BGO as a Hybrid Scintillator / Cherenkov Radiator for Cost-Effective Time-of-Flight PET

S. E. Brunner and friends

[1]*Radiation Science & Technology, TU Delft, Delft, The Netherlands*

TU Delft

FONDAZIONE BRUNO KESSLER

European Commission

Horizon 2020
European Union funding
for Research & Innovation

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Timing, timing, timing…

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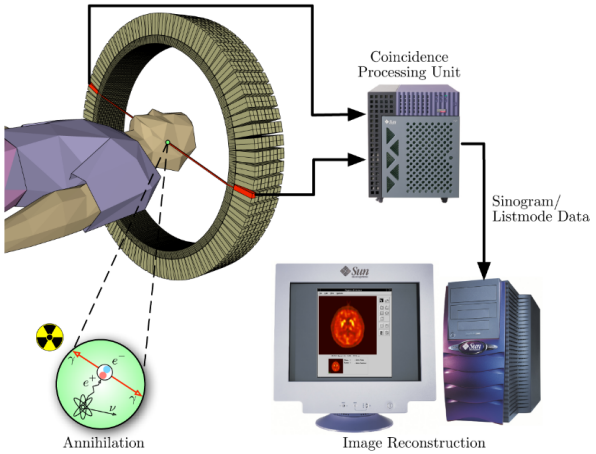
TOF-PET: Timing, sensitivity and cost effectiveness

Time-of-flight Positron Emission Tomography (TOF-PET)

- Best lab results 70 ps to 80 ps FWHM (LSO:Ce, $LaBr_3$:Ce)
- System CRT 300 ps to 400 ps FWHM (LSO:Ce based)



Wikimedia commons, http://en.wikipedia.org/wiki/Positron_emission_tomography

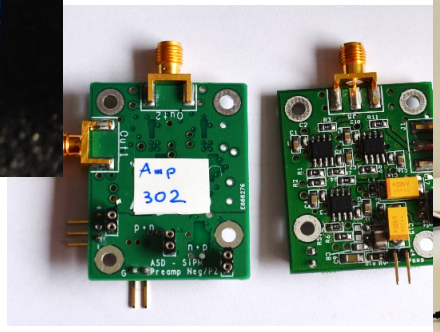
Ultimate timing

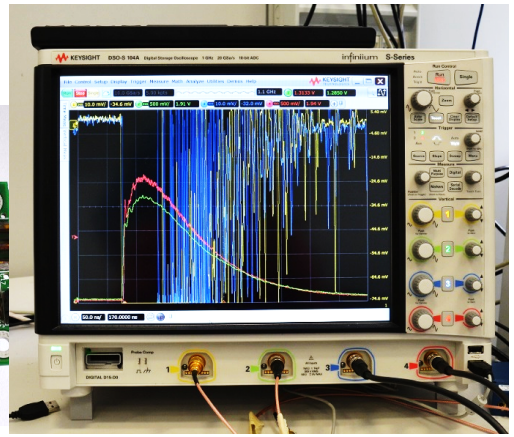
Cost efficient timing

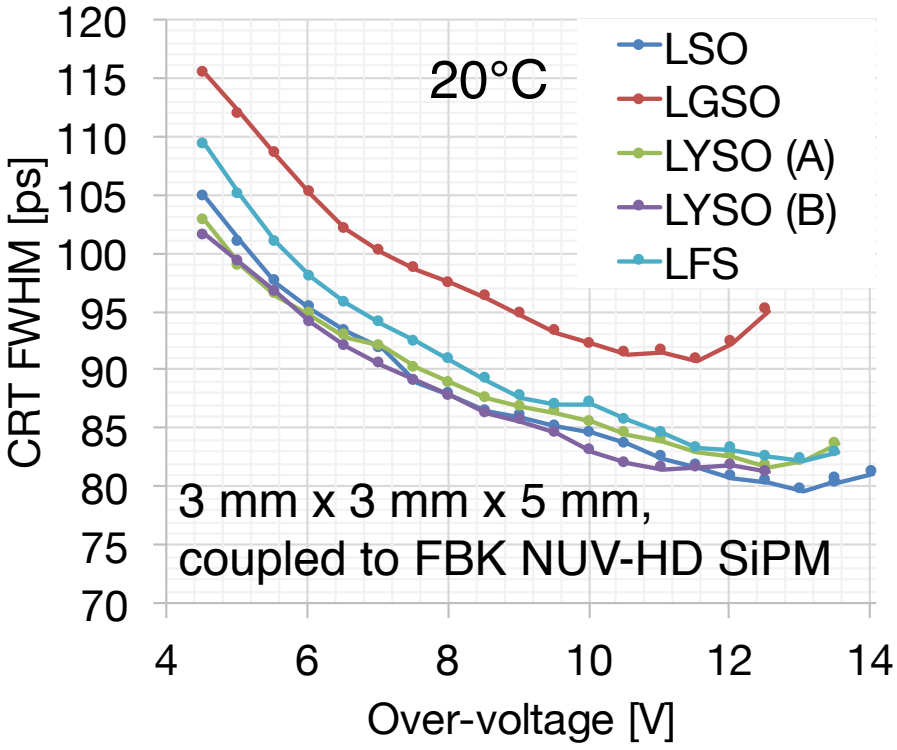
Towards system integration

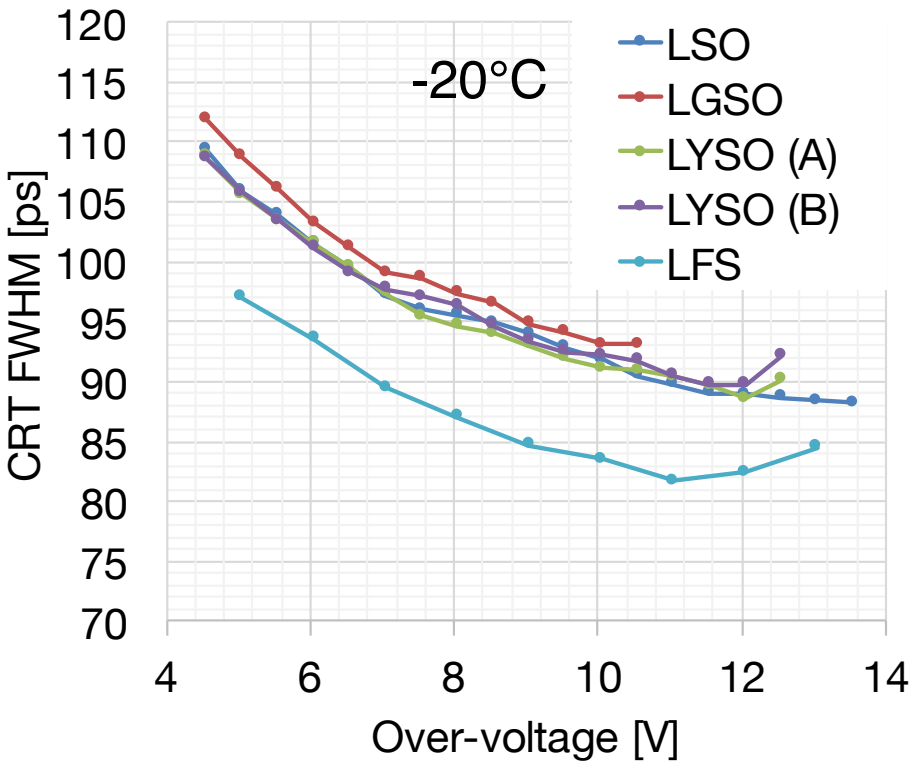
Ultimate timing
Study on codoped L(X)SO:Ce

