Search for Radiation Induced Transparency Change in the CMS ECAL

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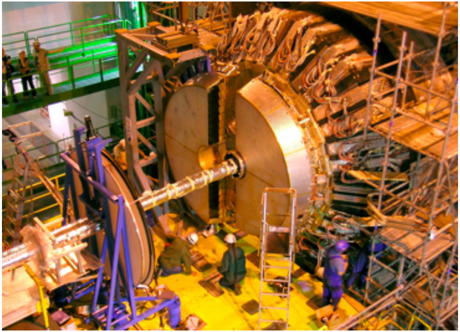
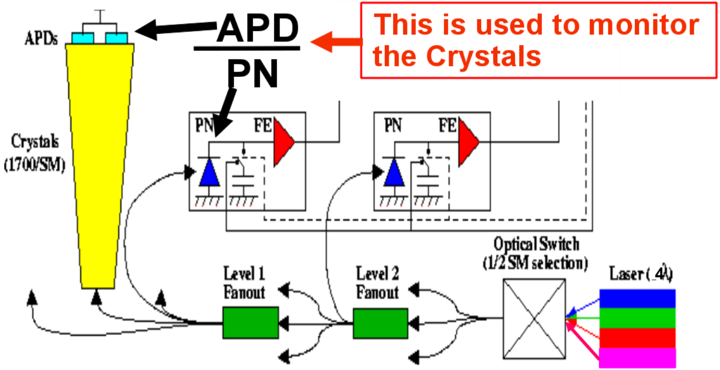
CMS Detector

- General Purpose Detector to Look for New Physics
- Desired sensitivity to see $H \rightarrow \gamma\gamma$ reaction
- Study to Understand Systematics of CMS ECAL
  - Radiation Effects in Lead Tungstate Crystals
  - VPT Instabilities



A. Bornheim, CalTech Tuesday Seminar (2005).

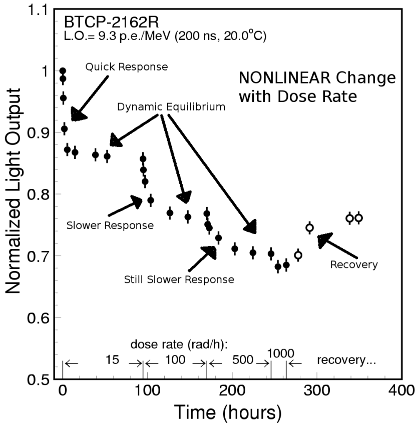
Laser Monitoring



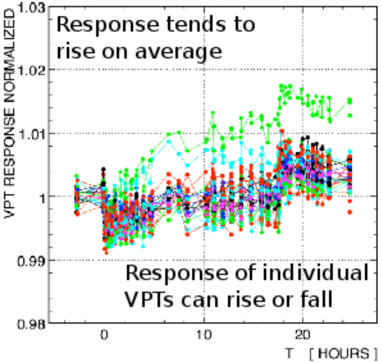
A. Bornheim, CalTech Tuesday Seminar (2005).

Expected Crystal Response

Change in transparency of a typical crystal for different dose rates [1]



VPT response for multiple VPTs with LED pulsing [2]

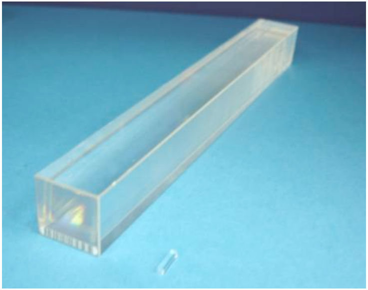


[1] R. Zhu 5/6/2006

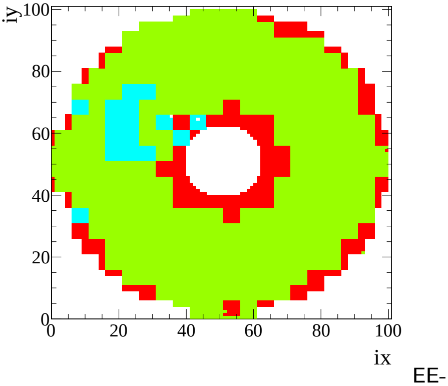
[2] D.A. Petyt 3/9/2009 from S. Ledovskoy

