The tokamak GOLEM CAAS report #4

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on behalf of the tokamak GOLEM team

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Basics physics of RE

- runaway electrons studied in various fields of physics
- in tokamaks RE generated during start-up phase of discharge, during low density discharges or plasma disruption
- GOLEM-like plasmas: low density plasma ($n_e \approx 10^{18}\ \mathrm{m}^{-3}$) and relatively high electric field ($E \approx 1-2\ \mathrm{V/m}$)

→ favourable conditions for RE generation

- estimated typical energies at GOLEM

→ critical energy: $W_c \approx 1.76\ \mathrm{keV}$

→ orbit shift limit: $E_{max} \approx 2\ \mathrm{MeV}$

→ time limit: $E_{max} \approx 2-4\ \mathrm{MeV}$

Commonly used detectors

- commonly used detectors scintillation detectors at tokamaks: NaI(TI), BGO, $LaBr_3$, $CeBr_3$, LYSO

Scintillator	Light yield (photons/keV)	Decay time [ns]	Density [g/cm3]	Hygroscopic
NaI(TI)	38	250	3.67	yes
$LaBr_3$(Ce)	63	16	5.08	yes
$LaBr_3$(Ce+Sr)	73	25	5.08	yes
LYSO	33	36	7.1	no
BGO	10	300	7.13	no
NaI(TI+Li)	35	240, 1.4 μs	3.67	yes
$CeBr_3$	60	18	5.1	yes
YAP(Ce)	25	28	5.37	no

- nowadays trend: usage of detectors with fast and high density scintillation materials

Diagnostic at GOLEM

Scintillation detectors

- 2× NaI(Tl) - 2 inch crystal, manufactured by ENVINET and NUVIA
- YAP(Ce) - 1 inch crystal, manufactured by CRYTUR
- 2× YAP(Ce) (25 mm) and 2× $CeBr_3$ (20 mm) demountable crystals sharing 2 photomultipliers, manufactured by Scionix

RE related diagnostics

- Strip detector
- Small size crystal with SiPM
- Radiometer
- Set of dosimeters

In near future:

- Timepix detectors

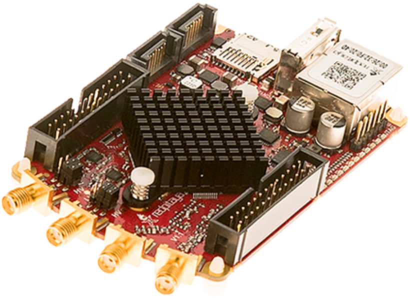
- re-initiated negotiation about installation of Cherenkov detectors

Characterisation of detectors - method

- fast data acquisition system based on RedPitaya (STEMlab 125-14)

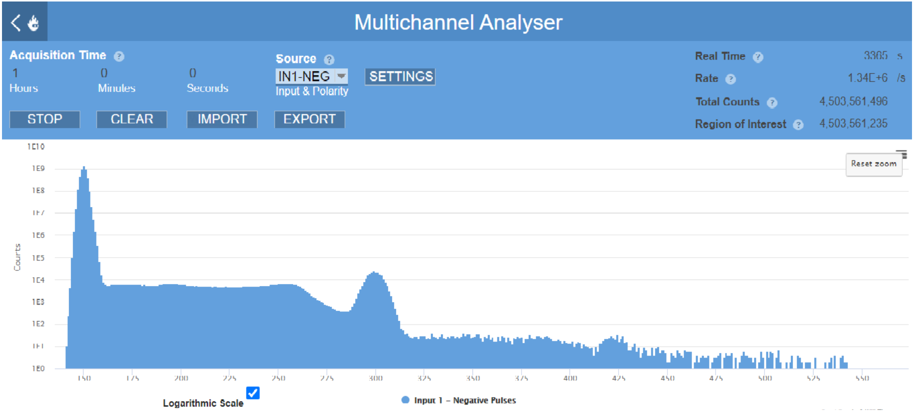
STEMlab 125-14

- channels: 2
- sample rate: 125 MS/s
- ADC resolution: 14 bit
- voltage range: $\pm$ 1/$\pm$ 20 V
- bandwidth: 60 MHz
- input impedance: 1 $\mathrm{M\Omega}$