Ultimate timing





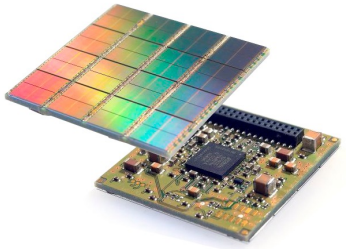


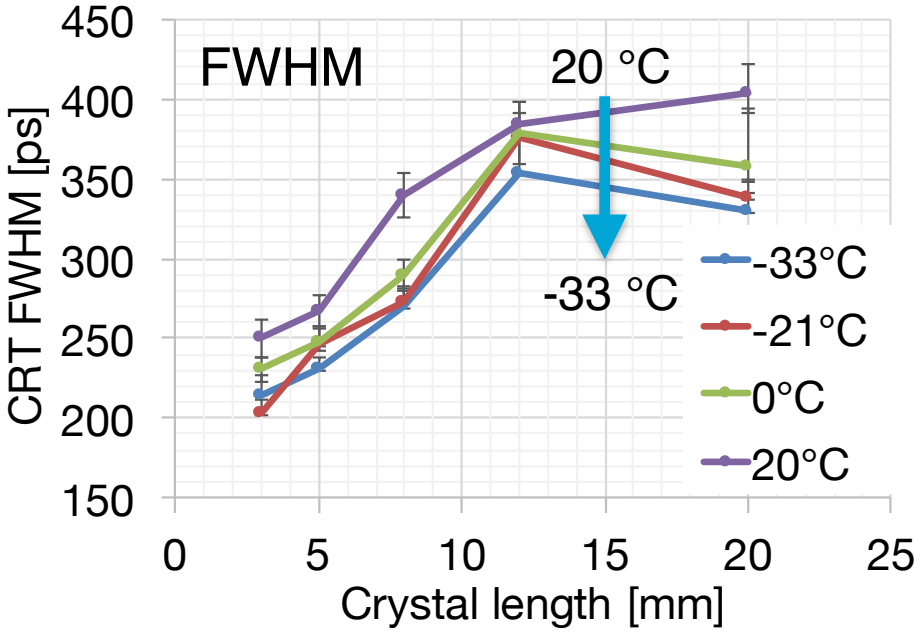


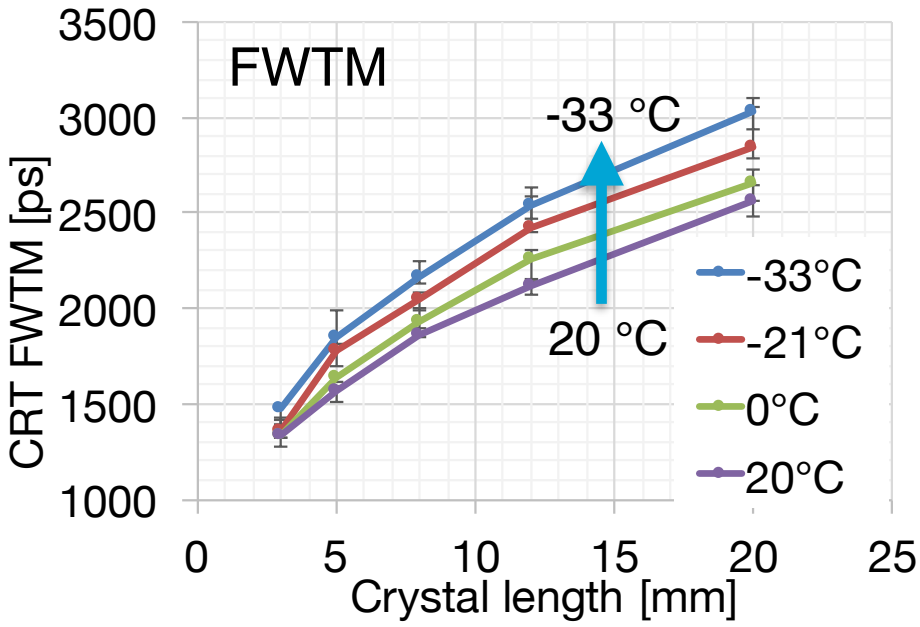
Collaboration with FBK. Thanks to A. Ferri, A. Gola and C. Piemonte!

Cost effective timing:
BGO as hybrid Cherenkov radiator / scintillator

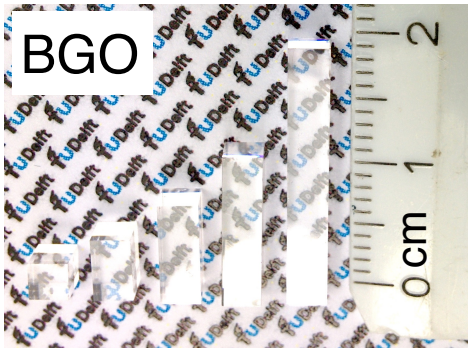
BGO & Digital Photon Counter: Coincidence Resolving Time





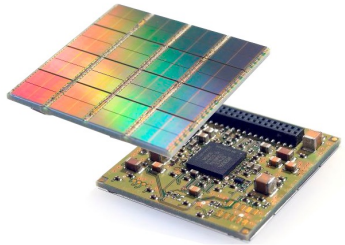


Crystal cross section 3 x 3 mm^2
Crystal lengths: **3 mm, 5 mm, 8 mm, 12 mm, 20 mm** coupled to Philips DPCs

