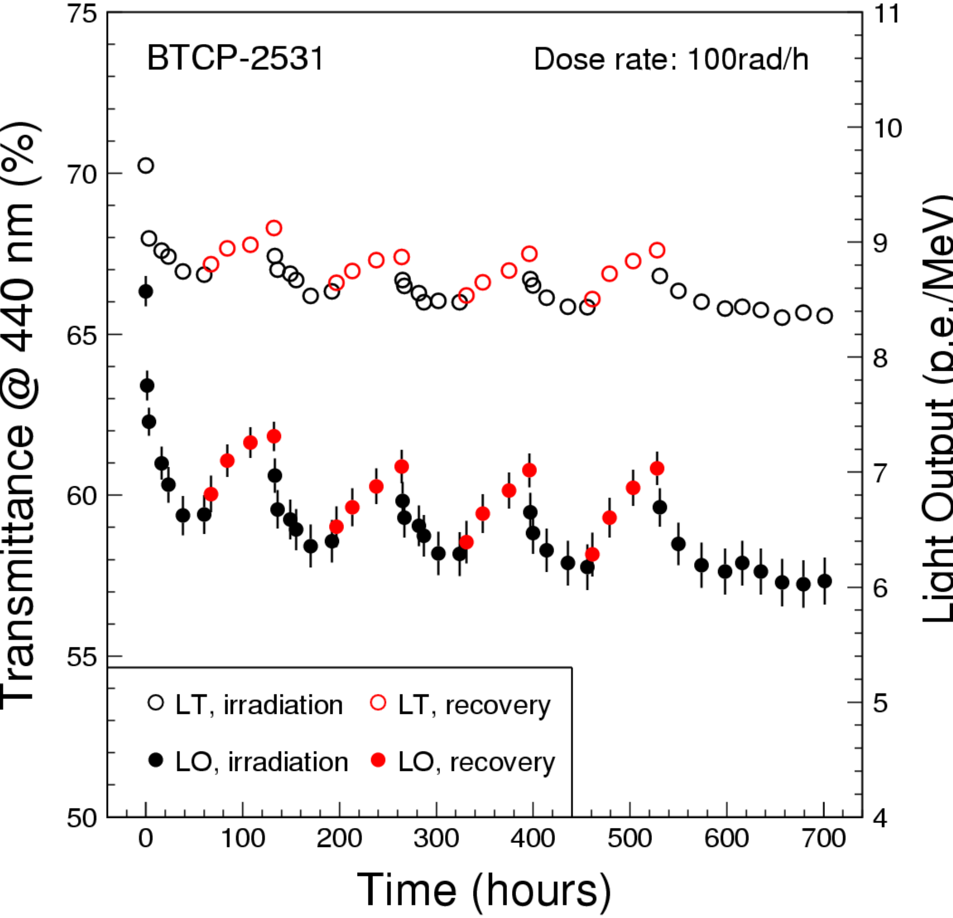
Recalling earlier observations from Lenny and Sasha we have no doubt observed light loss in PWO crystals. Since we are at 10^{32} or two orders of magnitude away from the designed luminosity it is important that we understand the level of light loss in PWO as a function of luminosity.

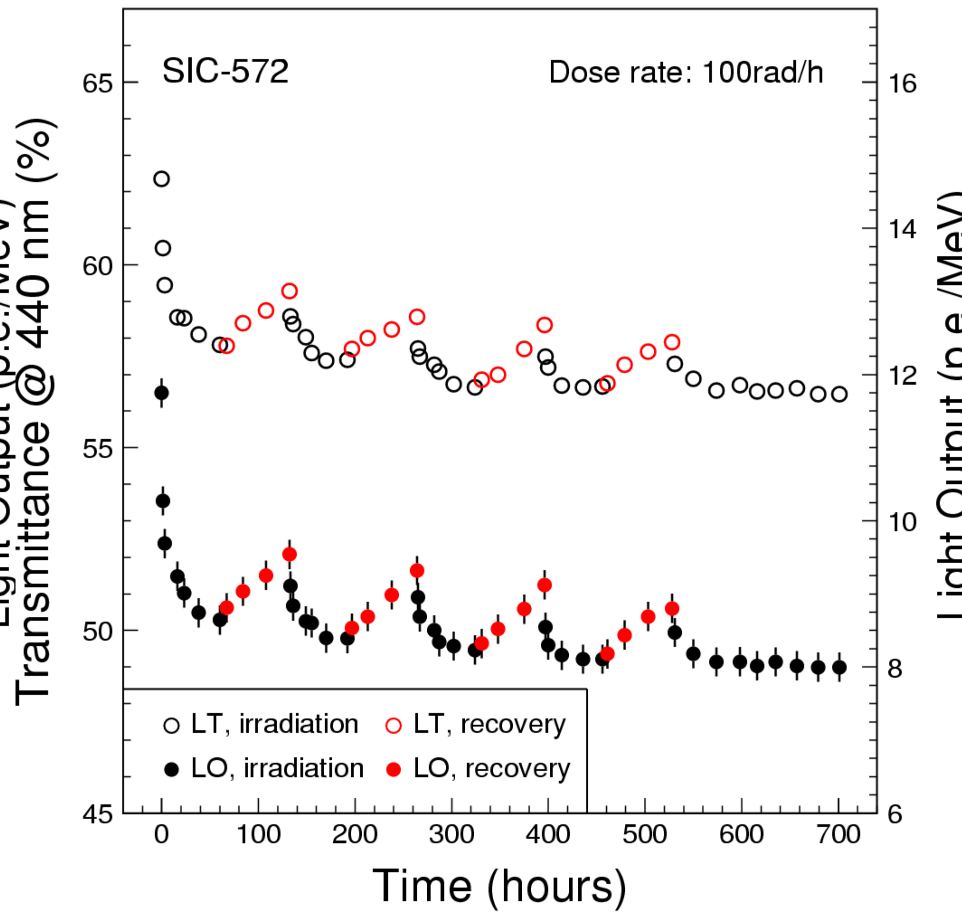
The following slides are based upon two sets of data measured at the Caltech Crystal lab in the last decade for two batches of PWO crystals produced at BTCP and SIC (two main producers for CMS). Some were presented in a CMS ECAL SLHC Workshop at Fermilab on 11/20/2008. The summary slides were sent this Summer to ECAL colleagues when the ECAL upgrade was in discussion.

