CsI(Tl)

Lead Tungstate Crystal and its Monitoring for CMS

BGO

Ren-yuan Zhu

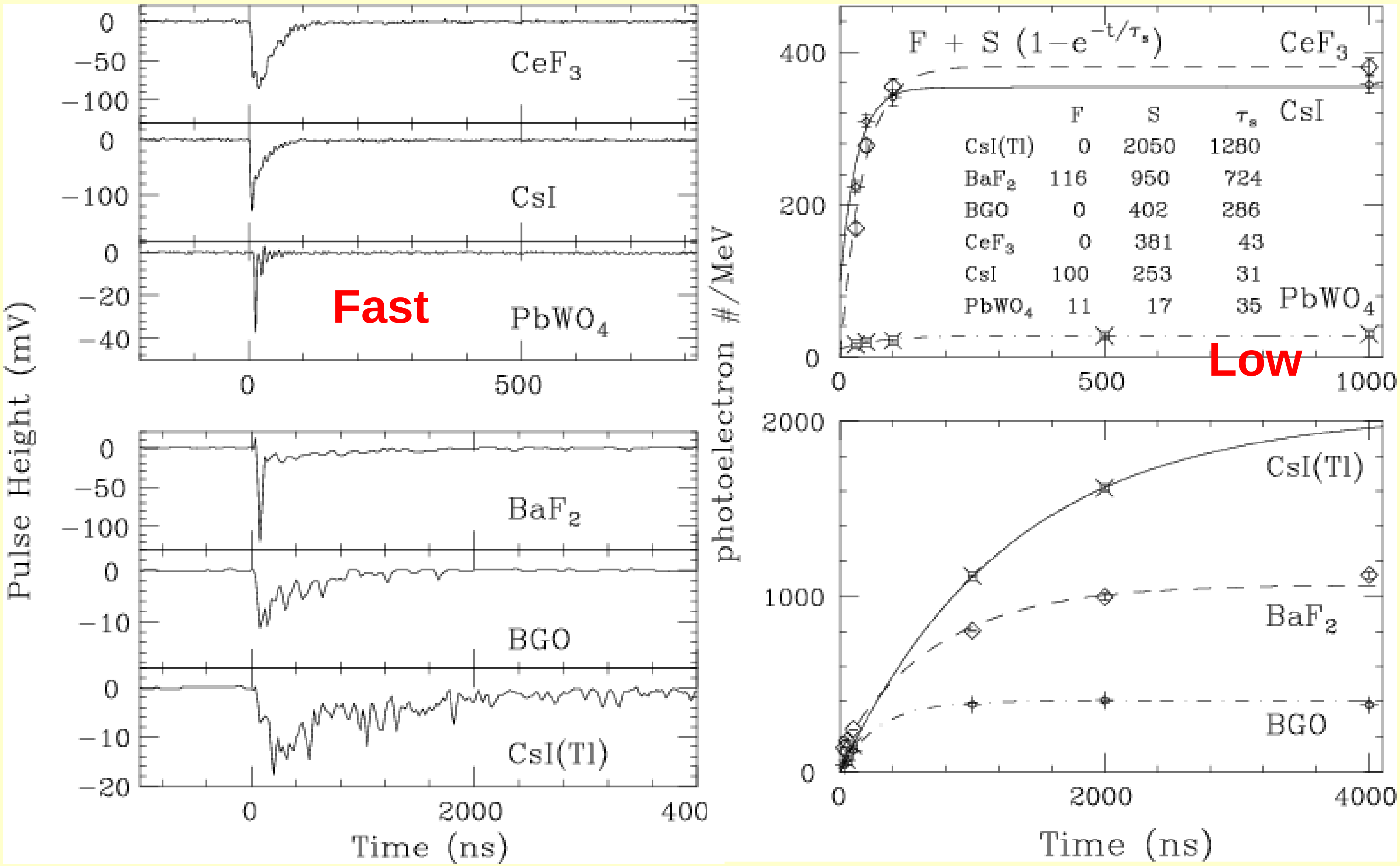
California Institute of technology

PWO

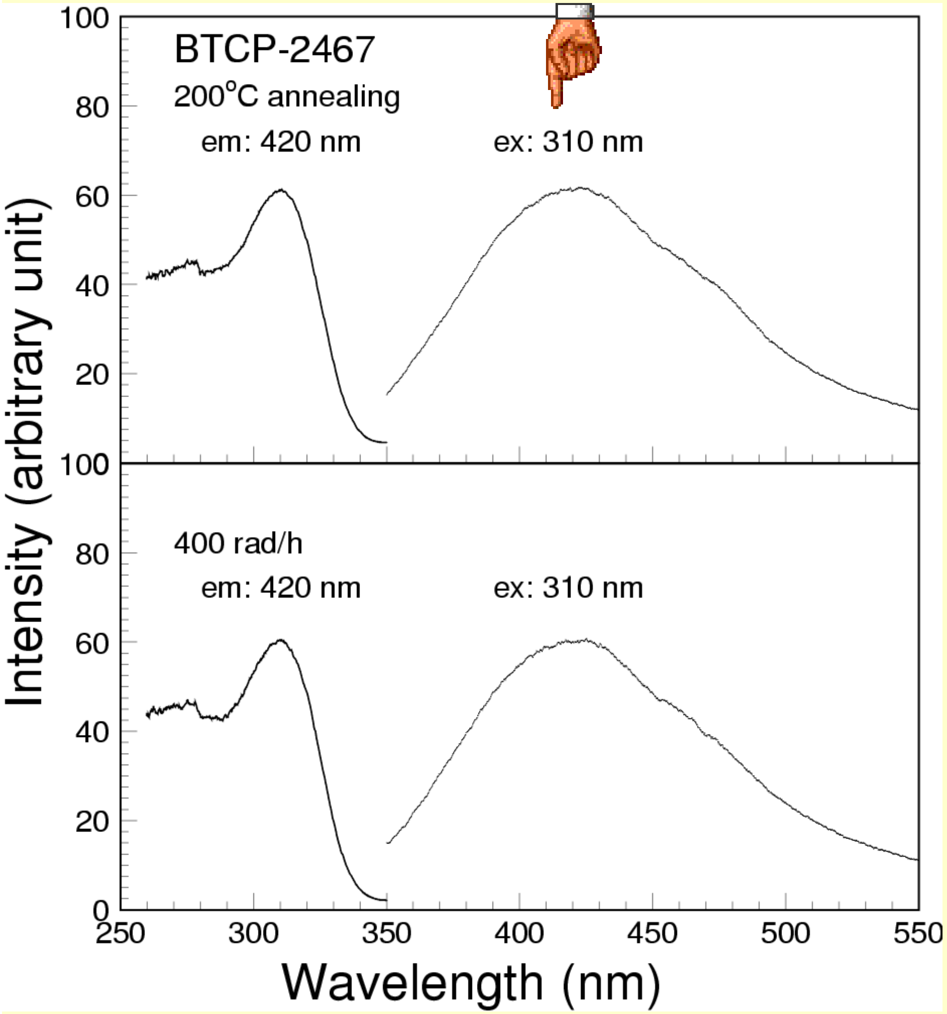
Introduction

- With high density and fast scintillation light, PWO crystal has gained broad application in high energy and nuclear physics: CMS, ALICE, BTeV, PrimEX, Photon Ball@COSY…
- Systematic R&D leads to PWO crystals of high radiation resistance.
- For a precision crystal calorimeter in radiation environment the radiation damage in PWO is taken care of by a light monitoring system.
- The application of PWO may be extended to medical instruments, well beyond academic world.