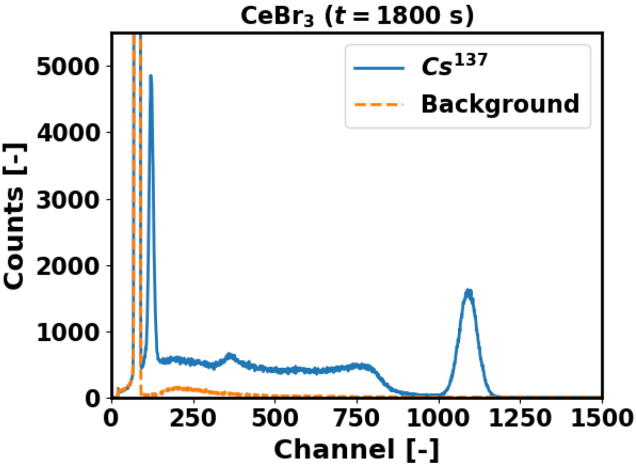
- input impedance of DAQ matched to 50Ω output impedance of the photomultipliers
- DAQ system controlled by Multichannel Analyser application

Characterisation of detectors - method



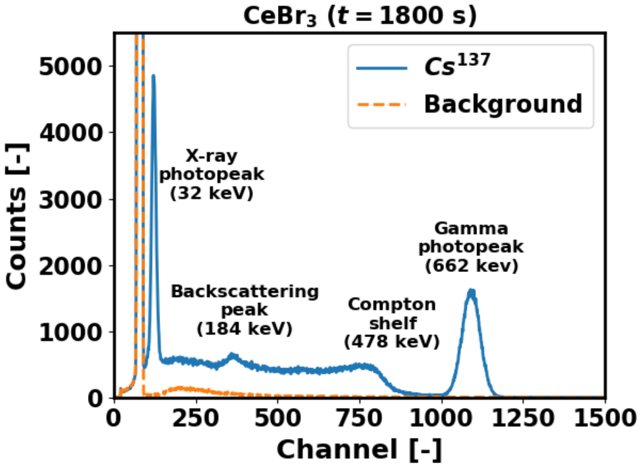
- data acquired with help of Multichannel Analyser web based application (freeware application - available on GitHub)

Characterisation of detectors - example spectrum



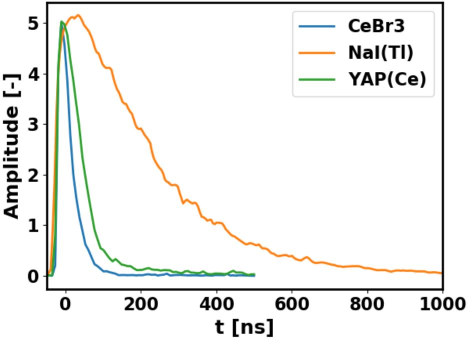
- important features of Cs^{137} gamma spectrum could be clearly distinguished

Characterisation of detectors - example spectrum



- important features of Cs^{137} gamma spectrum could be clearly distinguished

Characterisation of detectors - pulse shapes

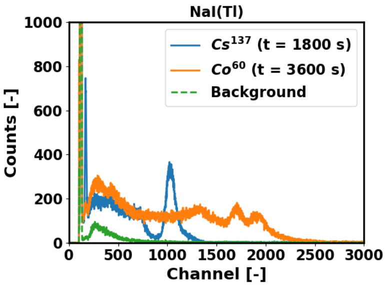


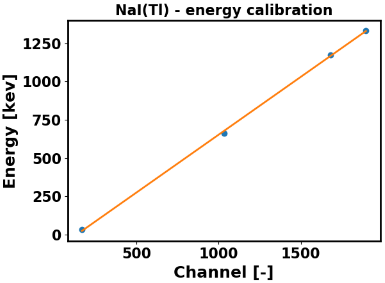
- comparison of pulse shape of different detectors: $CeBr_3$, NaI(Tl), YAP(Ce)

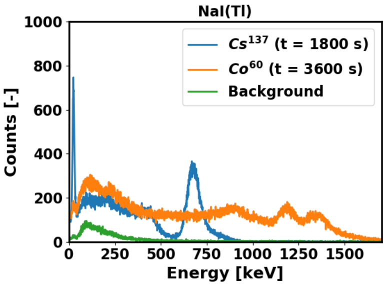
→ expected behaviour observed: decay time of $CeBr_3$ approx. 10 times faster than NaI(Tl)

→ $CeBr_3$, YAP(Ce) good choice for high rate photon counting (YAP(Ce) poorer energy resolution)

Characterisation of detectors - NaI(Tl)

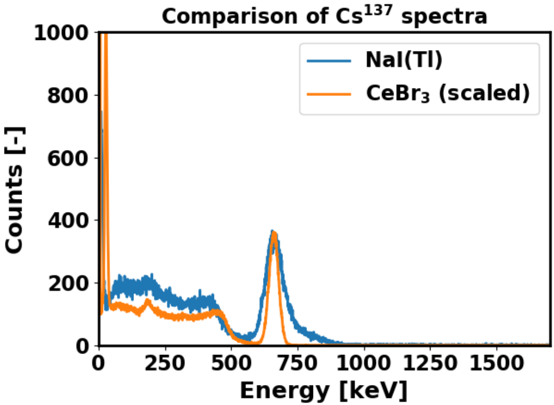






- four peaks used for energy calibration (Co^{60} - two gamma peaks, Cs^{137} - gamma and X-ray peak)
- energy resolution: $\approx$ 14 %@662 keV (typically 7%, old detector)