Light Loss versus Transmittance

Data measured for 5 CMS endcap size samples (BTCP & SIC) @ 100 and 400 rad/h & recovery

J.M. Chen et al., *A radiation damage and recovery study for lead tungstate crystal from BTCP and SIC*, AIP Conference Proceedings, **Volume 867**, 252-257 (2006).



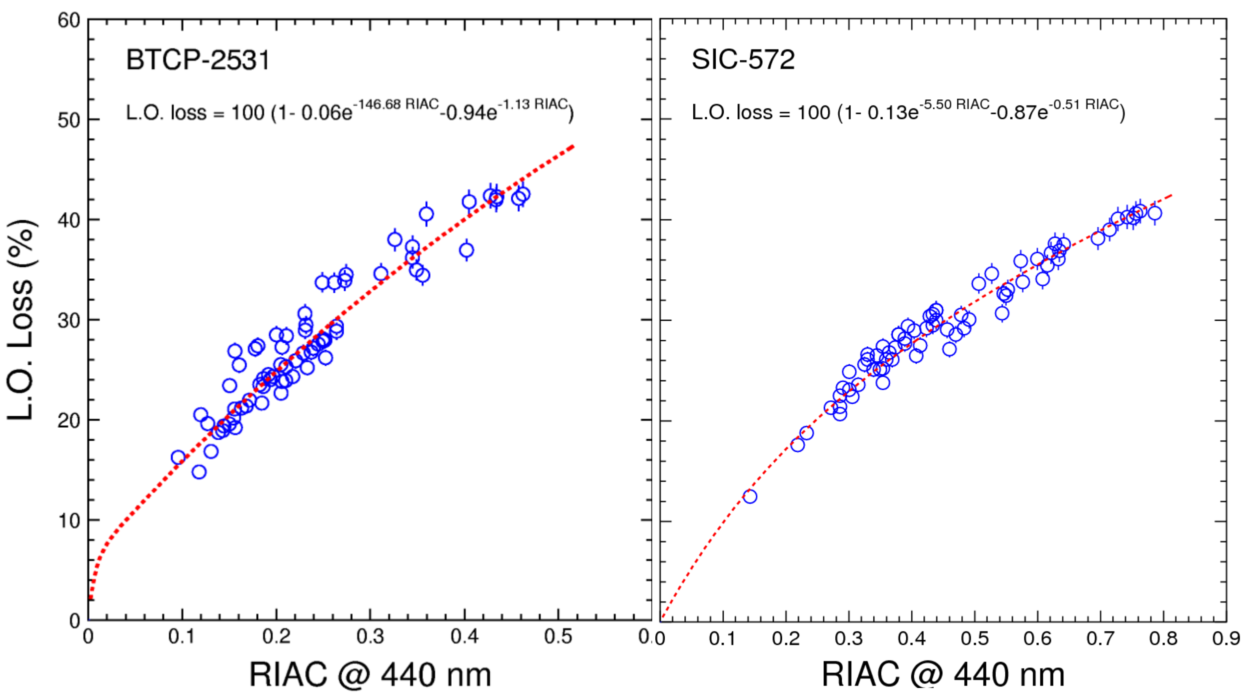


L.O. Loss versus RIAC (μ)