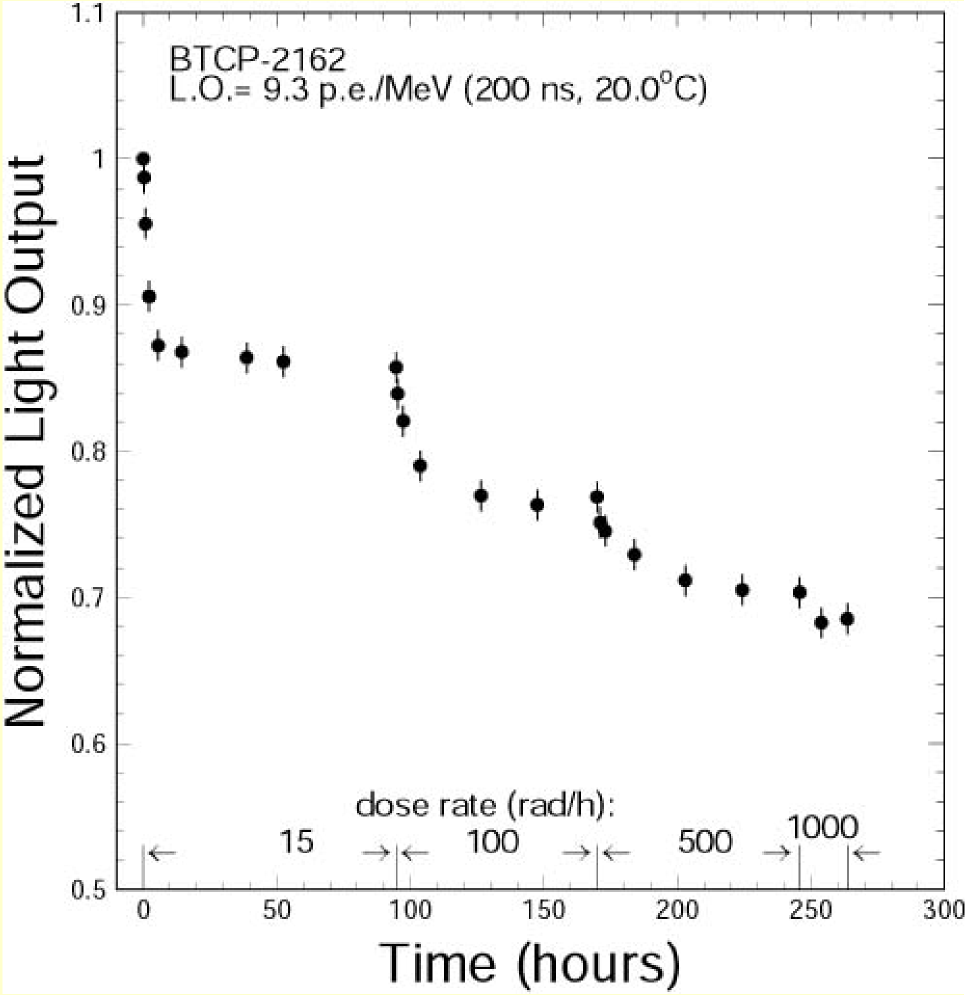
Light output and Decay Time



Scintillation and Dose Rate Dependence

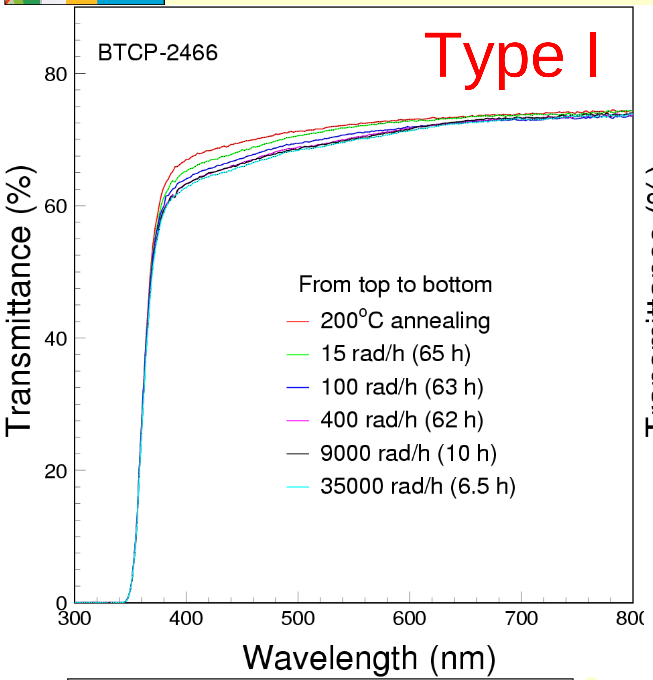


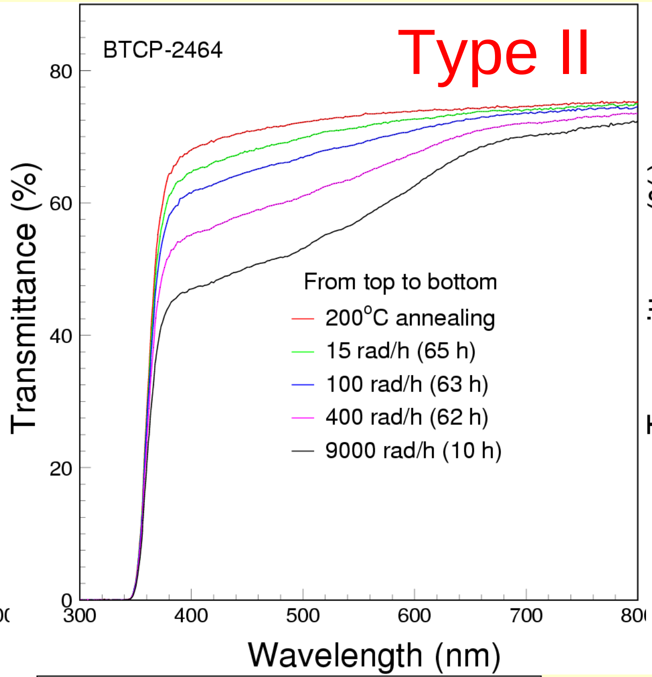
Damage is dose rate dependent because of the equilibrium between color center creation & annihilation

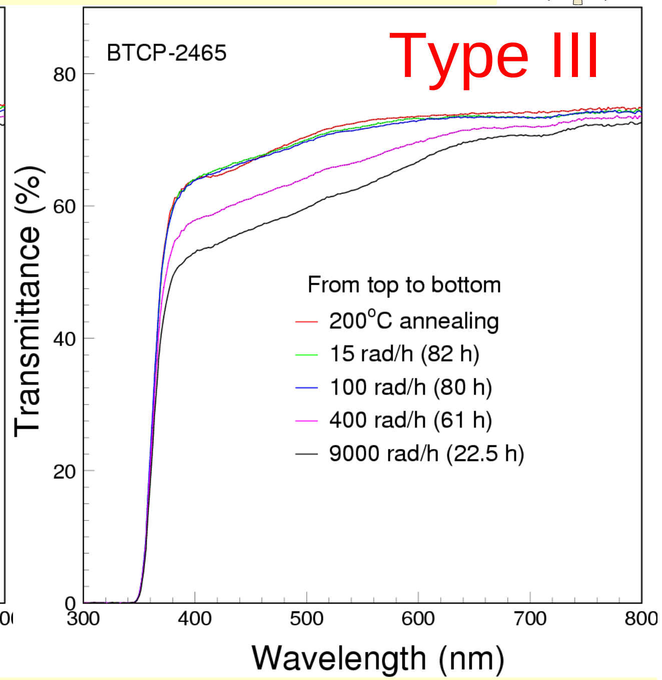


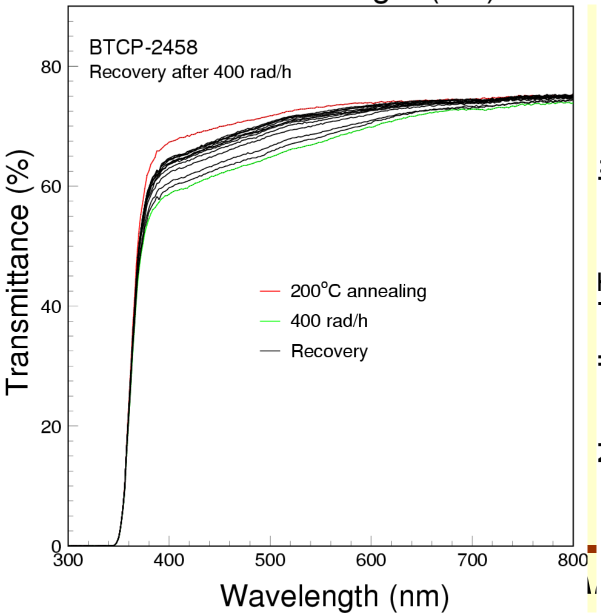
No variation of excitation/emission spectra: no damage in scintillation.