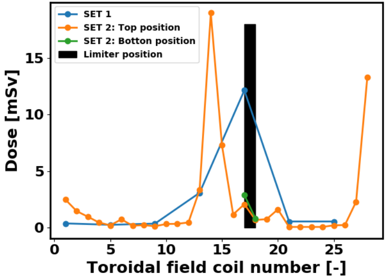
Characterisation of detectors - NaI(Tl) vs. $CeBr_3$



- measured energy resolution $\approx$ 6%@662 keV (typical value: $\approx$ 4-5%@662 keV)

Characterisation of radiation by dosimeters (2nd round)

- 2nd set of OSL dosimeters install at each toroidal field coil

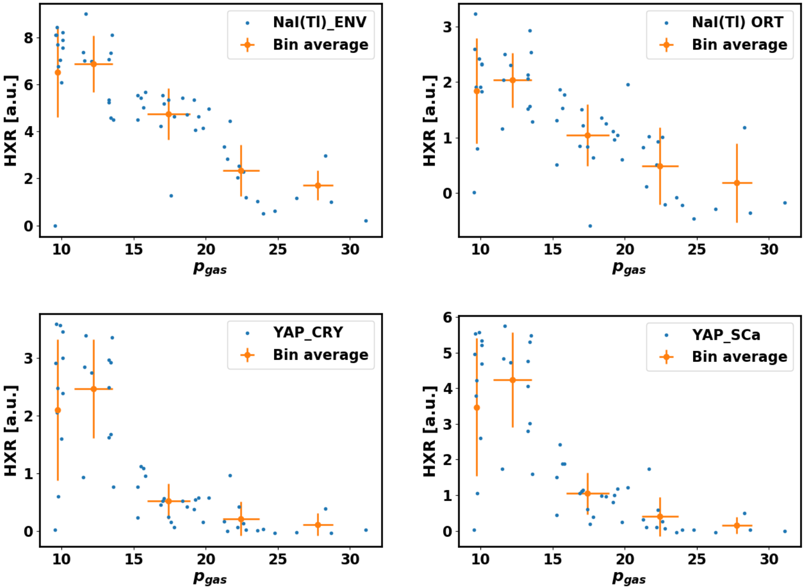


- consistent results given by 1st and 2nd set of dosimeters

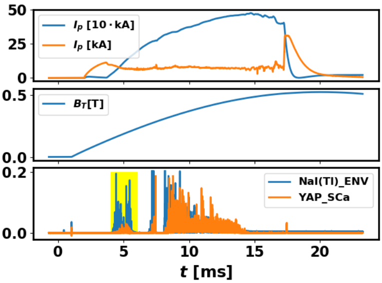
→ new feature in 2nd set of dosimeters

→ should be systematically exploit

Scan in pressure of working gas



Influence of magnetic field



#336808

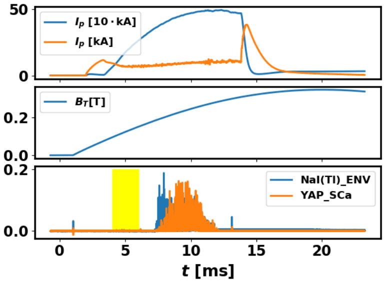
- discharge setting:
  $U_{CD} = 800\ \mathrm{V}$,
  $U_{BT} = 1300\ \mathrm{V}$

$\rightarrow$ higher magnetic field

#336807

- discharge setting:
  $U_{CD} = 800\ \mathrm{V}$,
  $U_{BT} = 800\ \mathrm{V}$

$\rightarrow$ lower magnetic field



Future work

- continuation in ongoing characterisation of scintillation detectors

→ installation and operation of detectors during last RE experimental campaign at COMPASS (November-December 2020)

- continuation in RE experiment with usage of new control features of tokamak GOLEM (if possible) - gass puff modulation, plasma position control
- analysis of existing data and evaluation of results
- for easier evaluation of data start with modelling of radiation transport (e.g. with FLUKA) - optimisation of shielding, better interpretation of experimental data

Conclusion

- characterisation of scintillation detectors

→ better interpretation of results preparation on RE experimental campaign at COMPASS

- new set of OSL dosimeters evaluated

→ consistent with previous observations, but new feature seen

- investigated influence of pressure of working gas

→ expected behaviour observed

- prompt losses after breakdown of plasma spotted for lower magnetic field

→ needs to be systematically observed and understood