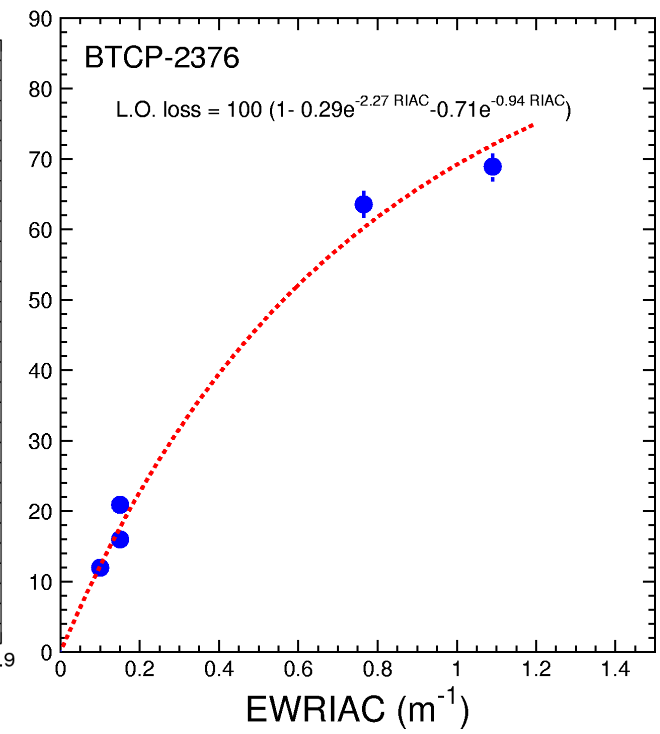
RIAC: radiation induced absorption coefficient