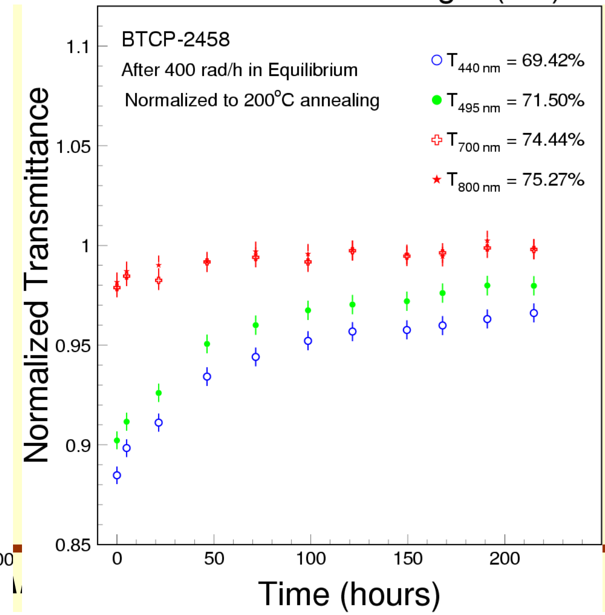
Transmittance Loss and Recovery





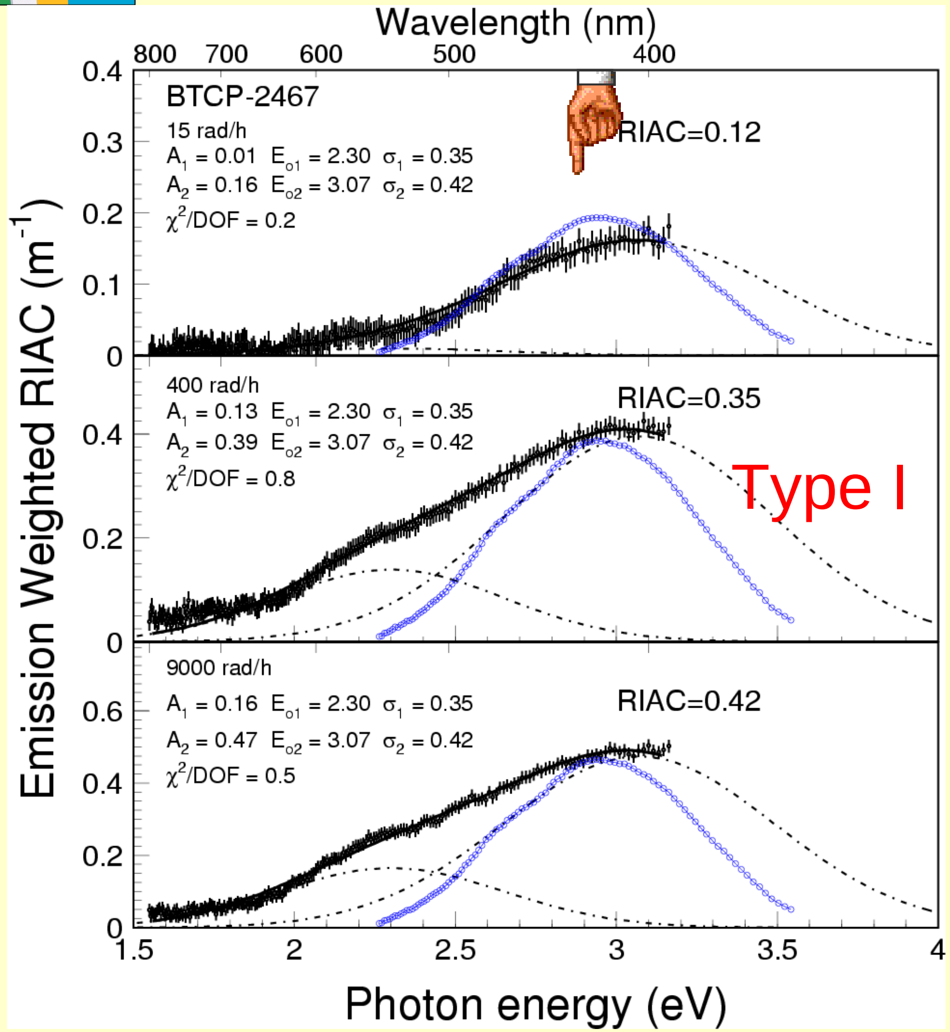






PWO crystals loss transmittance under irradiation and recover, leading to light output variation as a function of time, which needs to be monitored *in situ*.