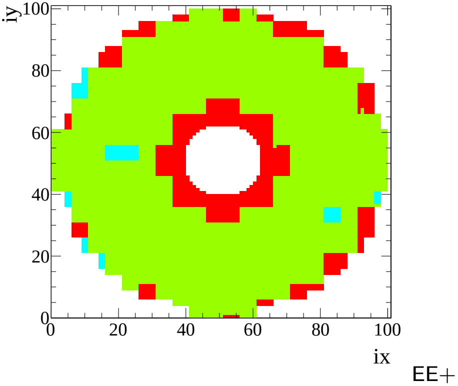
Motivation

- Try to be sensitive to any changes in VPT/PN signal due to radiation
    - Assume crystals far from CMS beam axis (with least radiation) will show least change
    - Assume non-beam related systematics are independent of ϕ and η
    - Assume crystals in areas of constant η behave similarly



Map of Crystals

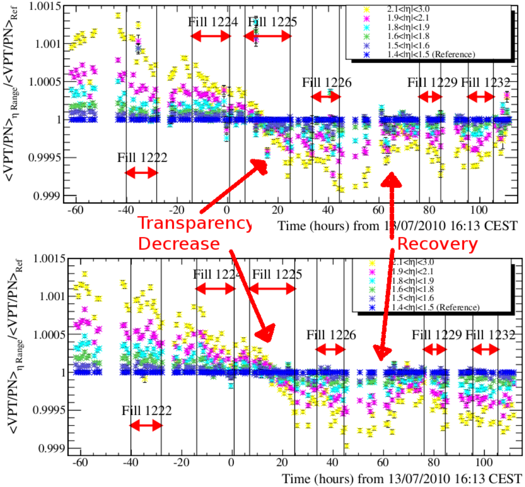




Red = SIC (Chinese), Green = BTCP (Russian), Blue = APATITY

VPT/PN Fluctuations in Russian Crystals

$<\text{VPT/PN}>_{\eta\,\mathrm{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



EE-

EE+

Fill 1222: $\int \mathcal{L}dt = 22.1$ nb^{-1}
$\bar{\mathcal{L}} = 0.60\ \mu\text{b}^{-1}/s$

Fill 1224: $\int \mathcal{L}dt = 30.3$ nb^{-1}
$\bar{\mathcal{L}} = 0.78\ \mu\text{b}^{-1}/s$

Fill 1225: $\int \mathcal{L}dt = 58.5$ nb^{-1}
$\bar{\mathcal{L}} = 1.00\ \mu\text{b}^{-1}/s$

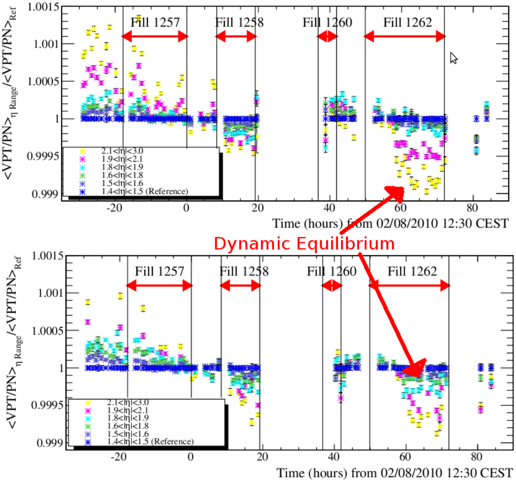
Fill 1226: $\int \mathcal{L}dt = 23.4$ nb^{-1}
$\bar{\mathcal{L}} = 0.65\ \mu\text{b}^{-1}/s$

Fill 1229: $\int \mathcal{L}dt = 17.2$ nb^{-1}
$\bar{\mathcal{L}} = 0.89\ \mu\text{b}^{-1}/s$

