i-TED

Status report

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and the n_TOF Collaboration

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Outline

• i-TED concept review

• Apparatus & methodology

• i-TED tests @ n_TOF in September’ 2017 // Preamp tests Massimo & N. Patronis

• i-TED tests @ n_TOF in November’ 2017 // Tests 16OChamber (Sebastian)

• Outlook and next steps
The i-TED concept

→ Reduce “extrinsic” neutron sensitivity background

$\text{C}_6\text{D}_6$ scattered neutron

$\text{C}_6\text{D}_6$ captured neutron

$\gamma$

n-beam

Radiation detectors

The i-TED concept

→ Reduce “extrinsic” neutron sensitivity background

C<sub>6</sub>D<sub>6</sub> captured neutron

C<sub>6</sub>D<sub>6</sub> scattered neutron

Radiation detectors

n-beam

The i-TED concept

→ Reduce “extrinsic” neutron sensitivity background

\[ \text{Captured neutron} \]

\[ \text{Scattered neutron} \]

\[ \text{Radiation detectors} \]

Macklin & Gibbons, ORNL, 1967

The i-TED concept

Reduce “extrinsic” neutron sensitivity background


The i-TED concept

→ Reduce “extrinsic” neutron sensitivity background

γ-Imaging → Better sensitivity

\[ \cos \theta = 1 + \frac{511}{E} - \frac{511}{E} \]

\[ \delta \theta = \frac{E}{\sin \theta} \left( \frac{1}{E^2} \left( \frac{\delta E}{E} \right)^2 + 2 \sin^2 \theta \left( \frac{\delta r}{r} \right)^2 \right)^{1/2} \]
The i-TED concept

High E-resolution → Better selectivity

60Co measurement with LaCl3 (i-TED)

204Tl(60Co) measurement with C6D6

γ-Imaging → Better sensitivity

\[
\cos \theta = 1 + \frac{511}{E} - \frac{511}{E^2}
\]

\[
\delta \theta = \frac{E}{\sin \theta} \left( \frac{1}{E^2} \left( \frac{\delta E}{E} \right)^2 + 2 \sin^2 \theta \left( \frac{\delta r}{r} \right)^2 \right)^{1/2}
\]
→ SiPMs instead of PS-PMTs:
  → High E-Resolution with SiPM albeit large dead-space between pixels
→ Scalable system (very low efficiency → large solid angle → many channels) → Compact electronics → Question on spectroscopic/timing performance?
SiPMs instead of PS-PMTs:

- High E-Resolution with SiPM albeit large dead-space between pixels
- Scalable system (very low efficiency → large solid angle → many channels) → Compact electronics → Question on spectroscopic/timing performance?
i-TED pre-requisites:
high energy resolution + good timing resolution

sensL SiPM ArrayJ 30035-64P-PCB
LaCl\textsubscript{3} 10/20/30mm

P. Olleros, Master Thesis, IFIC, 2017
SiPMs instead of PS-PMTs:

- Demonstrate High E-Resolution with SiPM albeit large dead-space between pixels
- Scalable system (very low efficiency → large solid angle → many channels) → Compact electronics → Question on spectroscopic/timing performance?

### i-TED implies developments:

- **SiPMs instead of PS-PMTs:**
  - Demonstrate High E-Resolution with SiPM albeit large dead-space between pixels
  - Scalable system (very low efficiency → large solid angle → many channels) → Compact electronics → Question on spectroscopic/timing performance?

#### 4x$C_6D_6$

- Efficiency (%)
- $E_y$ (MeV)

#### $4\pi$ i-TED

- Efficiency (%)
- $E_y$ (MeV)

### Image

- Capture sample
- Absorber PSD
- Scatter PSD
- Neutron beam
- $^6$LiH layers
- Photosensors

#### Parameters:

- $1 \times$ Scatter = 5x5 cm$^2$
- $1 \times$ Absorber = 10x10 cm$^2$
- Full i-TED = 4S + 4A = 500 cm$^2$
- # pixels = 8x8y = 64 ch
- Pixel size = 6x6 mm$^2$
- Area = 5x5 cm$^2$ = 25 cm$^2$
- 1280 channels!
PETsys Electronics S.A.

→ 128 channels (or pixels from SiPM)
→ 25 ps intrinsic t-resolution / 32 ps SiPM+ASIC / 200 ps Crystal + SiPM + ASIC
→ max. rate 160 kEvents/ch or 12 Mevents/board
→ energy via qdc for each channel

FPGA Virtex6

i-TED: readout electronics (PETsys) Test Sept.2017

i-TED @ EAR1:
i-TED prototype: September tests
i-TED prototype: September tests

→ Difficult to identify the $t_o$ of each bunch

$^{197}$Au$(n,\gamma)$ RUNS:

i-TED time-stamps:
i-TED prototype: September tests

Difficult to identify the \( t_0 \) of each bunch

\[ ^{197}\text{Au(n,\gamma)} \] RUNS:

i-TED time-stamps:

PS-Trigger times (TIMBER):
i-TED prototype: September tests

$^{197}$Au$(n,\gamma)$ RUNS:

i-TED time-stamps:

PS-Trigger times (TIMBER):
i-TED prototype: September tests

$^{197}$Au(n,$\gamma$) RUNS:

i-TED time-stamps:

PS-Trigger times (TIMBER):
i-TED prototype: September tests

→ Need an external trigger signal!!

i-TED time-stamps:

PS-Trigger times (TIMBER):

\( \Delta t = 6\text{ns} \)

\( \Delta t = 1\text{ms} \)
i-TED prototype: September tests

$\Delta t = 6\,\text{ns}$
$\Delta t = 1\,\text{ms}$

→ Need an external trigger signal!!
i-TED: new readout electronics (November test)