Two exponentials are needed to fit the data

Measured with Cs Source



Cosmic Ray Data



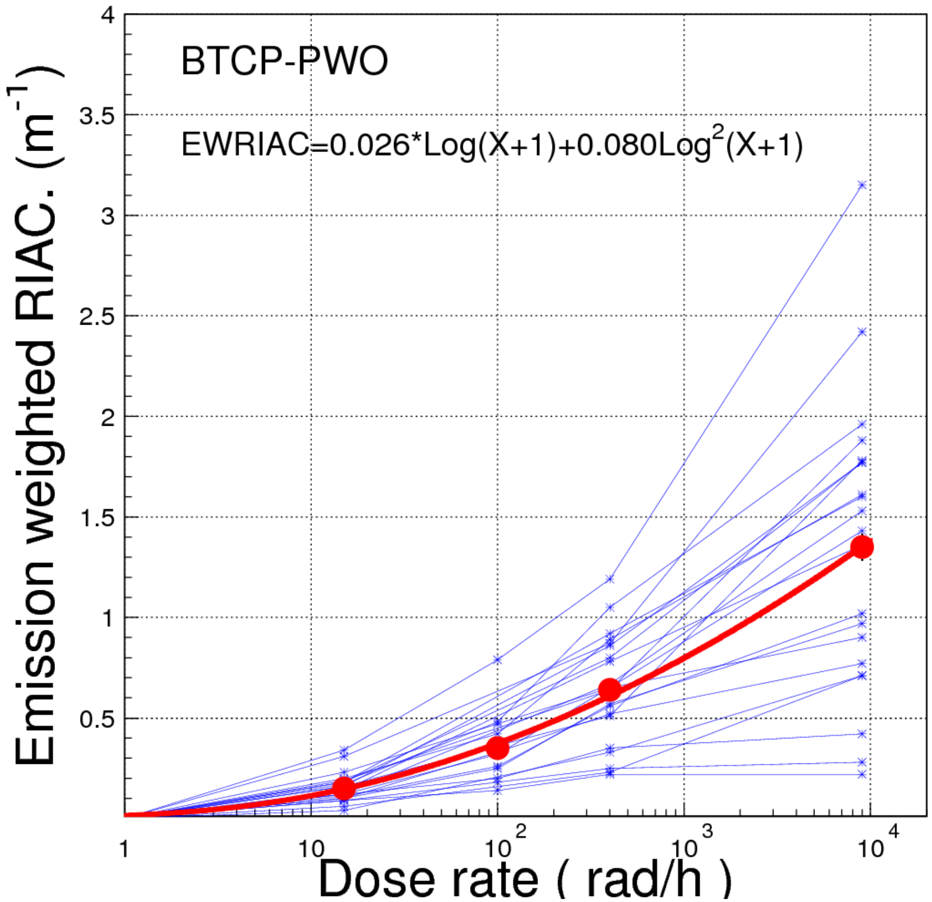
Summary of Light Loss vs. RIAC

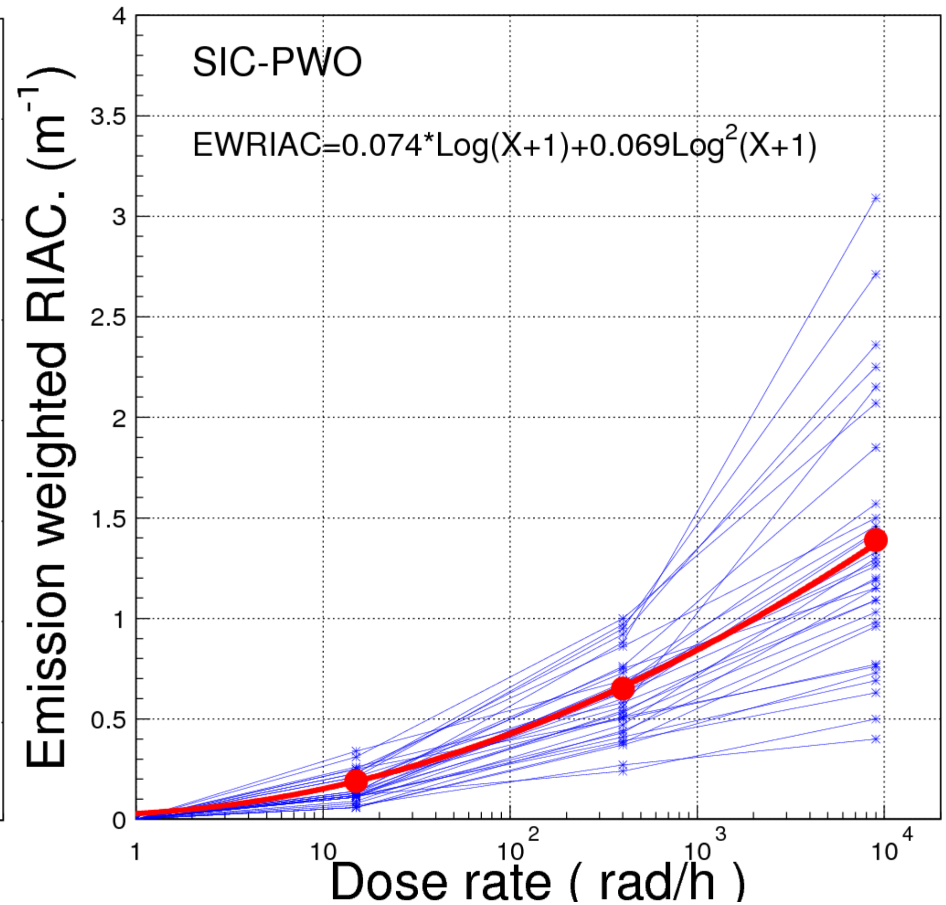
BTCP & SIC crystals are self-consistent
Two groups, however, behave differently

μ (m^{-1})	0.2	0.5	1.0	2.0	5.0	10.0
BTCP-2482	23.7%	43.3%	65.4%	87.2%	99.3%	100.0%
BTCP-2531	25.0%	46.6%	69.6%	90.2%	96.7%	100.0%
BTCP-2376	22.4%	44.8%	66.3%	85.9%	98.8%	100.0%
SIC-570	13.8%	31.1%	52.5%	77.4%	97.6%	99.9%
SIC-572	17.1%	31.8%	47.7%	68.6%	93.2%	99.5%

RIAC of Mass Produced Crystals

Average RIAC fits to 2nd order polynomials of log dose rate
Large spread of RIAC under high dose rate is noticed
R.H.~Mao et al., *Quality of Mass-Produced Lead Tungstate Crystals*}, IEEE Trans. Nucl. Sci. **NS-51** 1777 (2004)