Fill 1232: $\int \mathcal{L}dt = 17.1$ nb^{-1}
$\bar{\mathcal{L}} = 0.55\ \mu\text{b}^{-1}/s$

VPT/PN Fluctuations in Russian Crystals

$<$VPT/PN$>_{\eta \mathrm{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



EE-

EE+

Fill 1257: $\int \mathcal{L} dt = 102\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 1.66\ \mu\mathrm{b}^{-1}/s$

Fill 1258: $\int \mathcal{L} dt = 56.4\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 1.68\ \mu\mathrm{b}^{-1}/s$

Fill 1260: $\int \mathcal{L} dt = 15.3\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 2.41\ \mu\mathrm{b}^{-1}/s$

Fill 1262: $\int \mathcal{L} dt = 112\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 1.68\ \mu\mathrm{b}^{-1}/s$

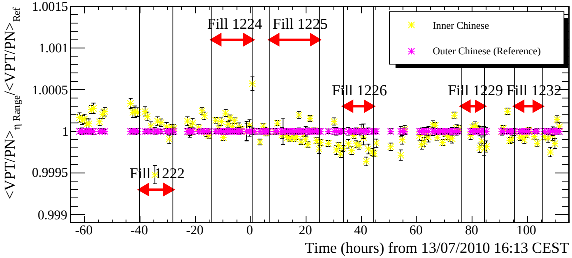
VPT/PN Fluctuations in Russian Crystals

- $\sim$1‰ change for radiation dose of $\sim$1 mGy* as estimated in slide 7 (2.1$<|\eta|<$2.3 ring in fill 1262 with $\int \mathcal{L}dt = 112.0$ nb^{-1} in 22 hr)
- Amount of change is highest in rings with highest η, lowest in rings with lowest η as expected
- $\sim$40% recovery in 31 hr between fill 1226 and fill 1229
- In fill 1262, dynamic equilibrium reached after $\sim$12 hours (signal fluctuates $<$0.3‰ after this time)
- Overall change of $>$1‰ in 2.1$<|\eta|<$2.3 ring in the 150 hr shown in slide 9 (Total $\int \mathcal{L}dt = 168.6$ nb^{-1} $\approx\sim$2 mGy* as estimated in slide 7)

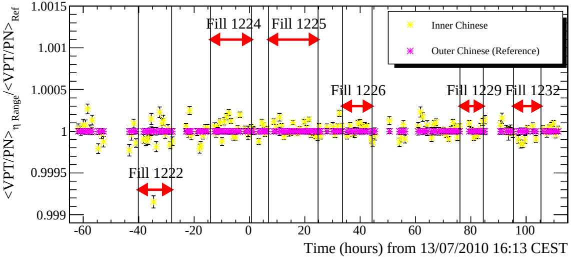
*Radiation doses have a large error and may be off to about a factor of 10

VPT/PN Fluctuations in Chinese Crystals

$<\mathrm{VPT/PN}>_{\eta\mathrm{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



EE-



EE+

No obvious beam effects

Fill 1222: $\int \mathcal{L}dt = 22.1\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 0.60\ \mu\mathrm{b}^{-1}/s$

Fill 1224: $\int \mathcal{L}dt = 30.3\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 0.78\ \mu\mathrm{b}^{-1}/s$

Fill 1225: $\int \mathcal{L}dt = 58.5\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 1.00\ \mu\mathrm{b}^{-1}/s$

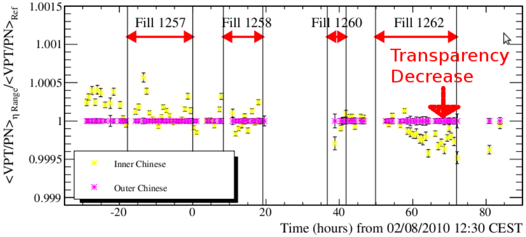
Fill 1226: $\int \mathcal{L}dt = 23.4\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 0.65\ \mu\mathrm{b}^{-1}/s$