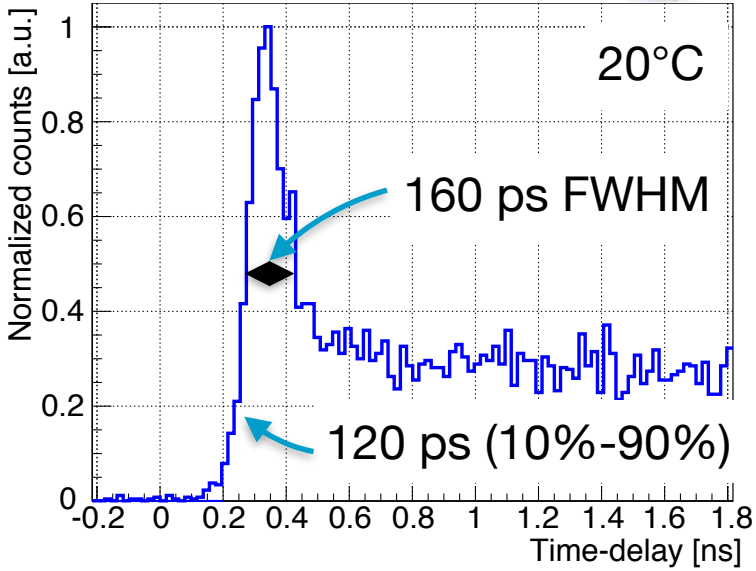


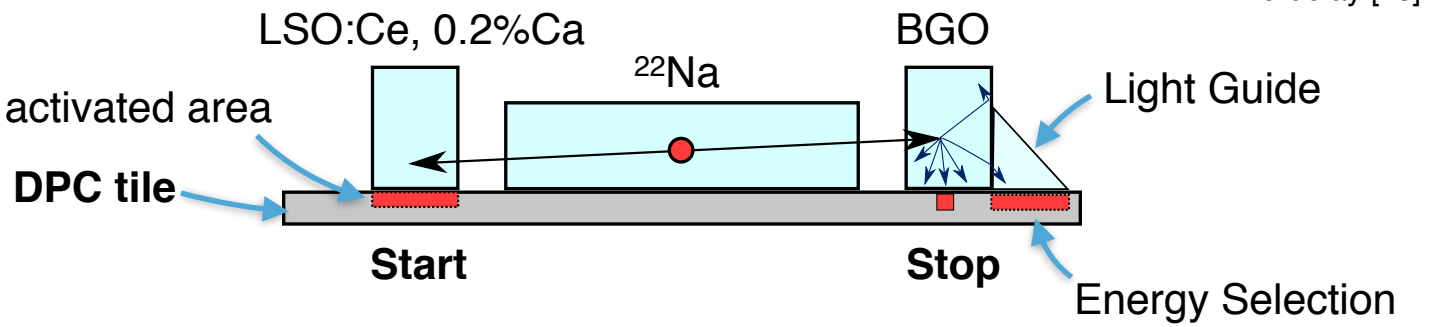
Investigating the BGO rise time

Time correlated single photon counting using a single Philips DPC sensor



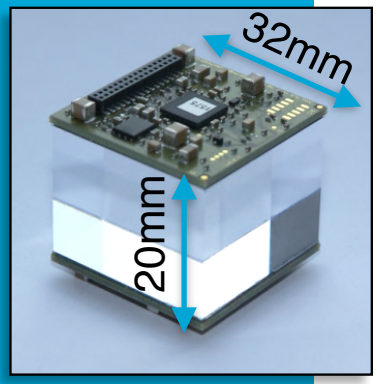
- **Start detector**
  - DPC-pixel
  - Ca-codoped LSO:Ce
  - TR = 90 ps FWHM
- **Stop detector**
  - DPC SPAD
  - SPTR = 48 ps FWHM
- **IRF ≈ 100 ps FWHM**





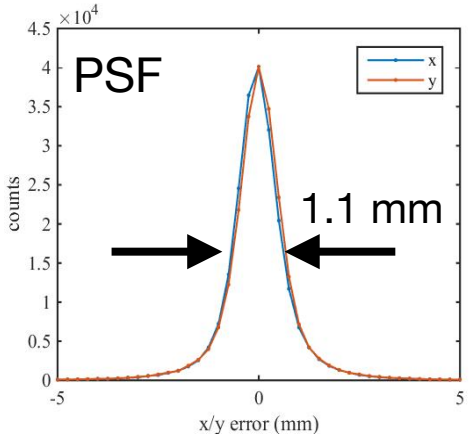
Towards system integration

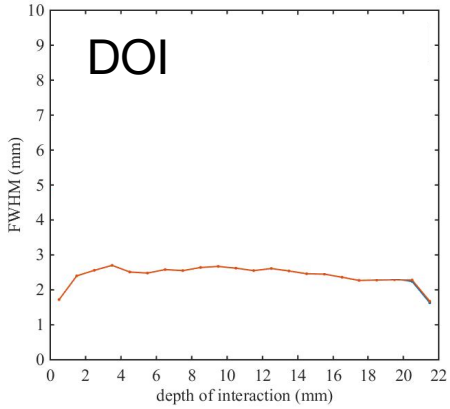
Towards system integration

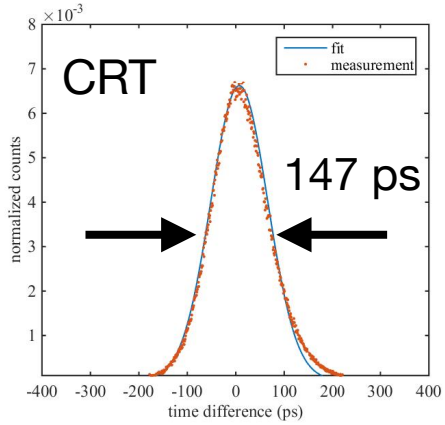


	state-of-the-art	BSR monolithic	DSR monolithic
Energy res.	< 12%	~ 10%	~ 10%
Spatial res.	~ 4 mm	1.7 mm	1.1 mm
DOI resolution	none	3.7 mm	2.4 mm
CRT	325 - 400 ps	214 ps	147 ps

