i-TED Commissioning Plans

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n_TOF Local Team &

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European Research Council

nTOF

CSIC

Consejo Superior de Investigaciones Científicas

n_TOF Collaboration Meeting, CERN, 10th June 2020

Outline

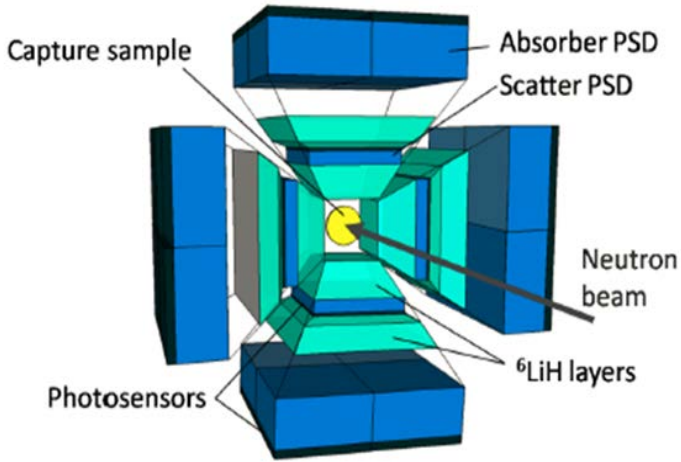
- **i-TED:** Short description of detector assembly
- Main aspects to commission at CERN n_TOF in 2021:
  - **Trigger** time-stamp issue (see Victor Babiano's talk @Tue.16:30)
  - **Count-rate** capability @ EAR2 (see J. Lerendegui's talk, CERN Feb. 2020 link)
  - **Background** response (see J. Lerendegui's talk @ Wed.15:45)
- Summary & Outlook

i-TED in a nutshell

- **i-TED:** Short description of detector assembly
  At variance with previous versions (iTED2 and iTED5.3), in 2021 i-TED will comprise 20 large monolithic LaCl3 crystals optically coupled to 8x8 pixelated SiPMs, featuring a total of **1280 readout channels**.

→ High resolution LaCl3(Ce) Crystals
→ SiPM photosensors (8x8 pixels)
→ ASIC-based readout electronics
→ AI-based analysis algorithms

2021 4π i-TED
20 LaCl3, 1280 ch



2018 i-TED prototype tested (3 LaCl3 crystals, 192 channels)

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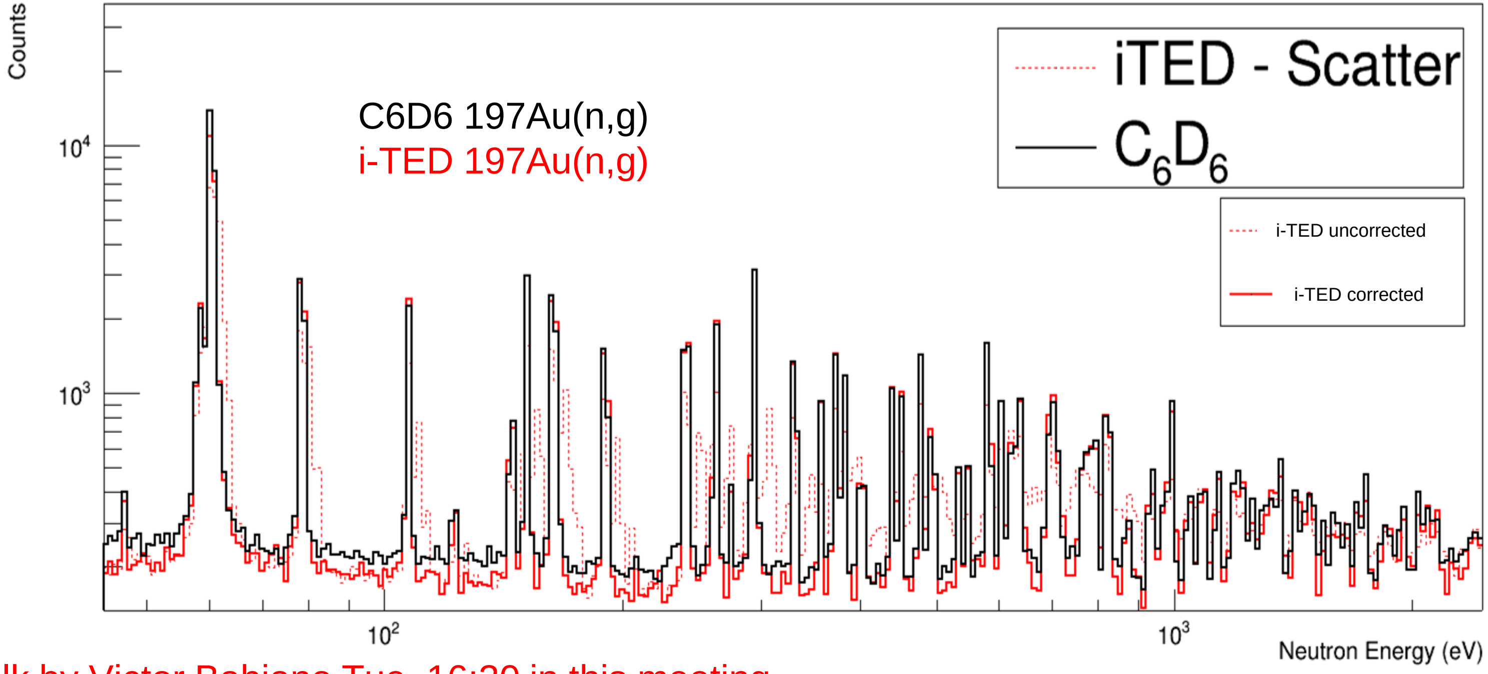
Trigger issue