Fill 1229: $\int \mathcal{L}dt = 17.2\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 0.89\ \mu\mathrm{b}^{-1}/s$

Fill 1232: $\int \mathcal{L}dt = 17.1\ \mathrm{nb}^{-1}$
$\bar{\mathcal{L}} = 0.55\ \mu\mathrm{b}^{-1}/s$

VPT/PN Fluctuations in Chinese Crystals

<VPT/PN>$_{\eta \mathrm{Range}}$ ≡ Normalized, corrected VPT/PN averaged over η range in legend



Fill 1257: $\int \mathcal{L}dt = 102$ nb^{-1}
$\bar{\mathcal{L}} = 1.66\ \mu$b$^{-1}/s$
Fill 1258: $\int \mathcal{L}dt = 56.4$ nb^{-1}
$\bar{\mathcal{L}} = 1.68\ \mu$b$^{-1}/s$
Fill 1260: $\int \mathcal{L}dt = 15.3$ nb^{-1}
$\bar{\mathcal{L}} = 2.41\ \mu$b$^{-1}/s$
Fill 1262: $\int \mathcal{L}dt = 112$ nb^{-1}
$\bar{\mathcal{L}} = 1.68\ \mu$b$^{-1}/s$

EE-

EE-

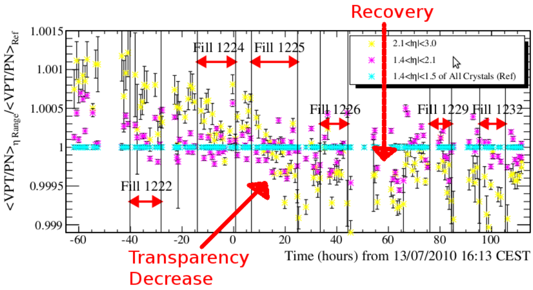
VPT/PN Fluctuations in Chinese Crystals

- $\sim$0.2‰ change for radiation dose of $\sim$2 mGy* as estimated in slide 7 (2.3$<|\eta|<$3.0 ring in fill 1262 with $\int \mathcal{L}dt = 112.0\ \mathrm{nb}^{-1}$ in 22 hr)
- Chinese crystals change 20% as much as Russian ones, with significantly higher radiation dose
- $<$0.1‰ overall change in 2.3$<|\eta|<$3.0 ring in the 150 hr shown in slide 12 (Total $\int \mathcal{L}dt = 168.6\ \mathrm{nb}^{-1}$ $\approx\sim$3 mGy* as estimated in slide 7)
- Testbeam results comparing Chinese and Russian crystals [click]

*Radiation doses have a large error and may be off to about a factor of 10

VPT/PN Fluctuations in APATITY Crystals

$<$VPT/PN$>_{\eta \mathrm{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



EE-

EE-

Fill 1222: $\int \mathcal{L} dt = 22.1$ nb^{-1}
$\bar{\mathcal{L}} = 0.60\ \mu$b$^{-1}/s$

Fill 1224: $\int \mathcal{L} dt = 30.3$ nb^{-1}
$\bar{\mathcal{L}} = 0.78\ \mu$b$^{-1}/s$

Fill 1225: $\int \mathcal{L} dt = 58.5$ nb^{-1}
$\bar{\mathcal{L}} = 1.00\ \mu$b$^{-1}/s$

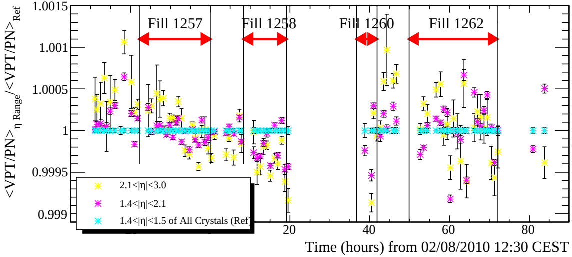
Fill 1226: $\int \mathcal{L} dt = 23.4$ nb^{-1}
$\bar{\mathcal{L}} = 0.65\ \mu$b$^{-1}/s$