Radiation Induced Color Centers



C_1: 2.30 eV (540 nm), width: 0.35 eV

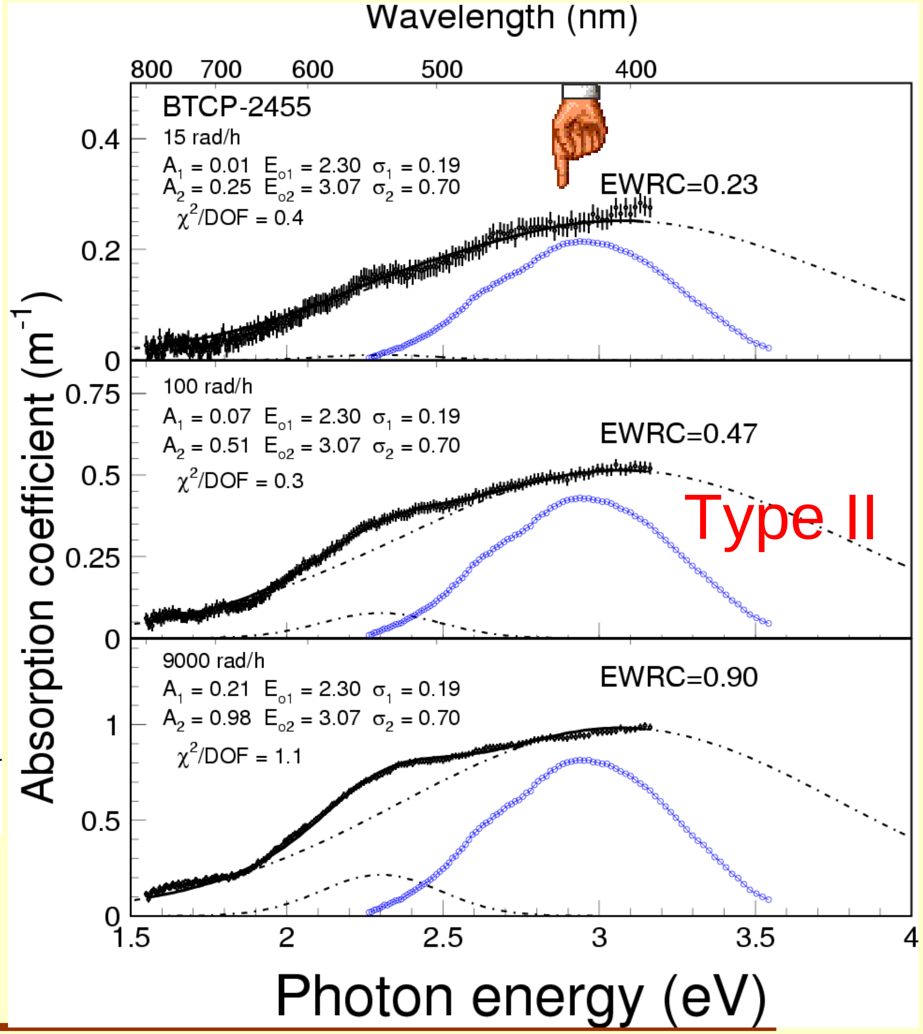
C_2: 3.07 eV (400 nm), width: 0.42 eV

Radiation induced CC density <0.4/m

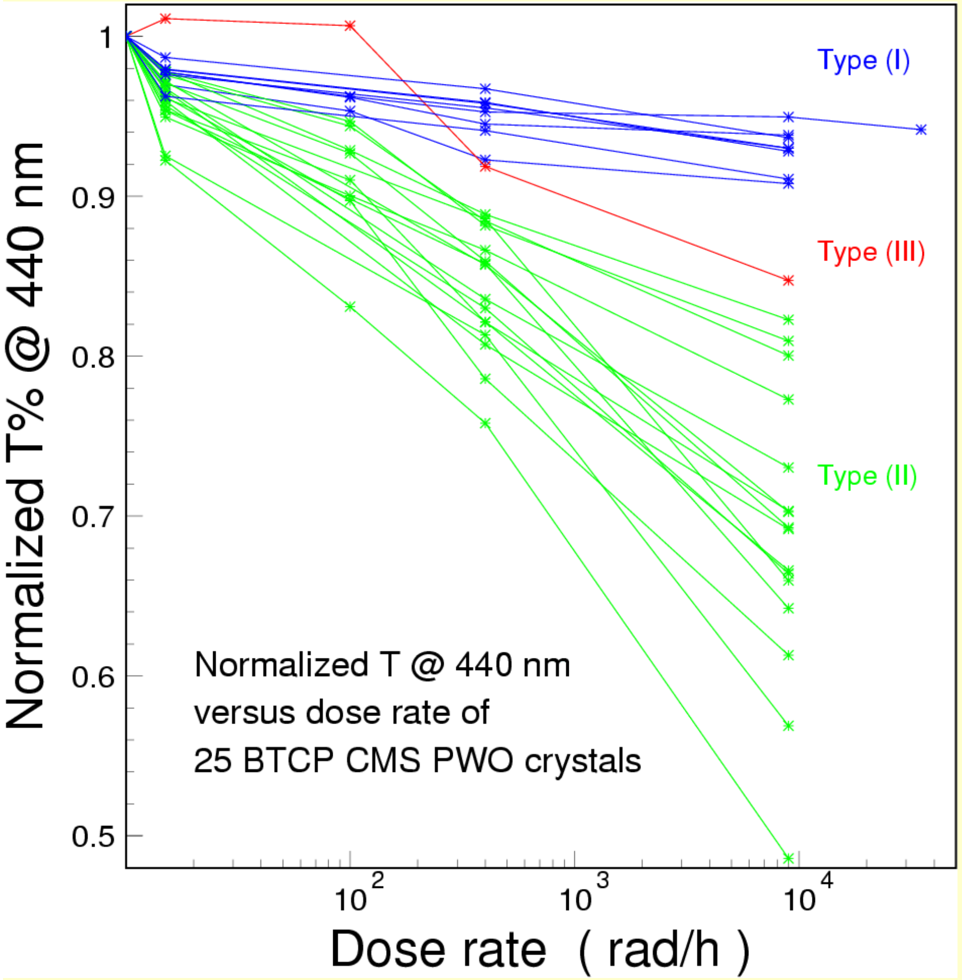
C_1: 2.30 eV (540 nm),width: 0.19 eV

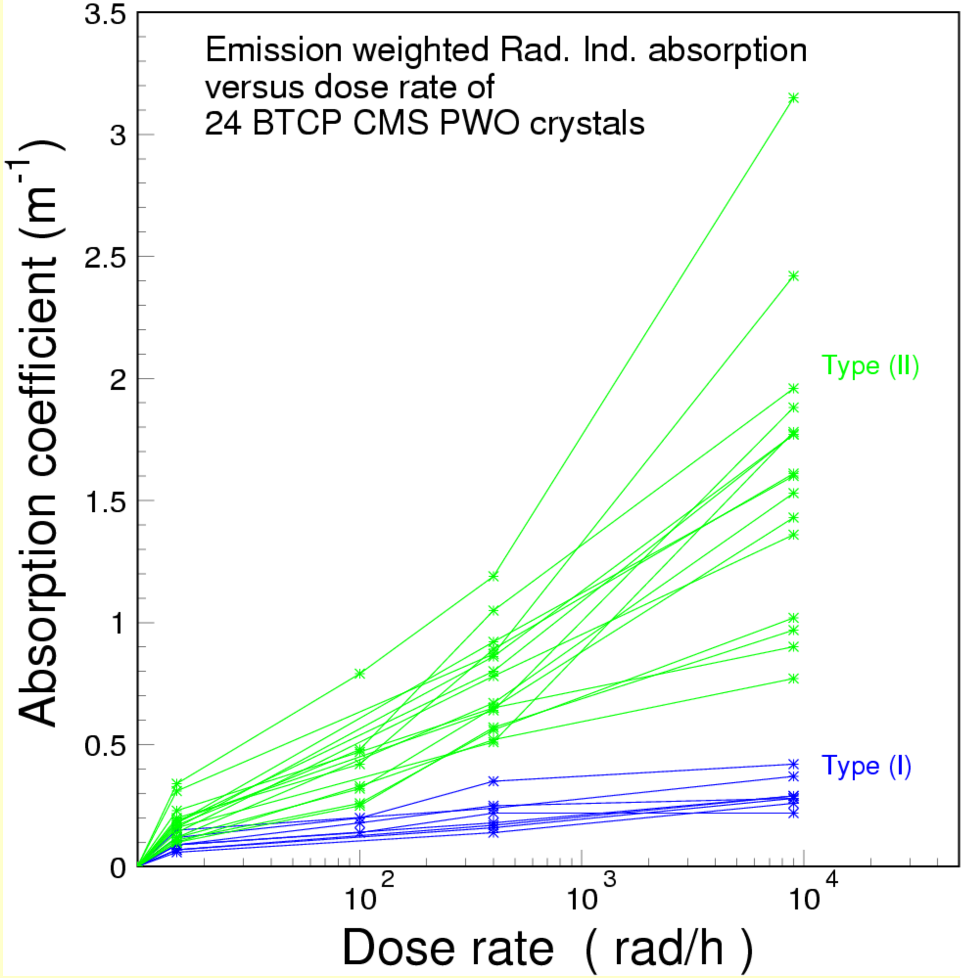
C_2: 3.07 eV (400 nm), width: 0.70 eV

Radiation induced CC density >0.5/m



Summary of 25 PWO Crystals



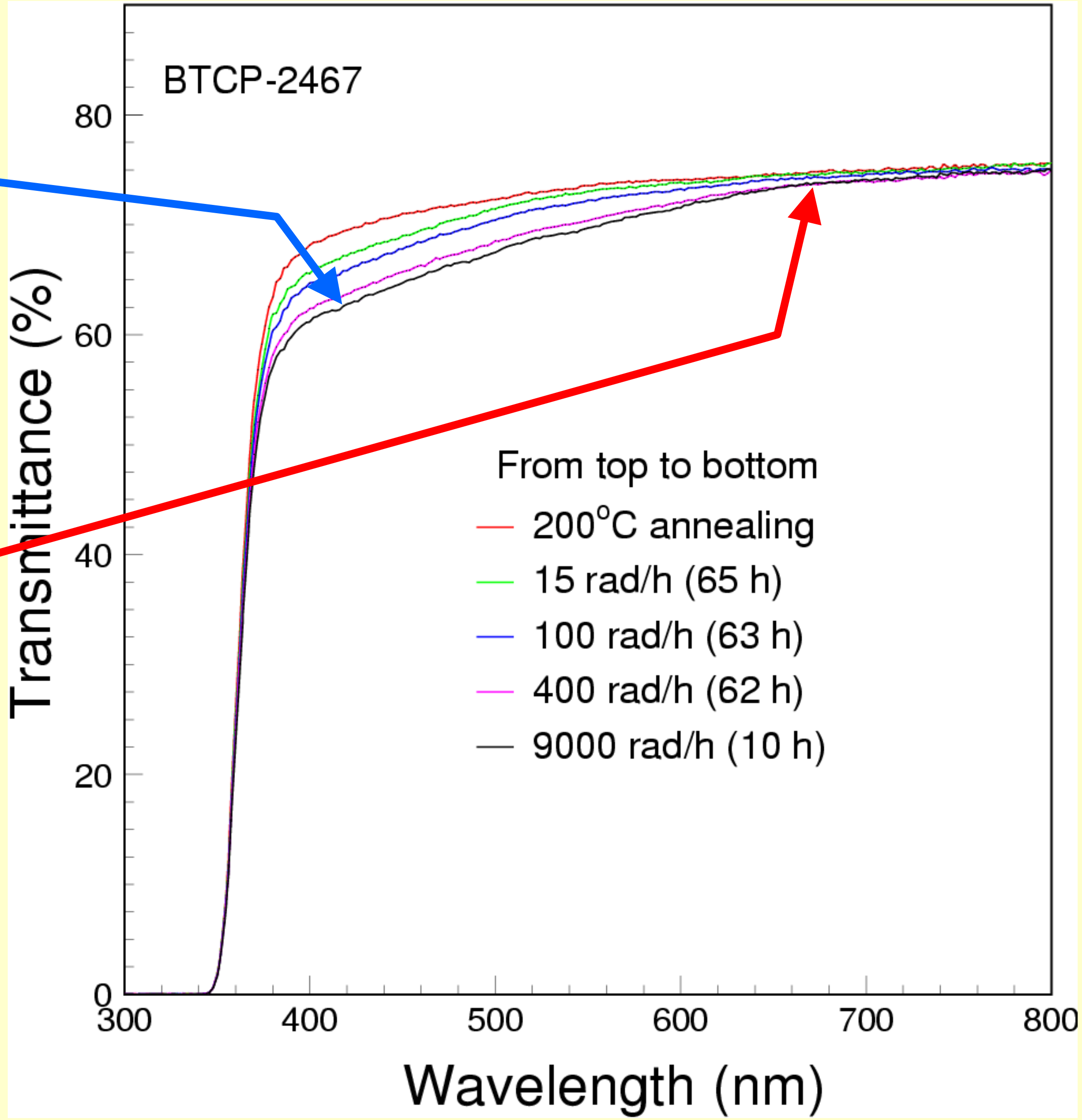


Radiation hard type I can be used for CMS endcaps, where 400 rad/h is expected.
Relative hard type II crystals are for barrel (15 rad/h). Type III crystals are rejected.