- Issue: unlike C6D6, i-TED cannot detect the gamma-flash and therefore an external trigger signal is required to build TOF-spectra
- Status: previous attempts to use an external trigger did not work reliably
- Plans & Options:
  - Ancillary trigger detector coupled to i-TED DACQ
  - External PS trigger using a NIM or TTL input-signal (instead of LVCMOS)
  - Protect trigger section of i-TED DACQ properly (Faraday Cage)
- Where: EAR1 and EAR2
- When: During Target#3 commissioning, only a gold sample (or similar) is needed.
- Compatibility: can be run with any other detector tests: sTED, L6D6, B6D6, SiMON, etc

Trigger time-stamp

- Current i-TED triggering system has been found (commissioning 2018) to be unreliable
- False triggers lead to splitted resonances and loss of "resolution"
- It can be corrected via software, but this is highly demanding and a non suitable solution
- Present triggering system can be improved



See talk by Victor Babiano Tue. 16:30 in this meeting.

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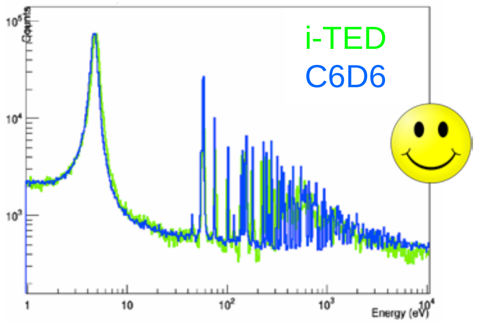
High count-rate response

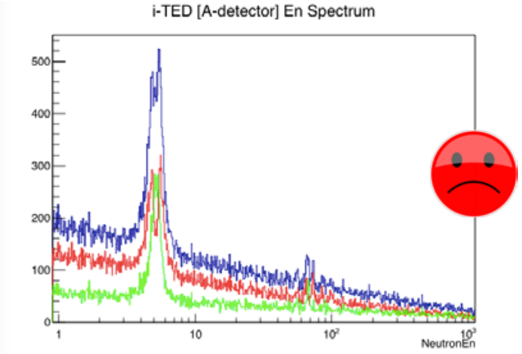
- Issue: i-TED DACQ has limitations to cope with high count-rates at EAR2
- Status: stress tests @ lab have shown max. CR of 500kHz
- Plans & Options:
    - Enlarge sample-detector distance: trade-off efficiency % counting-rate
    - Use high-threshold settings on readout ASICs -> Reduce dead-time
    - Implement alternative ToT signal processing approach
- Where: EAR2
- When: During Target#3 commissioning, only a gold sample (or similar) is needed.
- Compatibility: can be run with any other detector tests: sTED, L6D6, B6D6, SiMON, etc