G. Borghi 2016



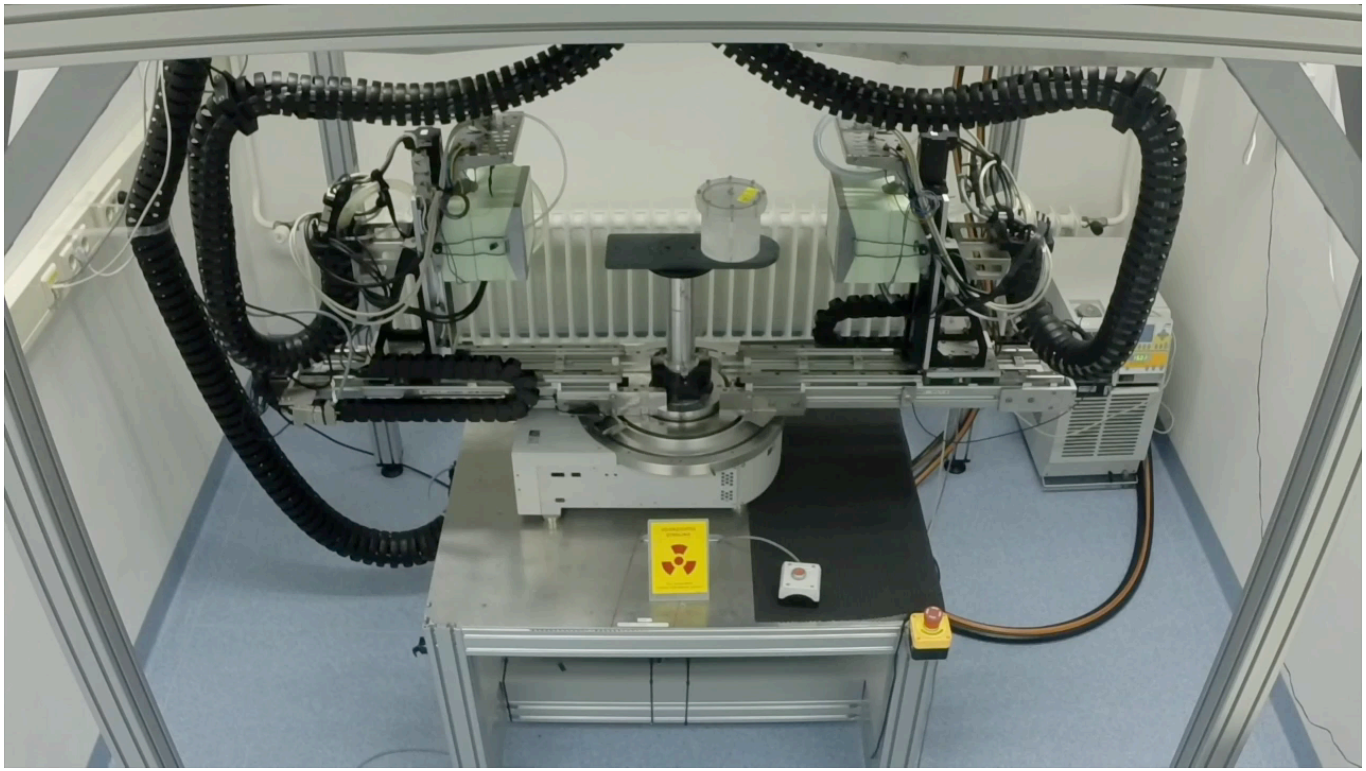




B. J. Beer et al. SNMMI 2015

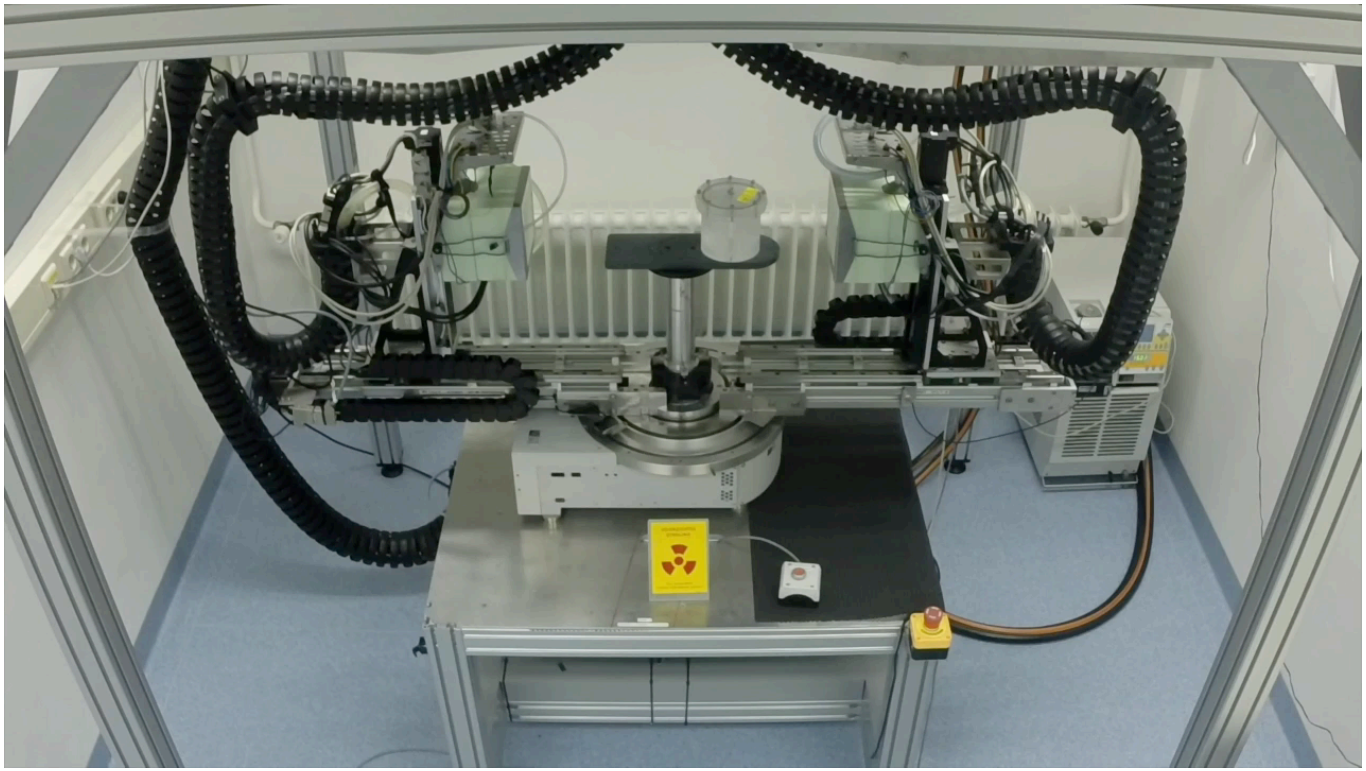
[1] G. Borghi, V. Tabacchini, and D. R. Schaart, “Towards monolithic scintillator based TOF-PET systems: practical methods for detector calibration and operation,” Phys. Med. Biol., vol. 61, no. 13, pp. 4904–4928, 2016.