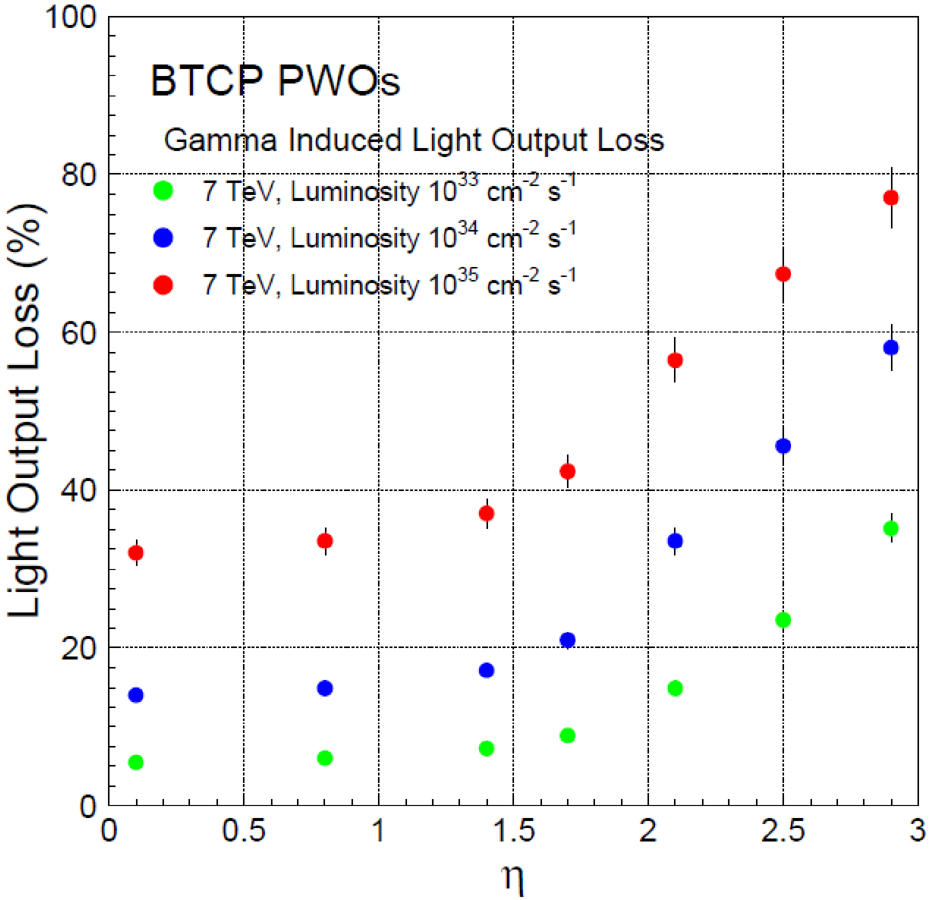
EM Dose Rate Used in Estimation

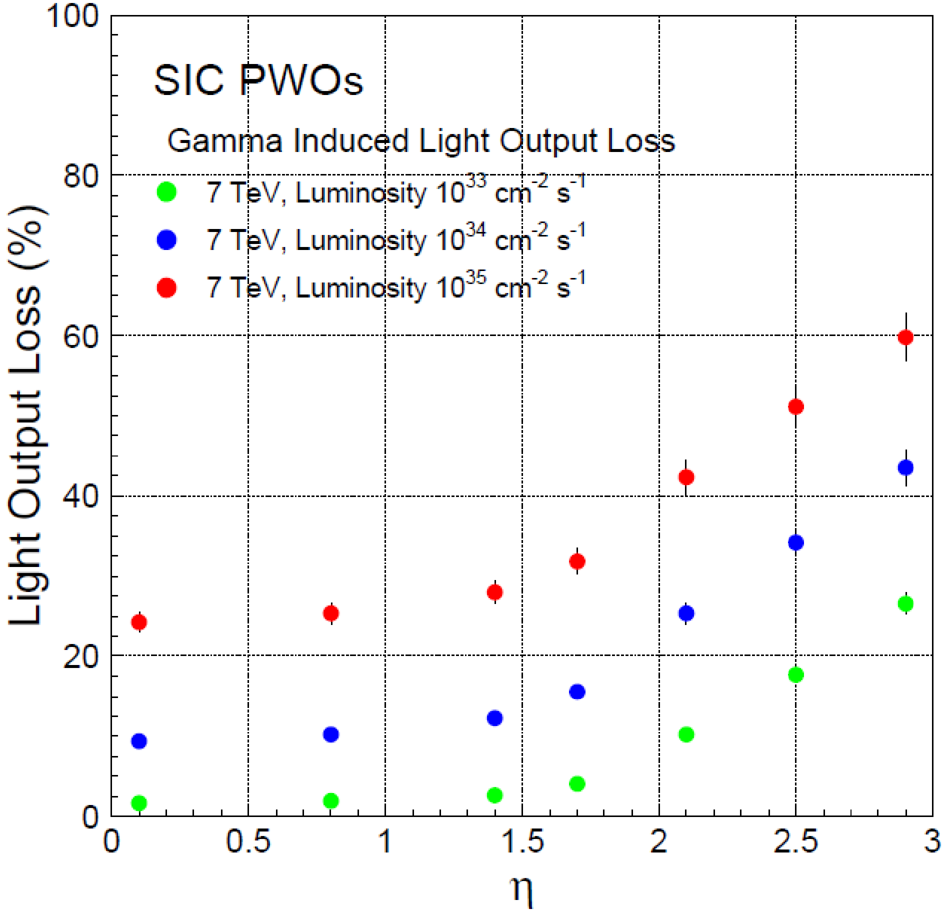
Data from CMS ECAL TDR (1996) for LHC of 14 TeV

Pseudo rapidity (η)		0.1	0.8	1.4	1.7	2.1	2.5	2.9
LHC (rad/h)	Ave	6	7	10	17	70	234	826
	Peak	17	19	25	41	160	478	1193
SLHC (rad/h)	Ave	60	70	100	170	700	2340	8260
	Peak	170	190	250	410	1600	4780	11930

