



Possibilities of IHEP Booster for the radiation hardness study of materials

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On behalf of the IHEP/Ecal group

Outline



HEP booster for the irradiation purpose

- **Booster proton beam structure**
- ☆ Simulation & measurements of hadron fluence at place of irradiation
- ☆ Crystals transmittance before & after irradiation

★ Conclusion

IHEP Booster for material irradiations



Proton energy: 1.32 GeV



Booster circular hall



Control room of the irradiation zone



Booster beam dump & irradiation zone



PANDA-RS irradiation facility

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Proton beam structure





- it is possible to use up to 29 bunches for irradiation purposes
- average intensity ~ 3.5•10¹¹ protons per bunch.
- average protons intensity on the target during the time of irradiation about of 10¹² p/s.

Proton bunch profile on the target





PWO irradiation setup





Many thanks to IHEP Radiation Research Department and Booster team for the excellent support

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Hadron fluence through crystals (E_h > 10 MeV)



Simulation was provided using MARS(IHEP) code by Igor Azhgirey



Each crystal was subdivided into 9 bins (1x1x22 cm³)

4•10¹¹ protons (E= 1.32 GeV) per second hits the

primary steel target



Distribution of the hadron fluence integrated in the crystal bins (fluence is in 10⁸ h/(cm² sec)) and fraction of the charged hadrons (in %)

| 0.5 | | 0.6 | | 0.7 | |
|--------------------|---|--------------------|---|--------------------|---|
| 11/0 | 3 | 7.970 | 6 | 5.776 | 9 |
| 0.8 9.9% | | 1.0 6.7% | | 1.4 4.6% | |
| | 2 | | 5 | | 8 |
| 1.7 6.9% | | 2.3 5.1% | | 2.2 4.3% | |
| | 1 | | 4 | | 7 |

Average hadron fluence through whole crystal 11869 is about of 1.3•10⁸ h/(cm² sec) (6.1% ch.harons)

| 0.9 4.1% | | 1.0 3.1% | | 1.1 2.5% | |
|--------------------|---|--------------------|---|--------------------|---|
| | 3 | | 6 | | 9 |
| 1.6 | | 1.5 | | 1.3 | |
| 3.5% | | 2.9% | | 2.5% | |
| | 2 | | 5 | | 8 |
| 1.9 | | 1.6 | | 1.4 | |
| 3.7% | | 3.2% | | 2.8% | |
| | 1 | | 4 | | 7 |
| | | | | | |

Average hadron fluence through whole crystal 11877 is about of 1.4•10⁸ h/(cm² sec) (3.1% ch.hadrons)

For our case the expected average hadron fluence during the time of irradiation will be around of 2.4•10¹³ h/cm² (# 11869) and 2.6•10¹³ h/cm² (# 11877)

Hadron spectra through crystals



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Hadron fluence measurement (activation analysis)



Integral fluence of hadrons (E> 30 MeV) during the process of irradiation (30.5 h) is determined by activation analysis Al (h,spall) ²²Na. (Thanks to V.Lukanin & G. Krupny, IHEP)



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Crystals transmittance



(AvaSpec-2048, resolution 0.3 nm)

Avalight-Xe Xenon pulsed light source (useable range 200 -750 nm) was used



Crystals # 11869 and # 11877 before irradiation



(AvaSpec-2048, resolution 0.3 nm)



Total hadrons fluence (E_h > 30 MeV) during the time of irradiation ~ 2.6•10¹³ n/cm²;

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(AvaSpec-2048, resolution 0.3 nm)



Total hadrons fluence (E_h > 30 MeV) during the time of irradiation ~ 1.5•10¹³ h/cm²

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Crystals induced radioactivity



The measurements (dose rate on the crystal surface) started in a seven days after the end of irradiation. Industrial dosimeter DKS AT1123 was used.

(Thanks to S. Drugachonok from IHEP RPD)





Conclusion



Two CMS EE crystals were irradiated in IHEP booster « neutron » field ($\langle E_h \rangle = 100 \text{ MeV}$). Duration of irradiation was about of 30 hours in the middle of November 2012.



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Total hadron fluence in crystals during the time of irradiation

| Crystal # | Calculations, E_h> 10 MeV (MARS/IHEP) | Measurements, E_h> 30 MeV Al (h, spall) ²² Na | | | |
|-----------|--|---|--|--|--|
| 11869 | ~ 1.8•10 ¹³ h/cm ² (~9% of ch. hadrons) | ~ 2.6•10 ¹³ h/cm ² | | | |
| | | | | | |
| 11877 | ~ 2.6•10 ¹³ h/cm ² (~4% of ch. hadrons) | ~ 1.5•10 ¹³ h/cm ² | | | |
| | Transparency loss about of 17% at 400 nm was observed | | | | |



In four months after the end of the crystals irradiation:

- practically no recovery in (350 - 400) nm wavelength region were observed;

- dose rate from induced radioactivity on the level about of $3 \mu Sv/h$ were defined.



СПАСИБО ЗА ВНИМАНИЕ

Backup slides

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Hadron fluence through crystals





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Ecal upgrade meeting, CERN, June 2013



(AvaSpec-2048, resolution 0.3 nm)





(AvaSpec-2048, resolution 0.3 nm)



Total fluence during the time of irradiation: neutrons ~ 2.5•10¹³ n/cm²; ch. hadrons ~ 8•10¹¹ ch.h/cm²

 $E_{p(n)} = 55 \text{ MeV}$



Star density

Energy deposition



Dashed line – neutrons as incident Solid line – protons as incident

Ecal upgrade meeting, CERN, December 2012

 $E_{p(n)} = 100 \text{ MeV}$



Star density

Energy deposition



Dashed line – neutrons as incident Solid line – protons as incident

Ecal upgrade meeting, CERN, December 2012

 $\mathbf{E}_{\mathbf{p}(\mathbf{n})} = \mathbf{1} \mathbf{GeV}$



Star density

Energy deposition



Dashed line – neutrons as incident Solid line – protons as incident

Ecal upgrade meeting, CERN, December 2012