Towards system integration



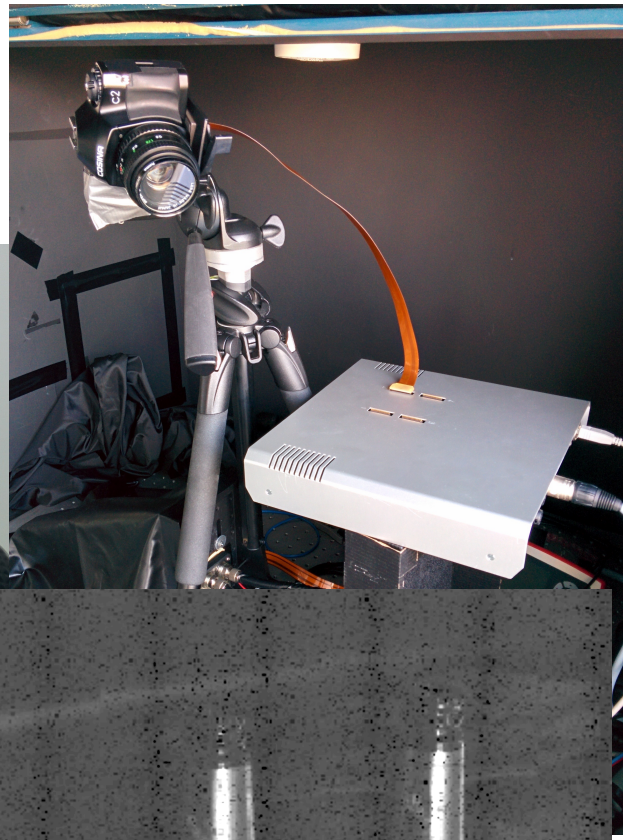
G. Borghi 2016

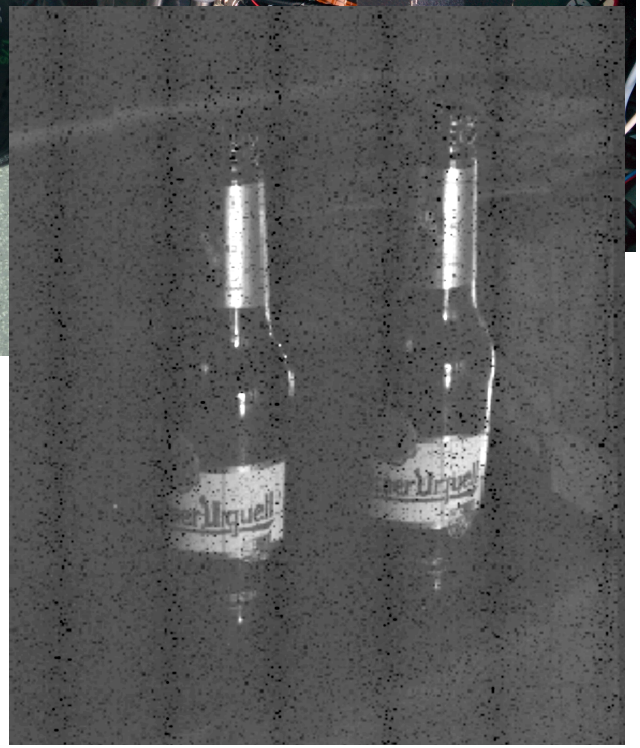
Towards system integration



G. Borghi 2016

Having some fun





Friday afternoon project: camera upgrade

Possible applications

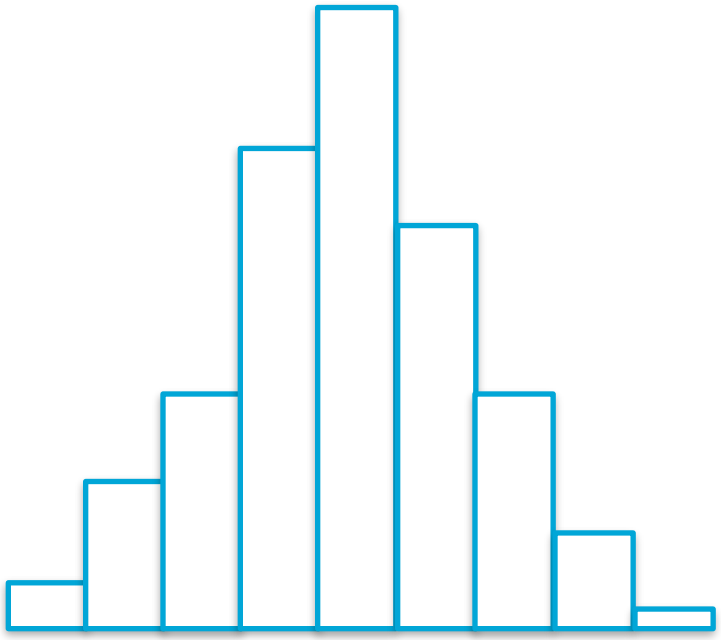
- Cherenkov luminescence imaging
- 3D-TOF imaging

Thanks to PDPC Aachen for their support!

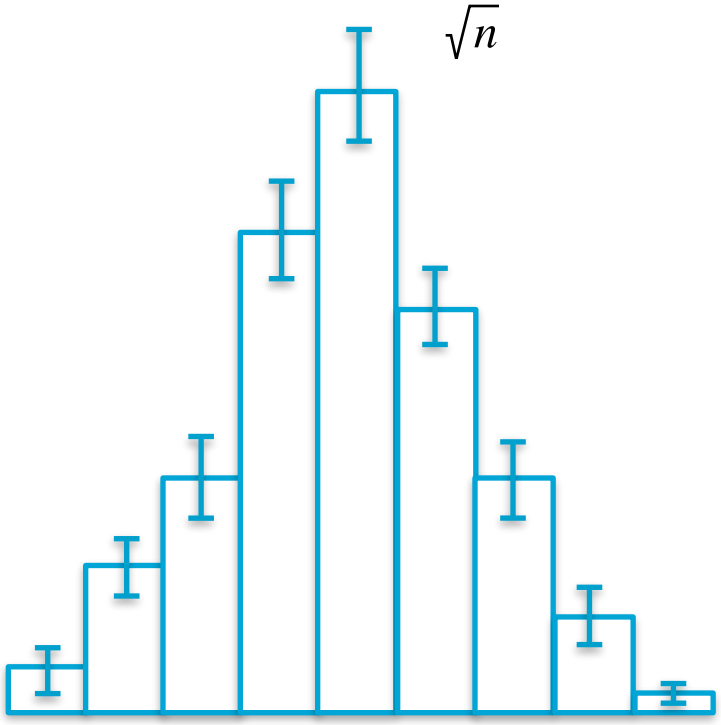
Questions?