Monitoring Radiation Damage

Radiation induces color centers
→ reduces transmittance in the blue and green
→ monitoring the relative loss of transmittance with pulsed laser light

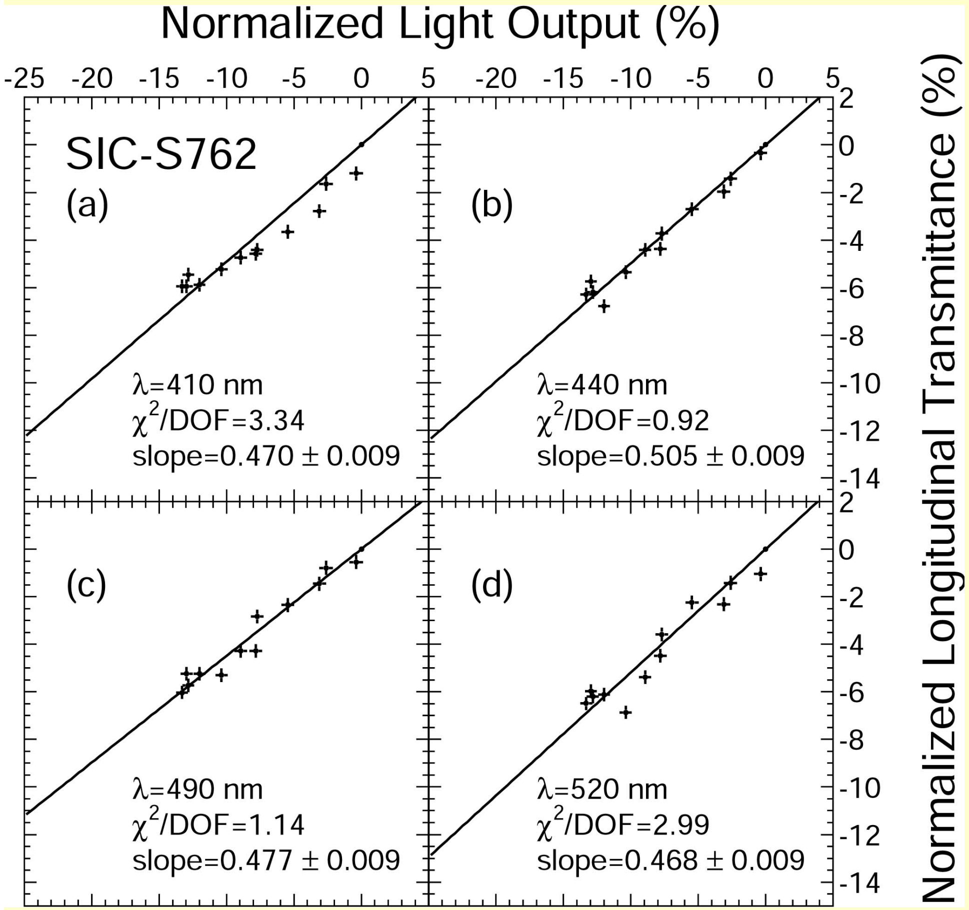
Little damage in the red
→ monitor with red and IR laser pulse to separate out possible variations in the other components of the readout chain