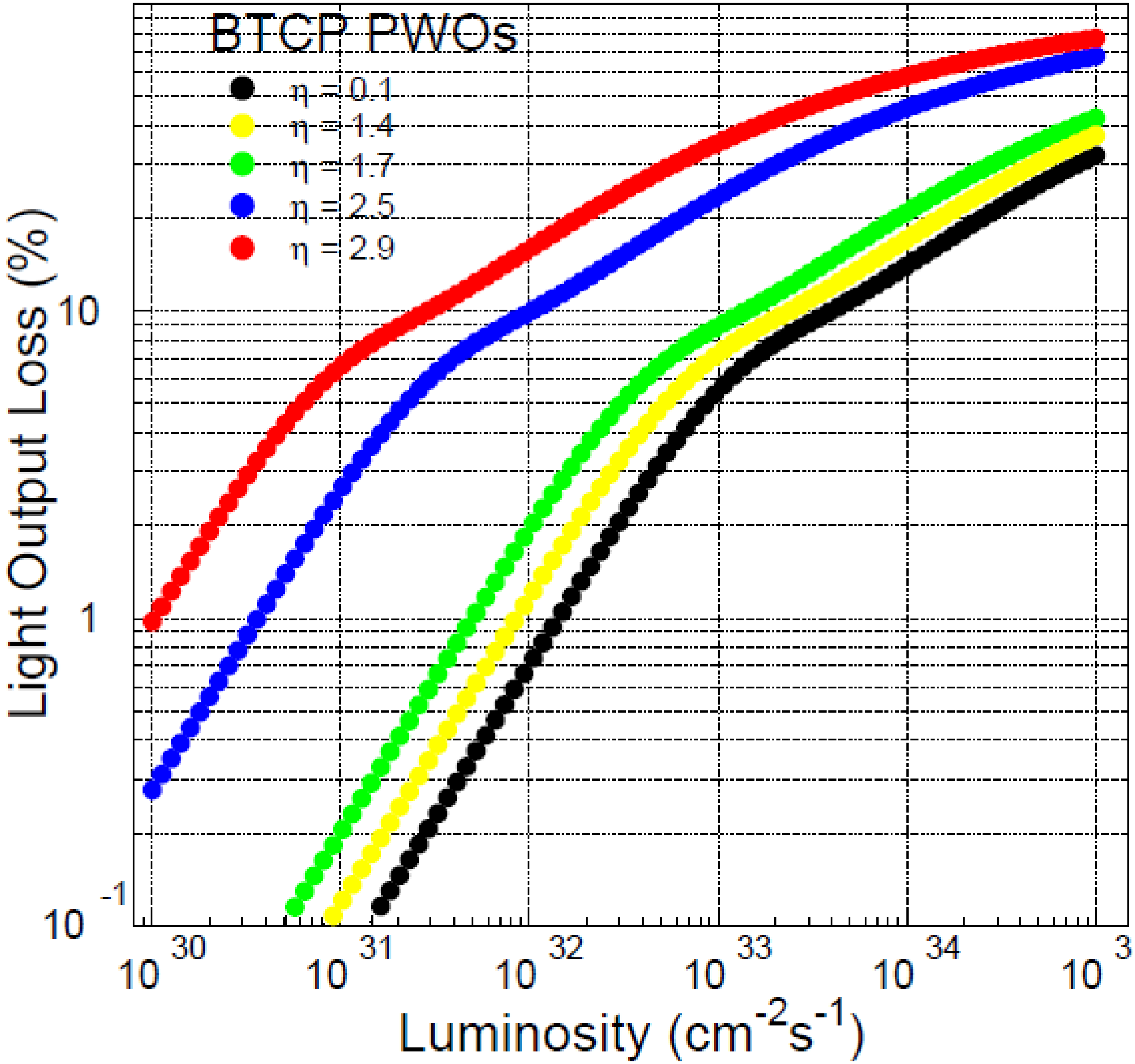
Expected LO Loss by EM Dose

Using two parametrizations extracted from data: about 10 and 5% light loss is expected at 10^{33} in the barrel because of the EM dose for BTCP and SIC crystals respectively