Data analysis

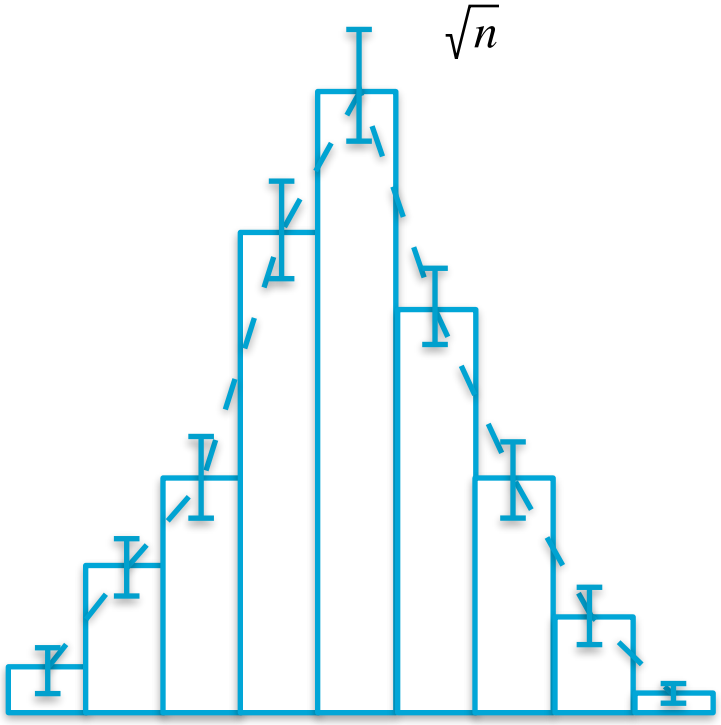
Data analysis



Data analysis



Data analysis



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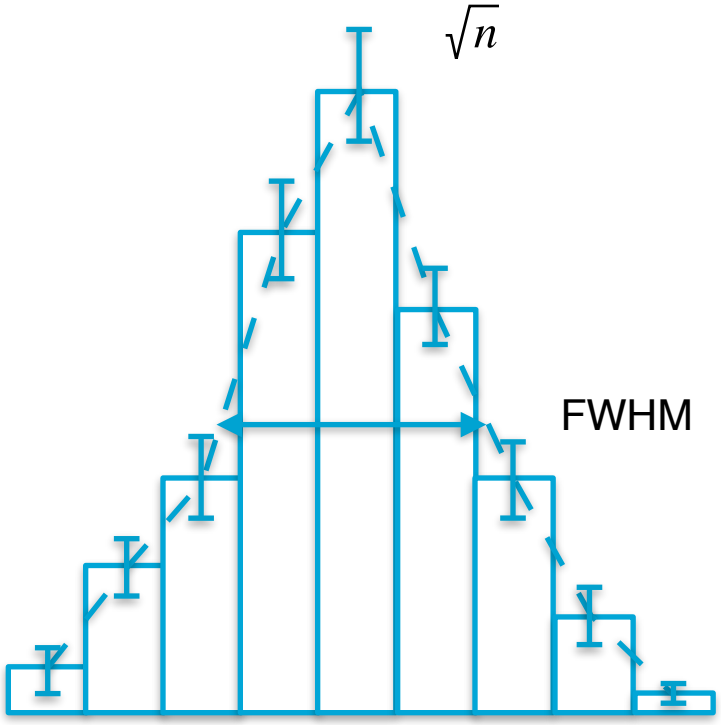

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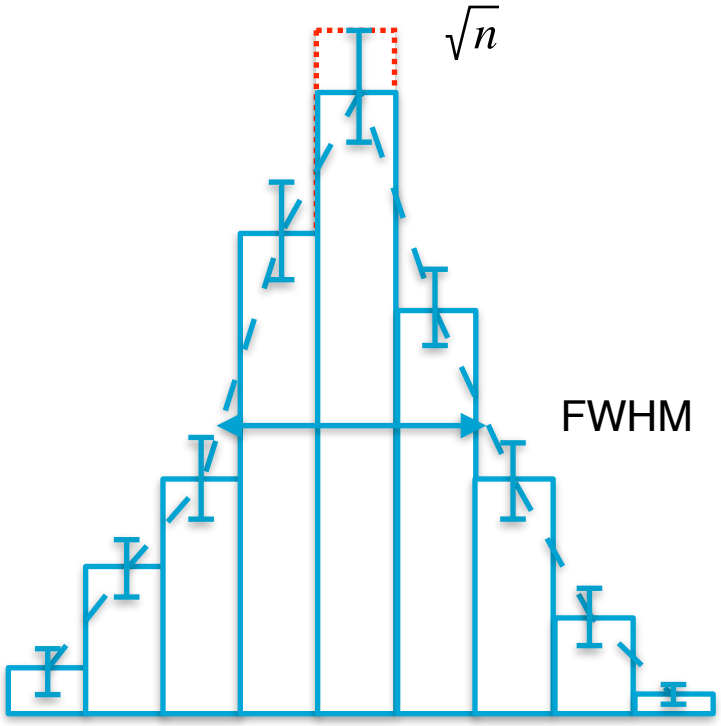

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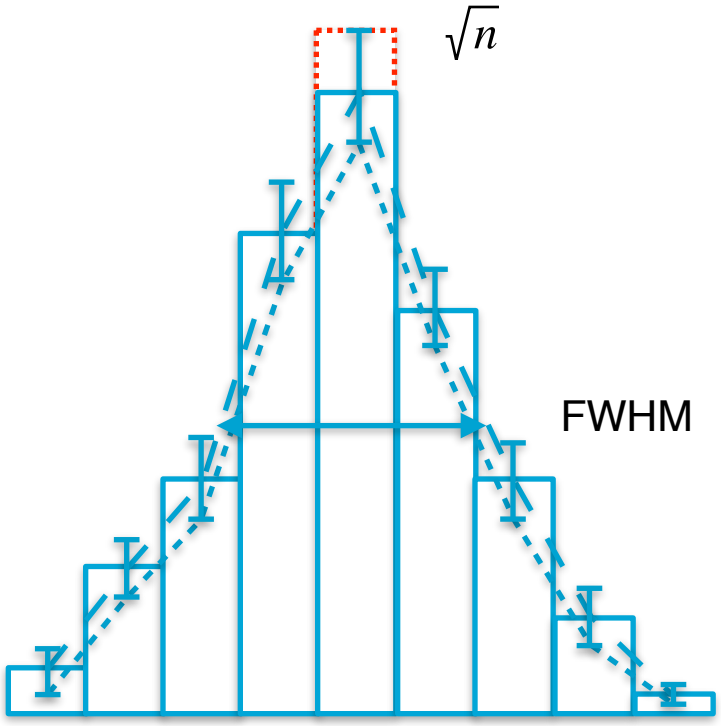