Fill 1229: $\int \mathcal{L} dt = 17.2$ nb^{-1}
$\bar{\mathcal{L}} = 0.89\ \mu$b$^{-1}/s$

Fill 1232: $\int \mathcal{L} dt = 17.1$ nb^{-1}
$\bar{\mathcal{L}} = 0.55\ \mu$b$^{-1}/s$

VPT/PN Fluctuations in APATITY Crystals

$<\text{VPT/PN}>_{\eta\text{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



Fill 1257: $\int \mathcal{L}dt = 102\ \text{nb}^{-1}$
$\bar{\mathcal{L}} = 1.66\ \mu\text{b}^{-1}/s$
Fill 1258: $\int \mathcal{L}dt = 56.4\ \text{nb}^{-1}$
$\bar{\mathcal{L}} = 1.68\ \mu\text{b}^{-1}/s$
Fill 1260: $\int \mathcal{L}dt = 15.3\ \text{nb}^{-1}$
$\bar{\mathcal{L}} = 2.41\ \mu\text{b}^{-1}/s$
Fill 1262: $\int \mathcal{L}dt = 112\ \text{nb}^{-1}$
$\bar{\mathcal{L}} = 1.68\ \mu\text{b}^{-1}/s$

EE-

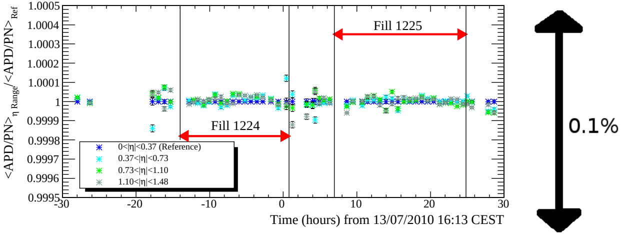
VPT/PN Fluctuations in APATITY Crystals

- $\sim$1‰ change for radiation dose of $\sim$1 mGy* as estimated in slide 7 (2.1$<|\eta|<$3.0 ring in fill 1225 with $\int \mathcal{L}dt = 58.5\ \mathrm{nb}^{-1}$ in 18 hr)
- Act more like Russian crystals
- $\sim$40% recovery in 31 hr between fill 1226 and fill 1229
- No obvious signs of reaching dynamic equilibrium
- Are near the center in EE- but change more easily than Chinese crystals
- $\sim$1.2‰ overall change in 2.3$<|\eta|<$3.0 ring in the 150 hr shown in slide 15 (Total $\int \mathcal{L}dt = 168.6\ \mathrm{nb}^{-1} \approx\sim$3 mGy* as estimated in slide 7)

*Radiation doses have a large error and may be off to about a factor of 10

APD/PN Fluctuations in the Barrel for all Crystals

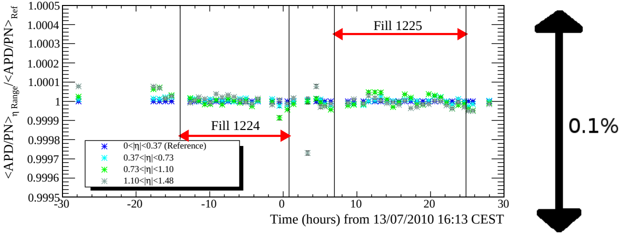
$<\mathrm{APD/PN}>_{\eta\mathrm{Range}} \equiv$ Normalized, corrected APD/PN averaged over η range in legend



EB-

Beam effects in barrel

<0.2‰



EB+

Fill 1224: $\int \mathcal{L}dt = 30.3\ \mathrm{nb}^{-1}$

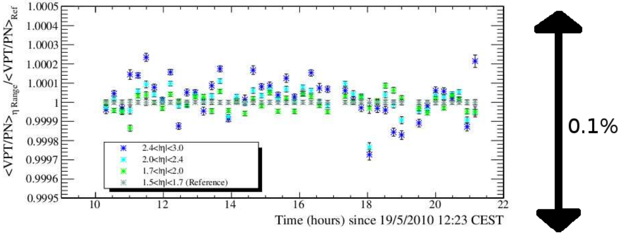
$\bar{\mathcal{L}} = 0.78\ \mu\mathrm{b}^{-1}/s$