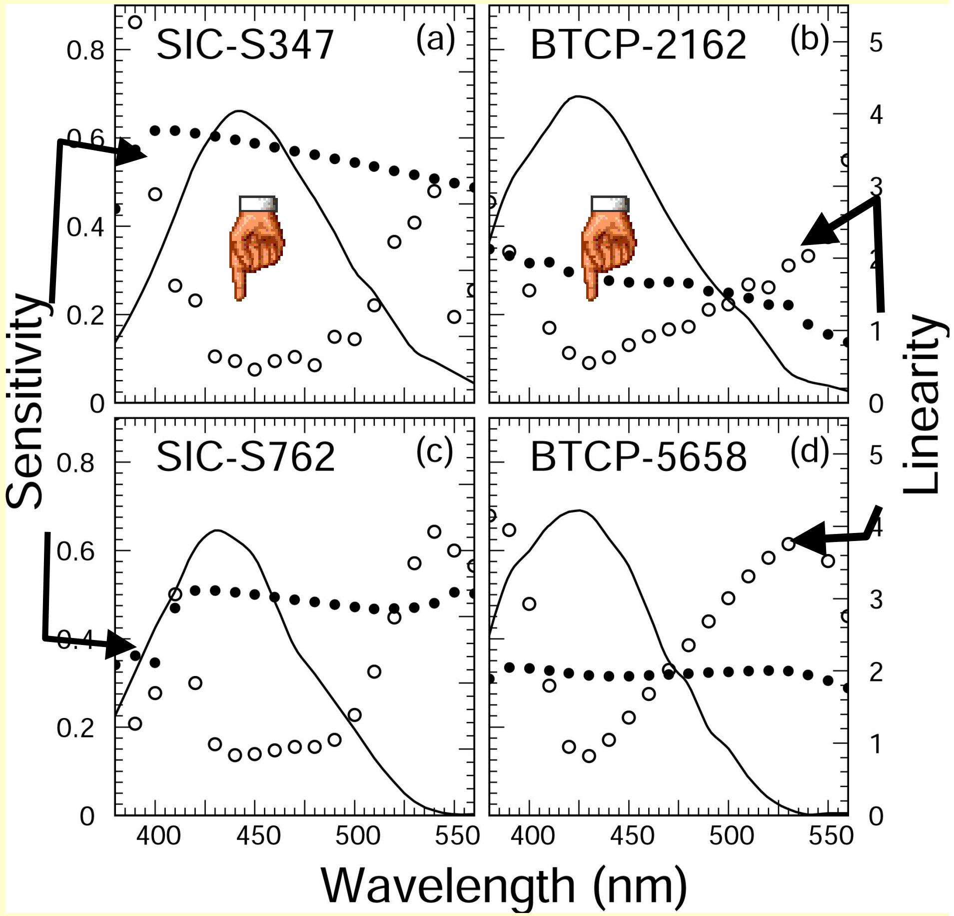


Choice of the Monitoring Wavelength

$\Delta(T) = S \times \Delta(LY)$

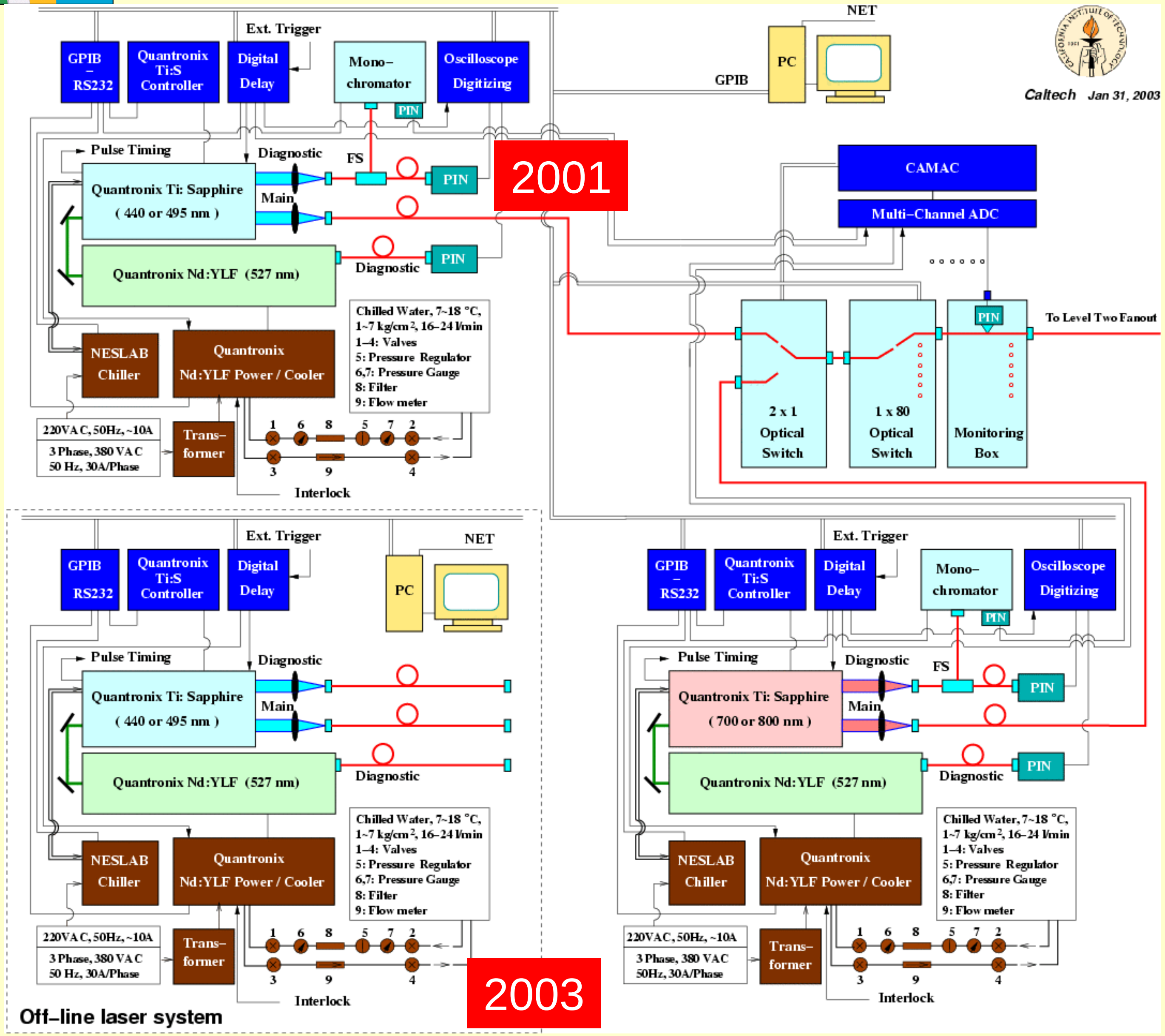
optimize sensitivity and linearity





→ 440 nm is chosen for the best linearity

Layout of Laser Light Source

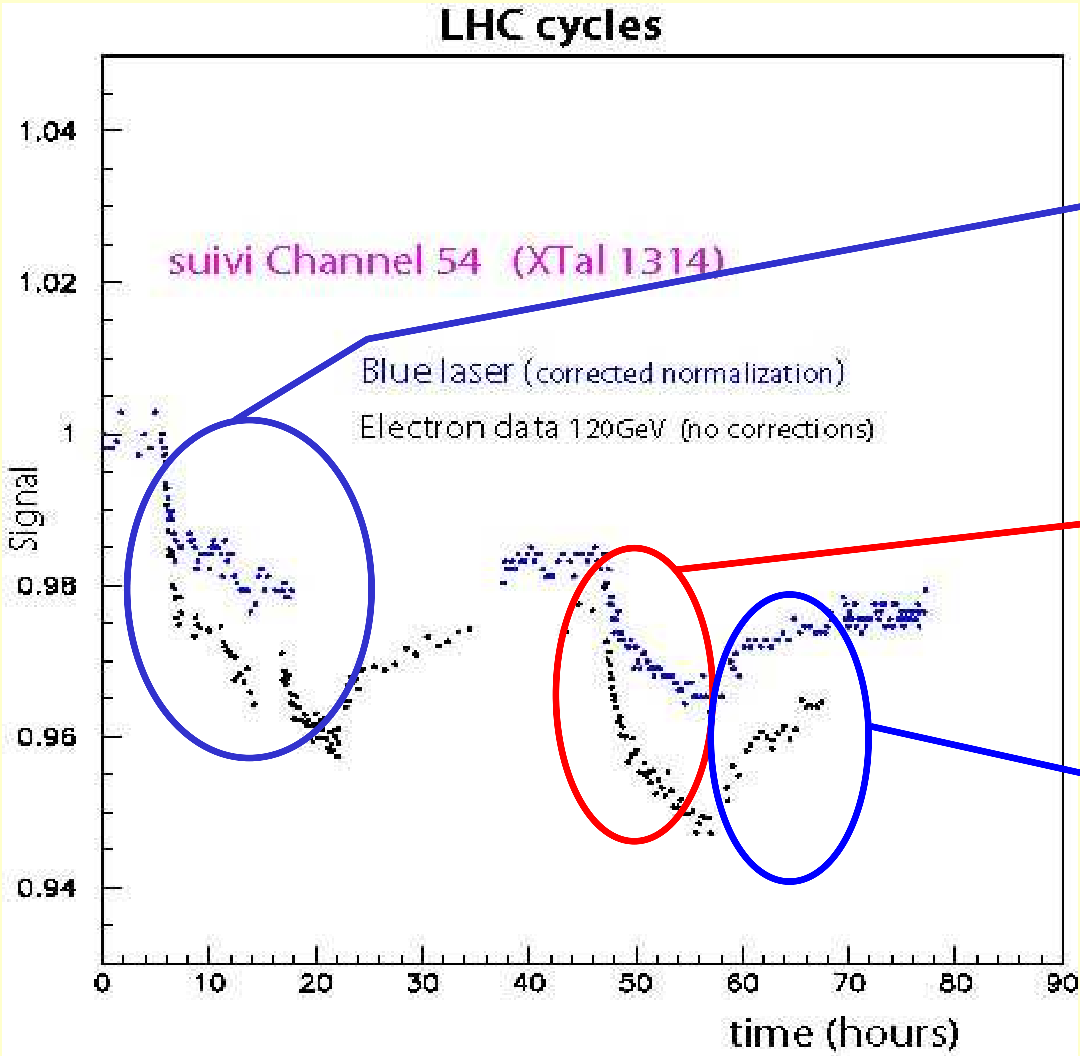


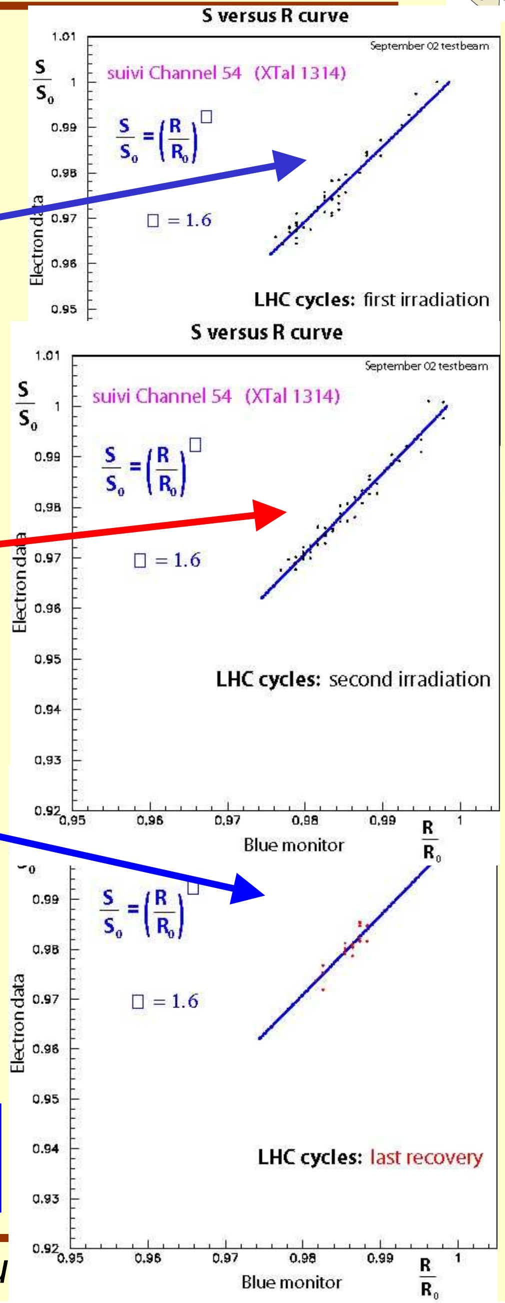
PC based Laser DAQ history recording of laser performance.