High count-rate response

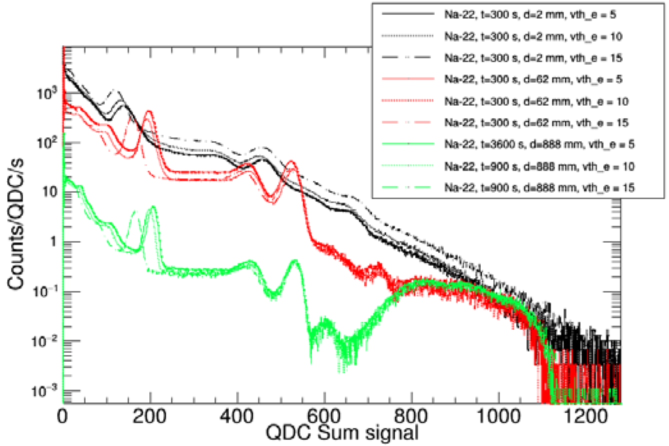
EAR1, i-TED OK

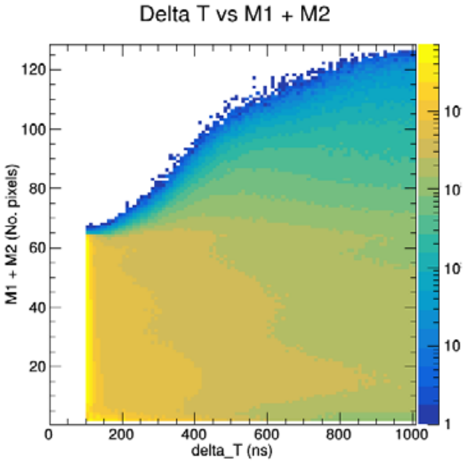


EAR2, i-TED KO



Max CR = 500 kHz /standard values





→ With standard ASIC configuration the maximal CR that can be measured with i-TED is of about 500kHz

→ Test if a measurement would still be feasible at EAR2, below this CR, enlarging detector-sample distance

→ Test other (less conventional) ASIC parameters (threshold, ToT, etc) in order to be able to cope with the EAR2 CRs

High count-rate response

- Issue: i-TED DACQ has limitations to cope with high count-rates at EAR2
- Status: stress tests @ lab have shown max. CR of 500kHz
- Plans & Options:
  - Vary sample-detector distance: trade-off efficiency % counting-rate
  - Use high-threshold settings on readout ASICs -> Reduce dead-time
  - Implement alternative ToT signal processing approach
- Where: EAR2
- When: During Target#3 commissioning, only a gold sample (or similar) is needed.
- Compatibility: can be run with any other detector tests: sTED, L6D6, B6D6, SiMON, etc