Fill 1225: $\int \mathcal{L}dt = 58.5\ \mathrm{nb}^{-1}$

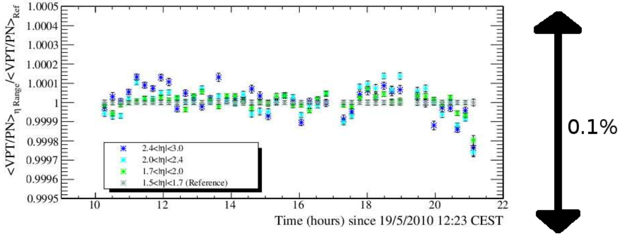
$\bar{\mathcal{L}} = 1.00\ \mu\mathrm{b}^{-1}/s$

VPT/PN Fluctuations with no beam for all Crystals

$<\text{VPT/PN}>_{\eta \text{Range}} \equiv$ Normalized, corrected VPT/PN averaged over η range in legend



EE-



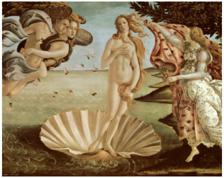
EE+

No large changes in transparency as observed with beam runs

Summary

- See changes in VPT/PN which are compatible with radiation induced transparency change
- Chinese crystals more resistant to change than Russian ones
- Some signs of recovery, but transparency does not recover fully
- Reach dynamic equilibrium in longer high intensity runs
- Observed changes do not fit typical thermal or VPT effects [click]

Art



Music

Food

Nature





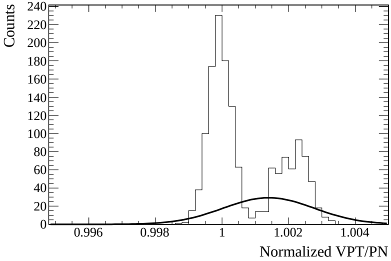

Acknowledgements

- Saclay team for setting up and operating the automated data processing
- Francesca Cavallari for the construction DB info on the crystals
- Adi Bornheim, Jan Veverka, Harvey Newman and the rest of the Caltech group for guidance
- University of Michigan CERN REU program and NSF for funding

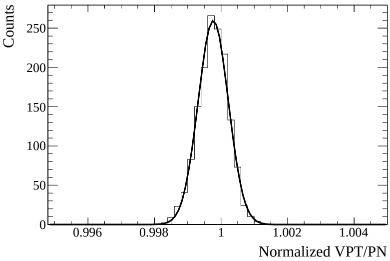
Bonus Slides

VPT/PN Distributions for Rings

Point with Large Error

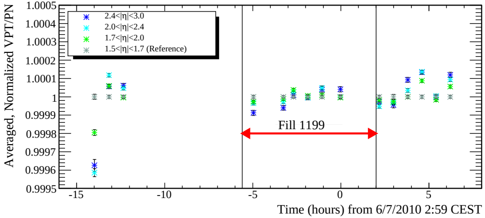


Later Point

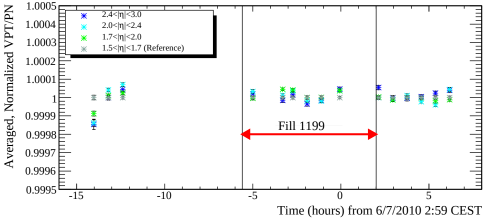


Spontaneous large errors can be caused by misalignment of laser.