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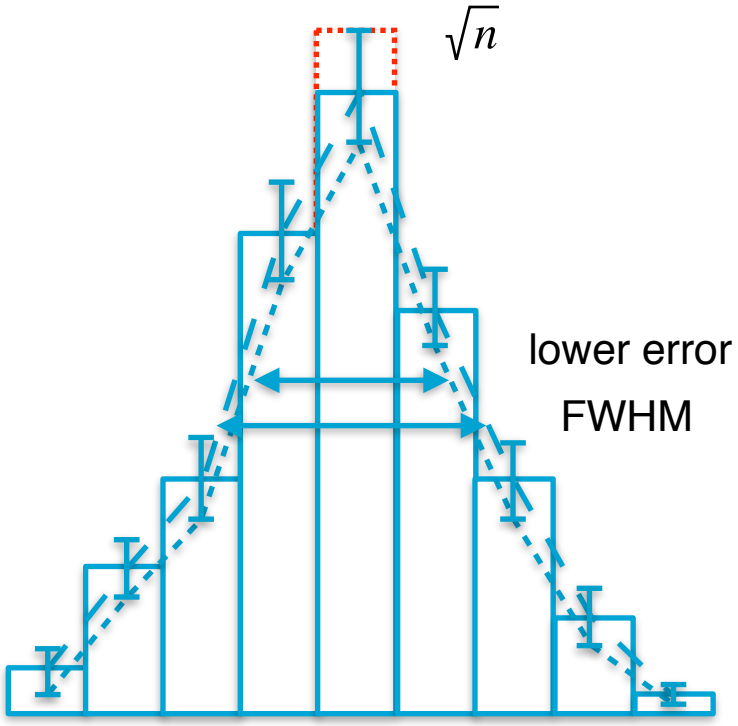

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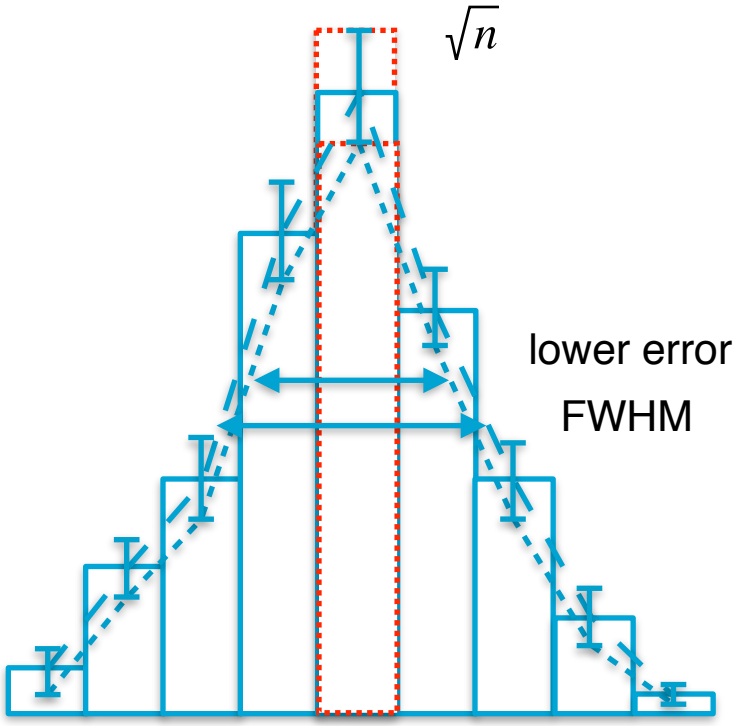

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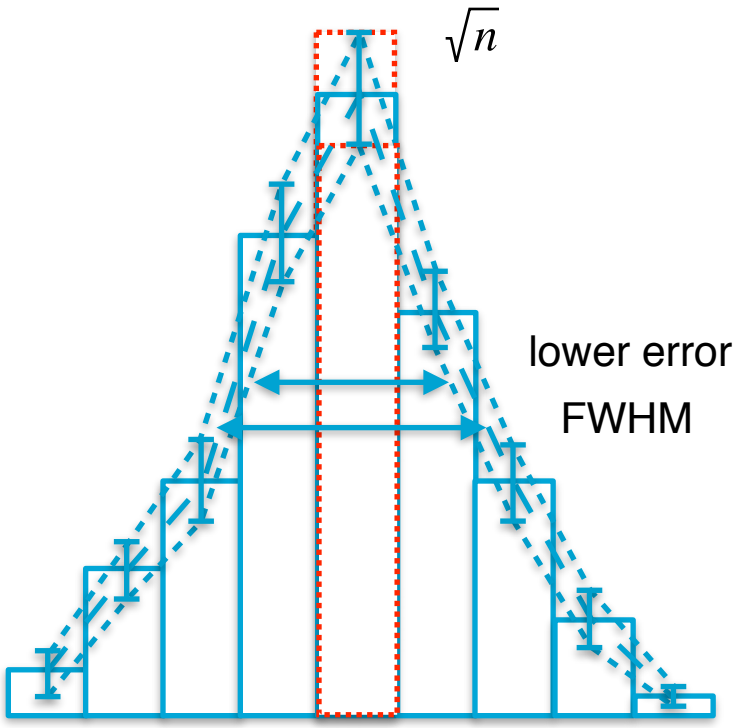