TTL-to-LVDS Converter:

→ PS-Trigger input into our dacq
i-TED external trigger tested in the lab

Oscilloscope: LVDS OK

TTL-to-LVDS Converter:

Pulse generator: n_TOF like trigger

i-TED (PETSYS) DACQ:
i-TED: new readout electronics (November test)
i-TED prototype: November tests

With n_TOF DACQ (signal displayer)

SiPM
Slow output

PMT
i-TED prototype: September tests

PCB Sum-board: only handles SLOW SiPM summed-outputs

C=4nF $\rightarrow$ $t=100$ns

C=200pF $\rightarrow$ $t=3$ns

SiPM

Fast output

SiPM

Slow output
i-TED prototype: September tests

With n_TOF DACQ (signal displayer)
i-TED prototype: November tests

With n_TOF DACQ

Run 107929 - Trigger 2423

PMT

Slow output of SiPM

Gamma-Flash
i-TED prototype: November tests

- Response OK for TOF
- HE part probably affected by unoptimized PSA
- Effect of the crystal radioactivity (alphas) in the large crystal

With n_TOF DACQ

LaCl$_3$-30 mm / PMT

Counts

10^2

10^3

Neutron Energy (eV)

10^1

10^2

10^3

10^4

10^5

10^6
i-TED prototype: November tests

With i-TED (PETSYS) DACQ:

- dsample = 8 cm, dSA=30 mm (SETUP 1)
- dsample = 5 cm, dSA=15 mm (SETUP 2)

PS n_TOF Triggers seen by i-TED DACQ
i-TED prototype: November tests

dsample = 8 cm  dSA=30 mm  SETUP 1
dsample = 5 cm  dSA=15 mm  SETUP 2

With i-TED (PETSYS) DACQ:

d-TED time stamps (ps):

i-TED PS Trigger time stamps (ps):
i-TED prototype: November tests

With i-TED (PETSYS) DACQ:

- dsample = 8 cm, dSA=30 mm  
  SETUP 1
- dsample = 5 cm, dSA=15 mm  
  SETUP 2

i-TED [S-detector] En Spectrum / All Files
i-TED prototype: November tests

With i-TED (PETSYS) DACQ:

dsample = 8 cm    dSA=30 mm    SETUP 1

dsample = 5 cm    dSA=15 mm    SETUP 2
i-TED prototype: November tests

With i-TED (PETSYS) DACQ:

- **SETUP 1**
  - $d_{\text{sample}} = 8 \text{ cm}$
  - $d_{\text{SA}} = 30 \text{ mm}$

- **SETUP 2**
  - $d_{\text{sample}} = 5 \text{ cm}$
  - $d_{\text{SA}} = 15 \text{ mm}$
### i-TED prototype: November tests

#### 9 h run
- About 9k Bunches
- $4.7 \times 10^{16}$ protons

#### S/B Setup

<table>
<thead>
<tr>
<th></th>
<th>S</th>
<th>A</th>
<th>i-TED (S&amp;A)</th>
</tr>
</thead>
<tbody>
<tr>
<td>S/B Setup 1</td>
<td>57</td>
<td>11</td>
<td>57</td>
</tr>
<tr>
<td>S/B Setup 2</td>
<td>59</td>
<td>14</td>
<td>56</td>
</tr>
</tbody>
</table>

#### Rel Eff. (%)

<table>
<thead>
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<th>A</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Rel. Eff. (%) Setup 1</td>
<td>100%</td>
<td>64%</td>
<td>0.15%</td>
</tr>
<tr>
<td>Rel. Eff. (%) Setup 2</td>
<td>100%</td>
<td>70%</td>
<td>0.2%</td>
</tr>
</tbody>
</table>

#### i-TED S-detector

#### i-TED A-detector

#### i-TED S&A in t-coin
i-TED prototype: November tests

137Cs
i-TED: Summary & Outlook

• Main technical commissioning of i-TED, both in terms of detectors (crystals, SiPMs, etc), readout electronics (PETSYS mod. Version) and processing software has been accomplished successfully.

• With the developed i-TED prototype, we have not found any major drawback in terms of performance, it seems also that with i-TED we can come much closer to the sample than in these tests (to enhance efficiency). To be tested.

• We have to complete the analysis, including:
  • C6D6 runs from september as a benchmark
  • Imaging in our i-TED runs of November

• For 2018 we are preparing the i-TED Demonstrator (i-TED2), which features 5 detectors (instead of 2), 1 detector for the S & 4 detectors for the A-detector.

• We need to perform a few additional technical detector-tests early 2018 and a dedicated performance commissioning in 2018 (more tomorrow).

THANKS FOR YOUR ATTENTION

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Backup slides
Remaining technical i-TED tests / 2018 (with parasitic neutron beam/n_TOF detector test):

- Effect of sample-detector distance, how close we can come with i-TED (its S-detector) to the sample → Efficiency / high En
- Possibility to use a veto time-gate to go higher in neutron energy, for the case that the detector is affected by the gamma-flash
- Combined capture & gamma-source measurement to develop sample-activity rejection algorithms
- Effect of the LiH moderator for reducing intrinsic neutron sensitivity
- i-TED response tests at EAR2
- Explore dynamic range of i-TED, how high we can go in g-ray energy
- Combined i-TED & TAC “matriuska-like” set-up, to enhance efficiency at high gamma-ray energy (see next slide).
i-TED + TAC (?):
→ Enhance efficiency for high-energy part of the capture cascade (Triple-coincidences S&A&TAC)