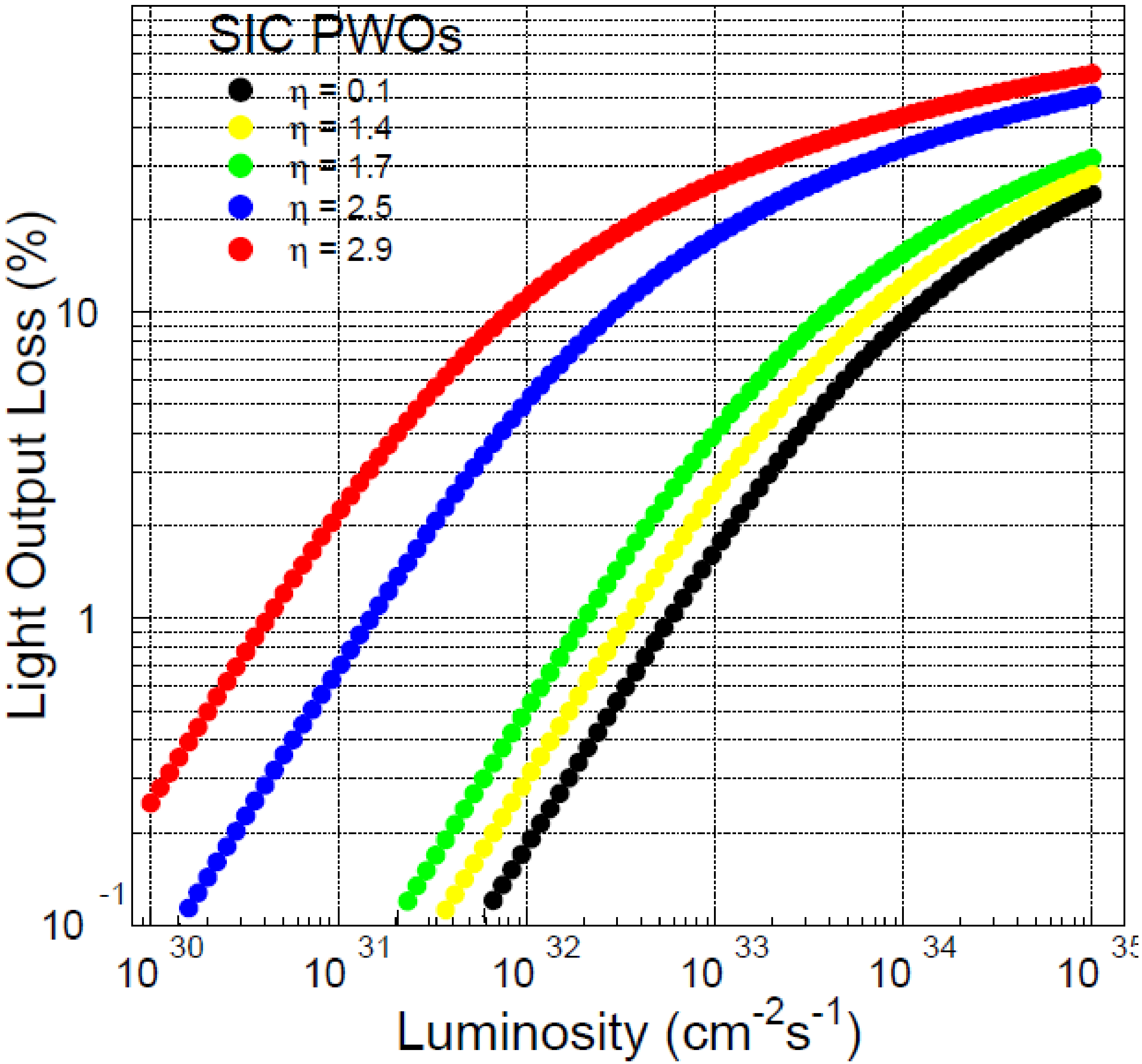


Light Loss Expected for BTCP PWO



A few percents are expected in the barrel at a few x 10^{32}, consistent with π^0 mass data shown on slide 2. More than 10% is expected at 10^{34}.