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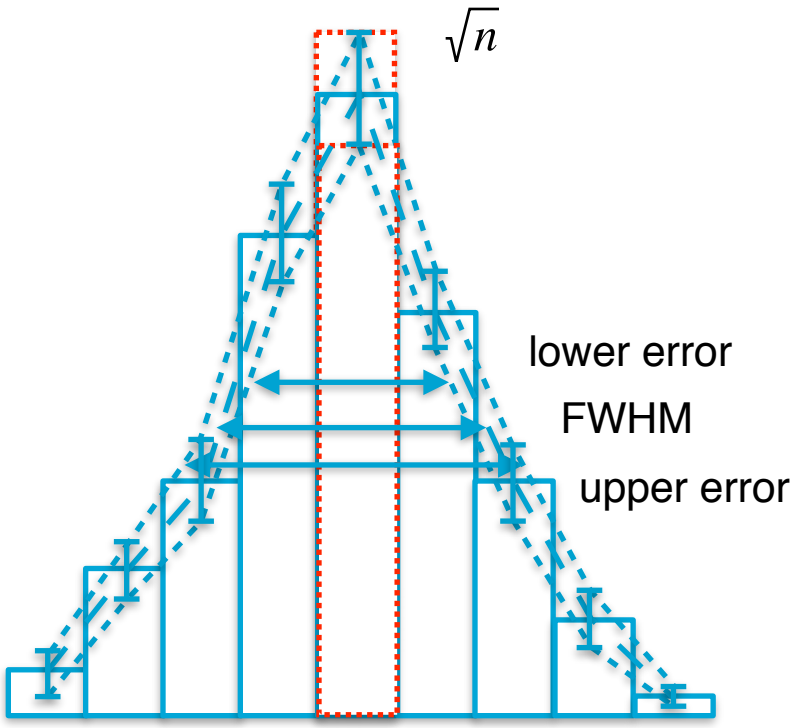
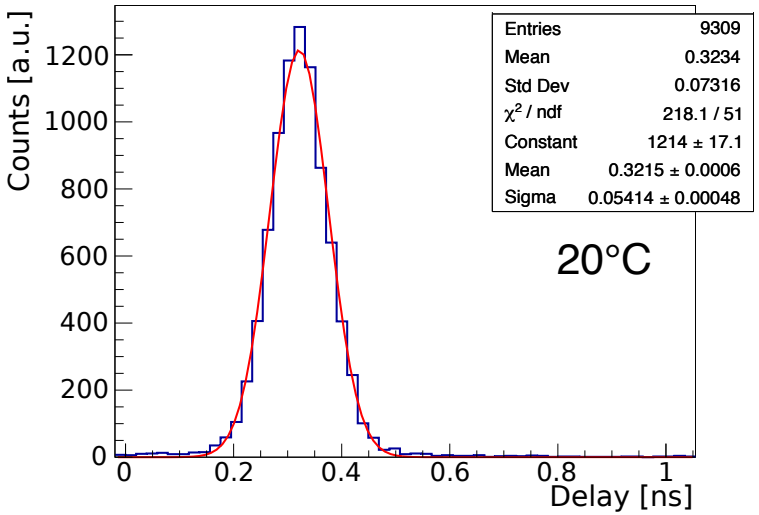
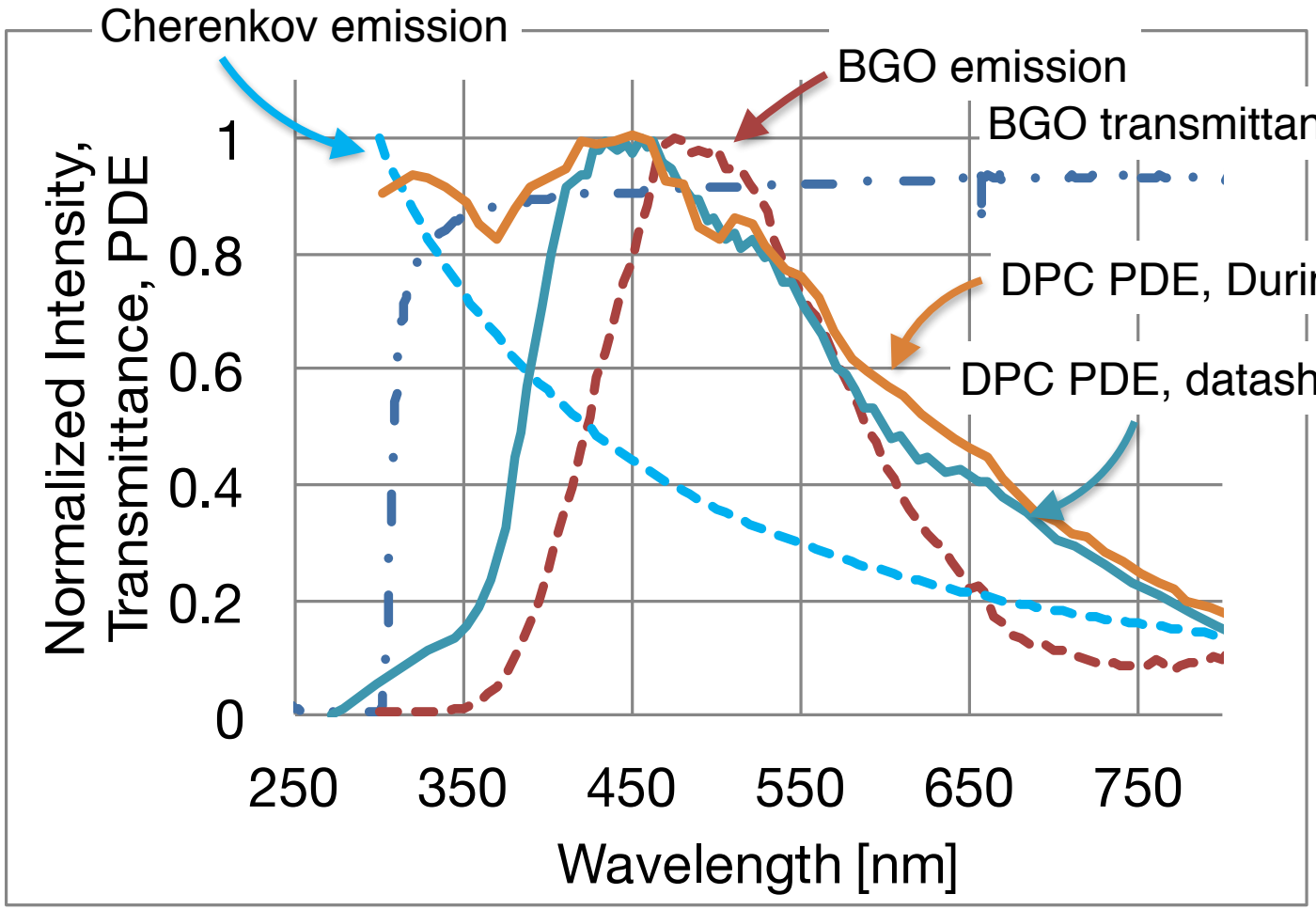


Determination of the IRF

- Ca codoped LSO:Ce as start detector
- 3x3x5mm^3, wrapped in Teflon
- CRT: 127ps FWHM
- start detector TR 90ps FWHM
- stop SPAD TR 48ps FWHM
- IRF ➠ 102ps FWHM (assuming Gaussian distribution)
- Contribution of photon travel spread not (yet) included
- Determination could be done e.g. with Cherenkov response from undoped LuAG, see Gundacker et al. PMB 61 (2016)



BGO and detector characteristics



[1]DPC PDE measured by Durini et al., IEEE NSS/MIC 2016, N28-19