Optical switch directs monitoring laser pulses to 80 super-modules and from there to crystals

Two laser systems: 440/495 nm and 700/800 nm with own diagnostics on wavelength, pulse shape and pulse intensity.

Experiences from 2002 Beam Test

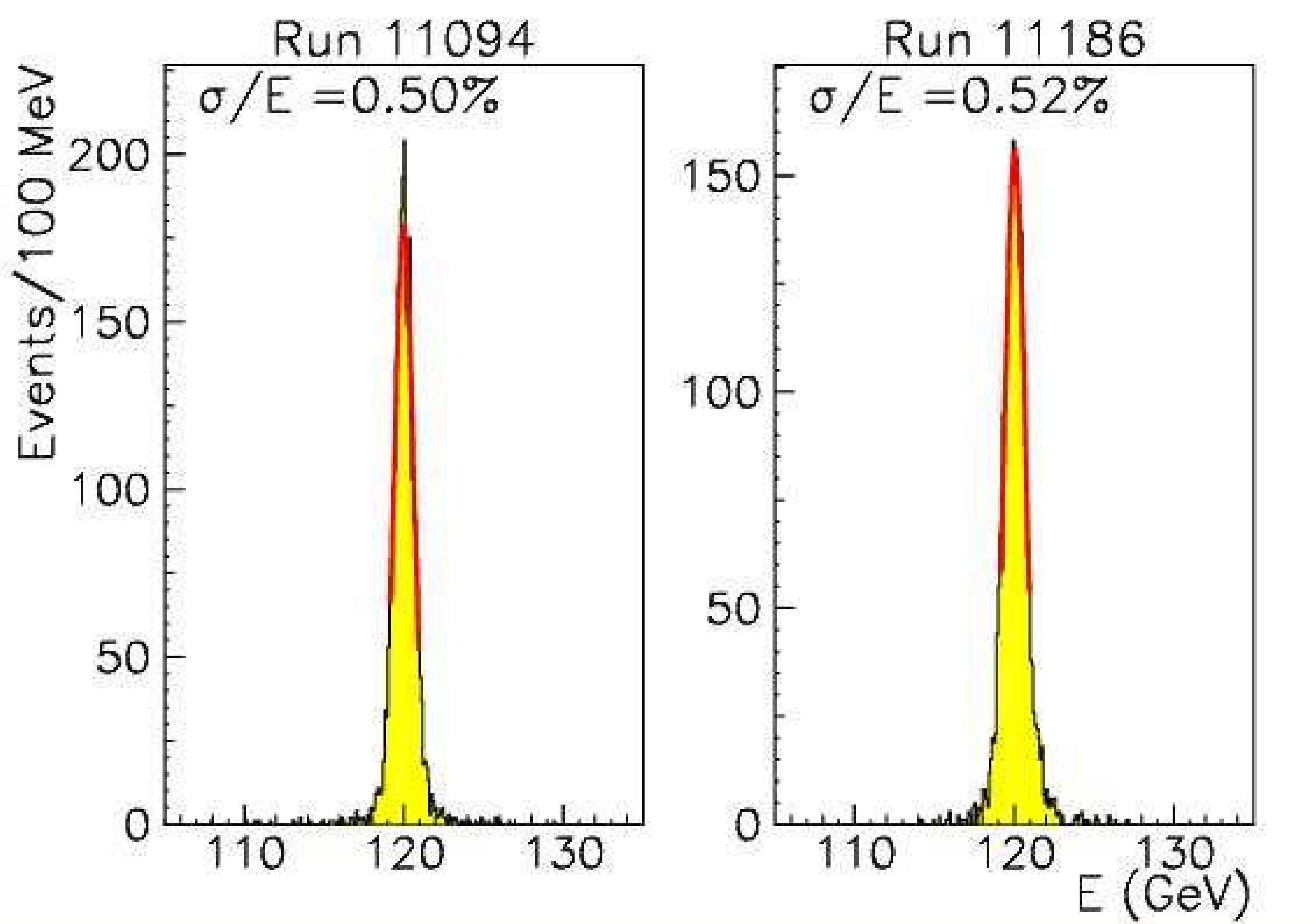




Same slope for all irradiations and recoveries

PWO Resolution With Light Monitoring

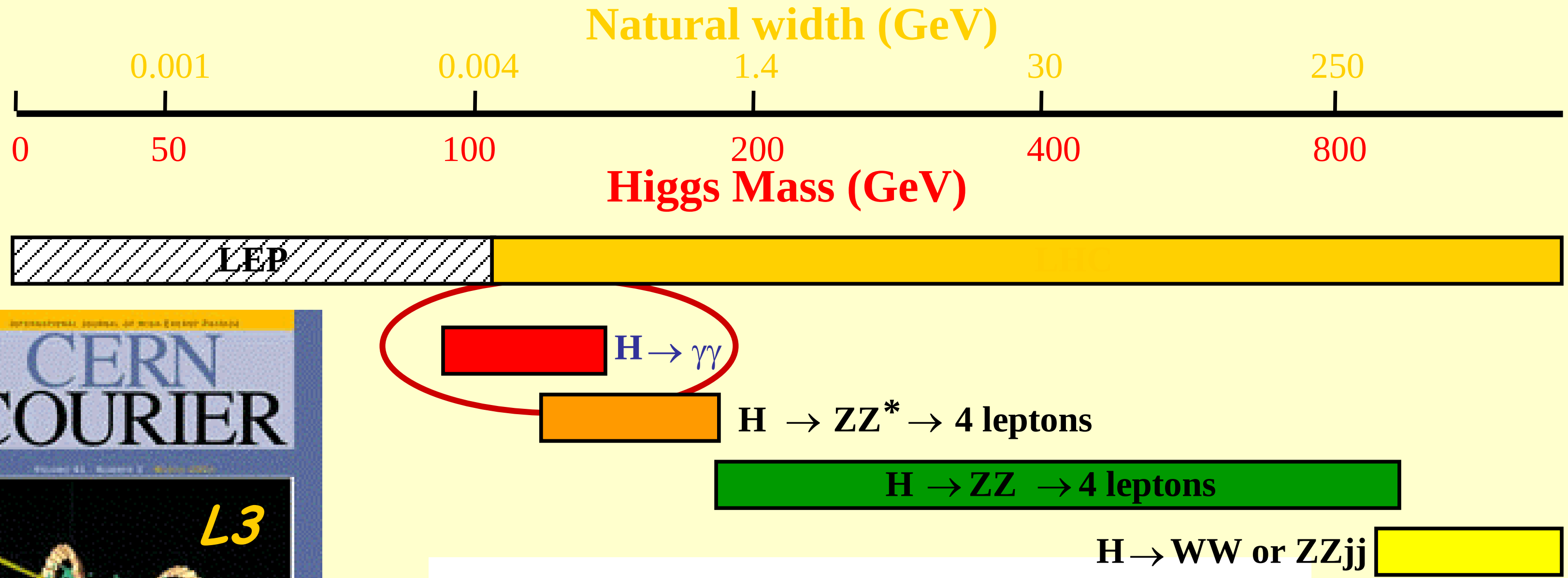
Before and after beam irradiation with 10% variation of crystal light output



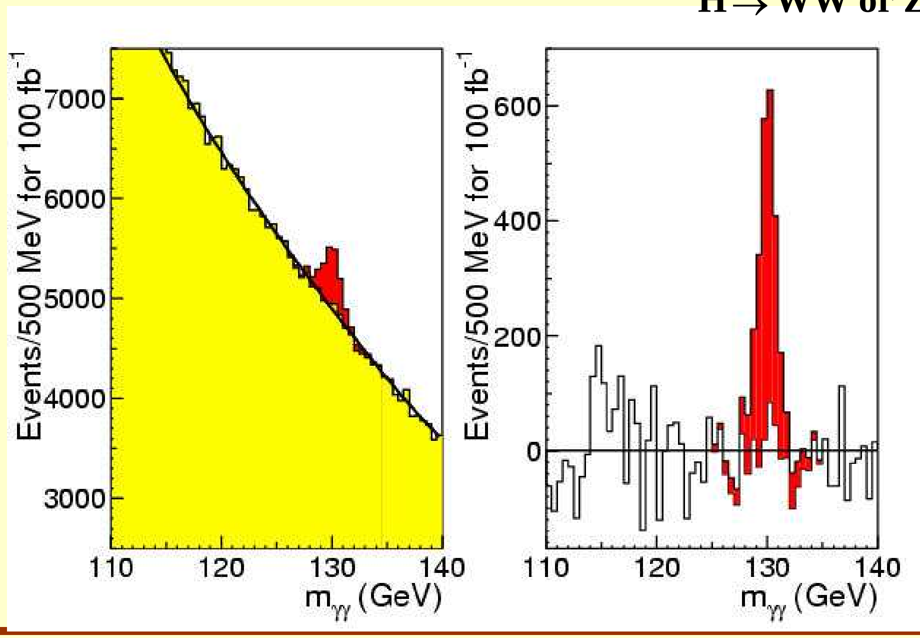
Summary

- Radiation damage in PWO crystal is fairly well understood: no damage in scintillation, damage is caused by radiation induced color center formation and is dose rate dependent.
- Recently developed PWO crystals (type I) are very radiation hard can be used at CMS endcaps, where 400 rad/h is expected.
- Variations of PWO crystal light output are monitored by a light monitoring system *in situ*.
- Important development has been achieved for precision crystal calorimetry in radiation environment. Looking forward to precision e/γ physics at LHC.