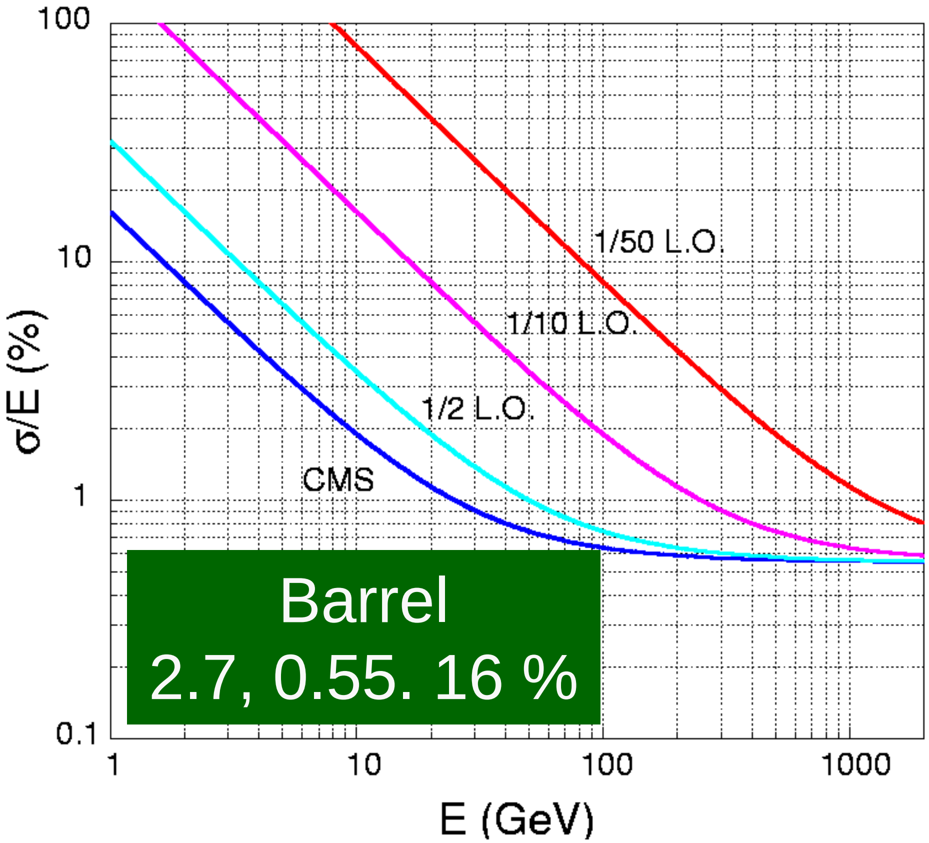
Light Loss Expected for SIC PWO

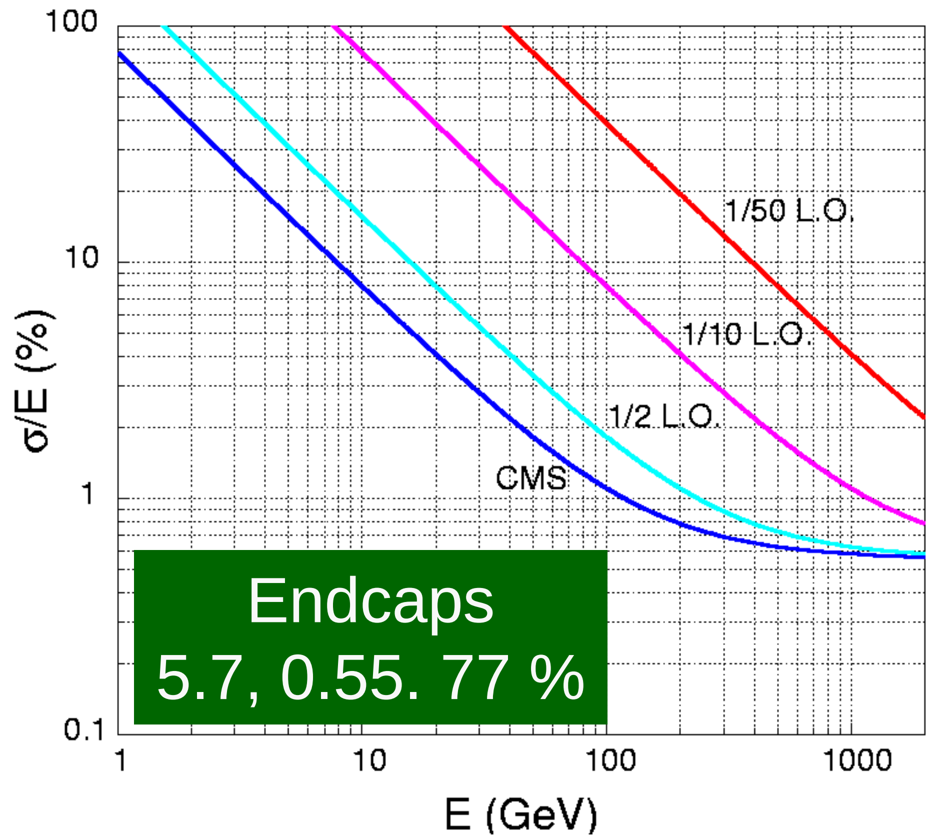


Should also see a few percents at high eta of endcaps at a few X 10^{32}.

Effect of Light Loss to Resolution

$\sigma E / E = a / \sqrt{E} \oplus b \oplus c/E$, E in GeV





The net effect of light loss to resolution is not dramatic, indicating that we have a working detector before SLHC. Note, the hadron damage induced loss is not included.

Summary

- Lead tungstate crystals suffer from radiation damge originated from photons/electrons and hadrons. Data obtained at LHC showed that significant light loss is observed at both the barrel and endcaps.
- Data measured at the Caltech crystal lab are used to parametrizing the expected light loss, which is consistent with the ɣ-ray induced light loss.
- Extrapolate to the designed LHC luminosities at 10^{34} 10 to 60% light loss in average is expected. It is a serious challenge to our monitoring system.
- Next two years will see significant light loss in PWO. Adding the loss due to hadrons will make the whole picture more clear.