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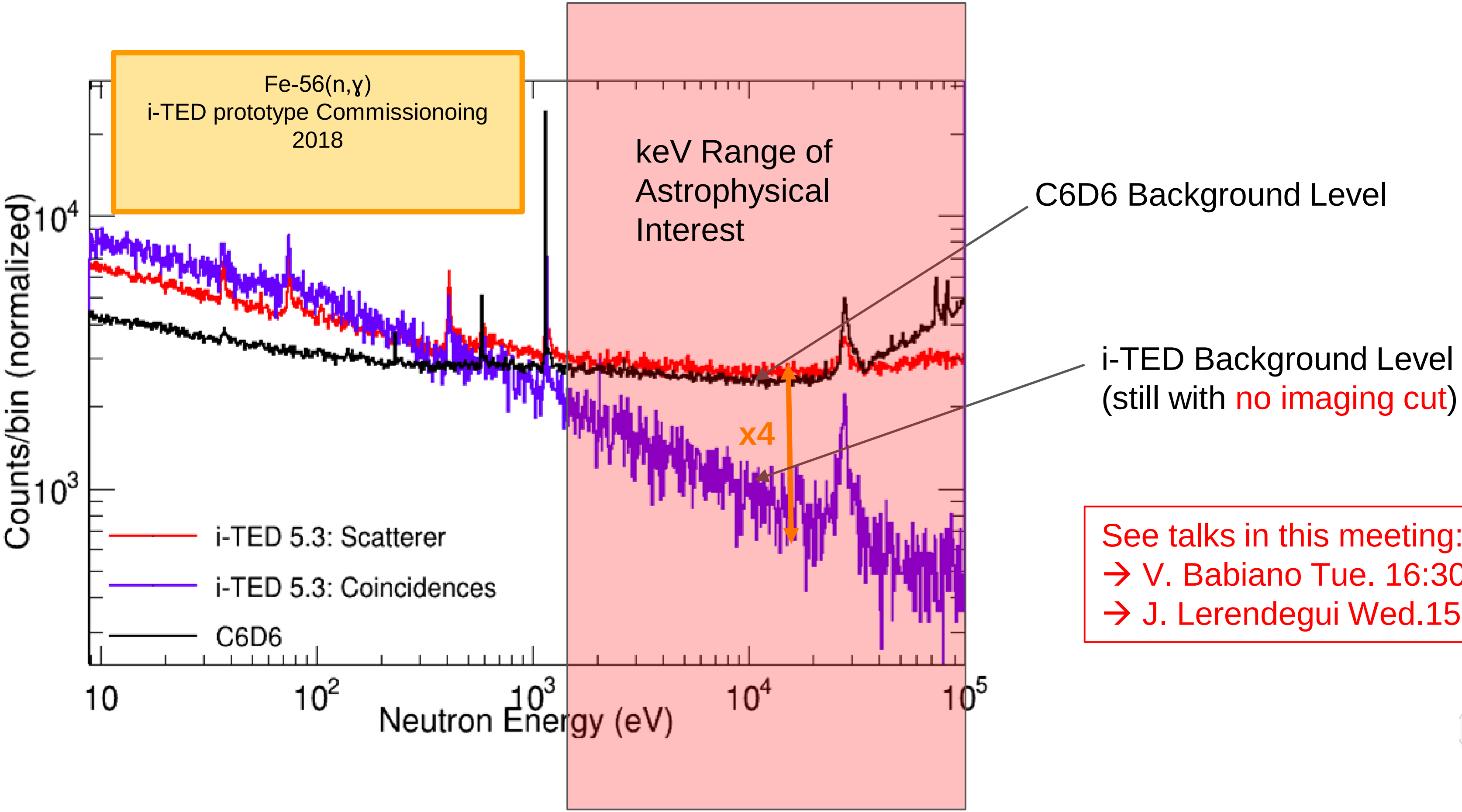
Background response

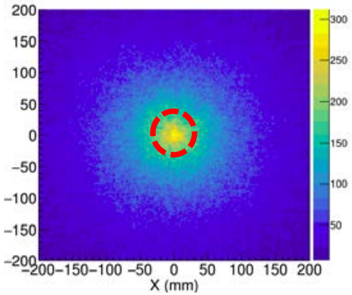
- Issue: optimize i-TED background rejection capabilities & optimization
- Status:
    - Preliminary results from prototype commissioning in 2018 (Victor Babiano’s talk Tue. 16:30) → Analytical Compton (Lambda-method)
    - MC simulations based on experimental background spectra (Jorge Lerendegui’s talk Wed.15:45) → ML based algorithms
- Plans & Options:
    - Carbon sample → artificially increase scattered neutron background
    - Iron sample → Signal-to-background test
- Where: EAR1 & EAR2
- When: During Target#3 commissioning, in parallel to other detector tests

Background response



See talks in this meeting:
→ V. Babiano Tue. 16:30
→ J. Lerendegui Wed.15:45

Background: ML vs. g-ray Imaging



vs.