Higgs Hunt at Low Mass



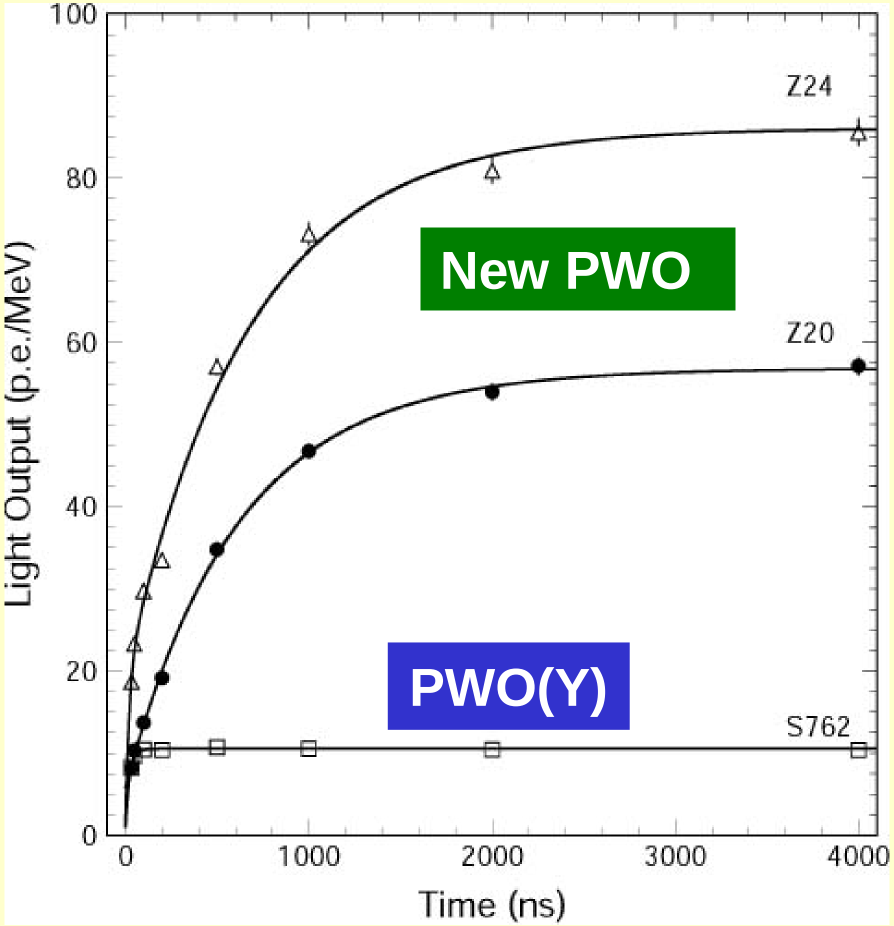
LEP observed an excess of events around 115 GeV



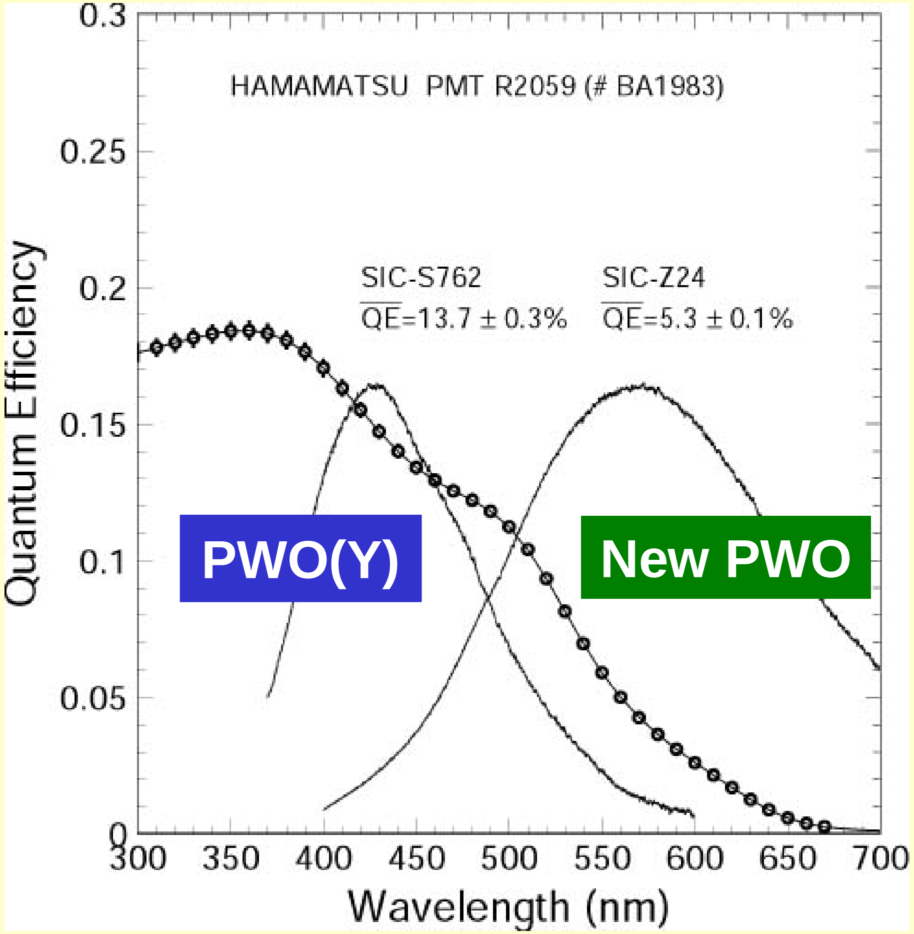
H →γγ signal in CMS ECAL @ design resolution

PWO Crystal with High Light Yield

Decay Kinetics



QE of PMT and Emission



Taking into account of PMT QE, new PWO has 10 X LY

Properties of Crystal Scintillators

Crystal	NaI(Tl)	CsI(Tl)	CsI	BaF_2	BGO	$PbWO_4$	LSO(Ce)	GSO(Ce)
Density (g/cm^3)	3.67	4.51	4.51	4.89	7.13	8.3	7.40	6.71
Melting Point (°C)	651	621	621	1280	1050	1123	2050	1950
Radiation Length (cm)	2.59	1.85	1.85	2.06	1.12	0.9	1.14	1.37
Molière Radius (cm)	4.8	3.5	3.5	3.4	2.3	2.0	2.3	2.37
Interaction Length (cm)	41.4	37.0	37.0	29.9	21.8	18	21	22
Refractive Index [a]	1.85	1.79	1.95	1.50	2.15	2.2	1.82	1.85
Hygroscopicity	Yes	Slight	Slight	No	No	No	No	No
Luminescence [b] (nm) (at peak)	410	560	420 310	300 220	480	560 420	420	440
Decay Time [b] (ns)	230	1300	35 6	630 0.9	300	50 10	40	60
Light Yield [b,c] (%)	100	45	5.6 2.3	21 2.7	9	0.1 0.6	75	30
d(LY)/dT [b] (%/ °C)	~0	0.3	-0.6	-2 ~0	-1.6	-1.9	?	?
Experiment	Crystal Ball	CLEO BaBar BELLE	KTeV	(L*) (GEM) TAPS	L3 BELLE	CMS ALICE BTeV…	-	-

a. at peak of emission; b. up/low row: slow/fast component; c. measured by PMT of bi-alkali cathode.