VPT/PN Fluctuations for run with $\int \mathcal{L}dt = 5.6\text{nb}^{-1}$

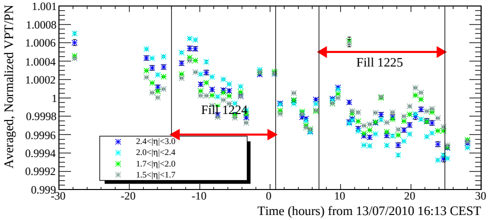


EE-

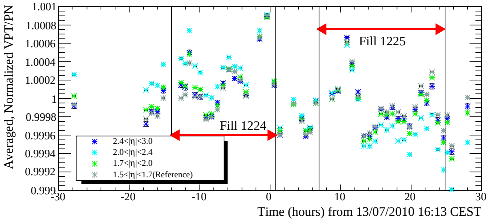


EE+

VPT/PN Fluctuations Normalized to barrel



EE-

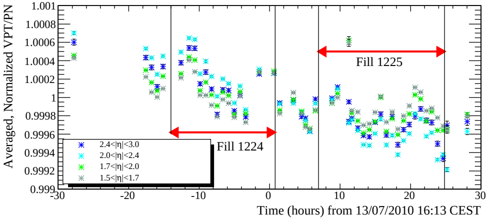


EE+

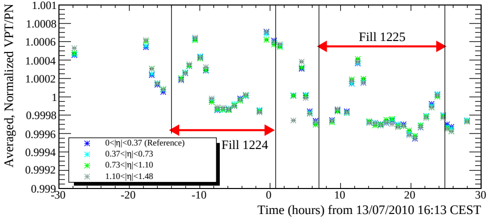
First Fill (Runs 139881-140106): $\int \mathcal{L}dt = 30.3\text{nb}^{-1}$

Second Fill (Runs 140110-140149): $\int \mathcal{L}dt = 58.5\text{nb}^{-1}$

Systematic Fluctuations in Photodector Signal



EE

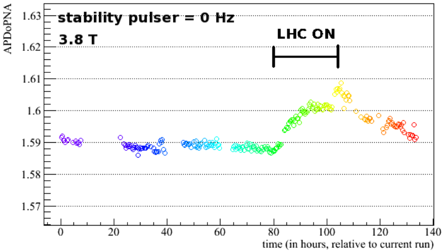


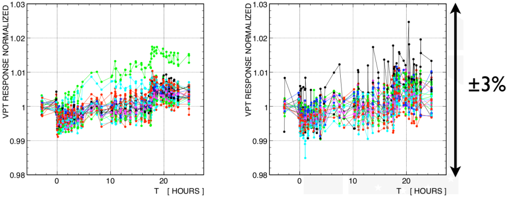
EB

First Fill (Runs 139881-140106): $\int \mathcal{L}dt = 30.3\text{nb}^{-1}$

Second Fill (Runs 140110-140149): $\int \mathcal{L}dt = 58.5\text{nb}^{-1}$

VPT/PN Fluctutations from VPT Effects

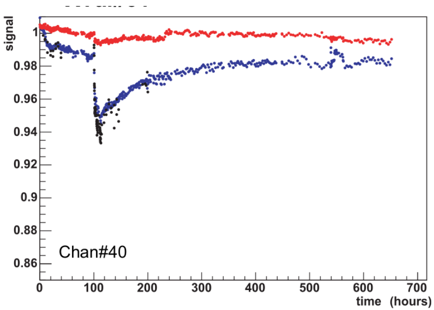




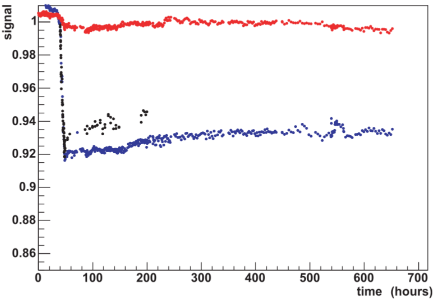
S. Ledovskoy 2/9/2009

D.A. Petyt 3/9/2009 from S. Ledovskoy

VPT/PN Fluctutations from Radiation Effects in Russian Crystals



VPT/PN Fluctutations from Radiation Effects in Chinese Crystals



P. Verrecchia 28/7/2004

VPT/PN Fluctutations from Radiation Effects in APATITY Crystals