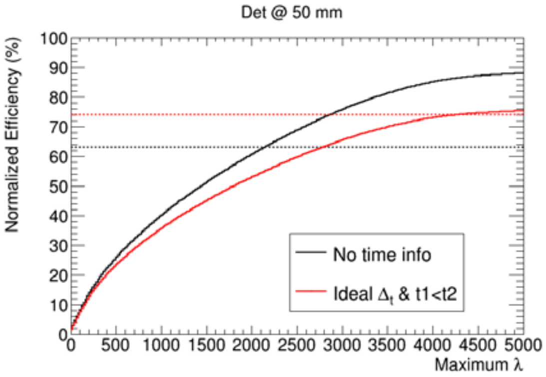
Convolutional Neural Networks

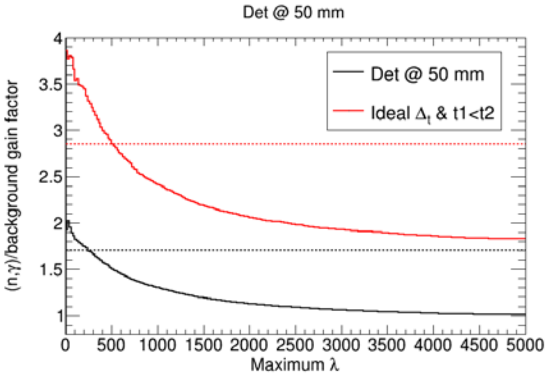
- **ML Background Rejection Models / Classifiers:**
  - **k-Nearest neighbors:** `from sklearn.neighbors import KNeighborsClassifier`
  - **Logistic Regression:** `from sklearn.linear_model import LogisticRegression`
  - **Support Vector Classifier (SVC):** `from sklearn.svm import SVC`
  - **Gaussian Naive Bayes (NB):** `from sklearn.naive_bayes import GaussianNB`
  - **Random Forest:** `from sklearn.ensemble import RandomForestClassifier`
  - **XGBoost Classifier:** `from xgboost import XGBClassifier`

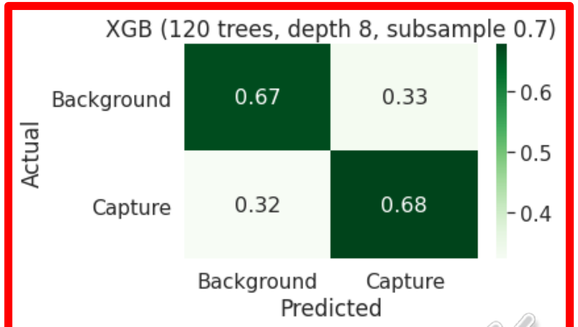
(n,g) efficiency fraction = True positive = 68%

(n,g)/background= True positive/ False Negative = 0.68/0.33 = 2.06

- ML methods have the advantage, versus the analytical g-ray imaging approach, that they can be effectively implemented without a significant loss of g-ray efficiency and provide a larger gain in S/B-ratio (!)







See talk by J. Lerendegui Wed.15:45

Summary & Outlook

- Most remaining aspects of i-TED can be commissioned in parallel to the Target#3 commissioning and to other detector's commissioning, such as
  - **Trigger** time-stamp issue
  - **Count-rate** capability at EAR2
- More specific to i-TED is the need of data for optimization of background rejection algorithms:
  - **Background** response: dedicated runs with natC, 197Au and 56Fe, which can serve also for other detector's commissioning

Tentative commissioning beam-time request (based on previous experience 2018):

Sample	Aim	Protons EAR1	Protons EAR2	Area
197Au	Trigger / i-TED splitted	1E17		EAR1/EAR2
197Au	Count Rate		3E17	EAR2
natC	Background (n/g bkg)	2E17	1E17	EAR1 + EAR2
Lead	Background (in-beam g)	2E17	1E17	EAR1 + EAR2
56Fe	S/B-Ratio Test	1E18	5E17	EAR1 + EAR2

Most beam-time compatible with other detectors & techniques tests? e.g. sTED, L6D6, B6D6 (refilled), new PHWT tests (Samuel), etc?
To be coordinated within next detector meeting?