The Jalousie detector concept for powder diffraction studies

Irina Stefanescu

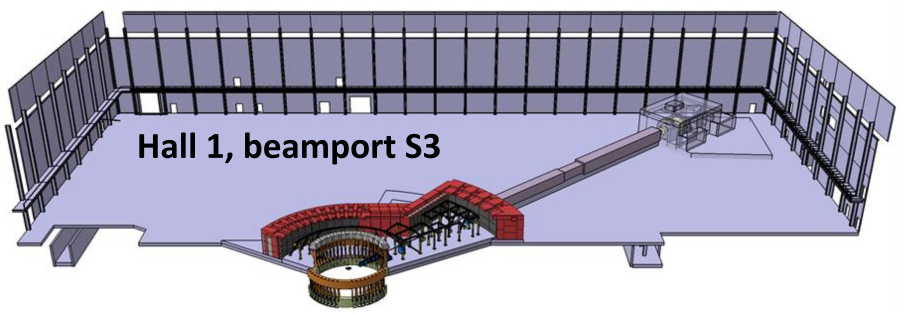
ESS DG

The DREAM instrument

- DREAM will be the ESS powder diffractometer
- Partners: FZ Jülich (D) and LLB (F) (76-24)

- Short instrument (~76 m)
- Expected flux on sample ~10^9 n/s/cm^2

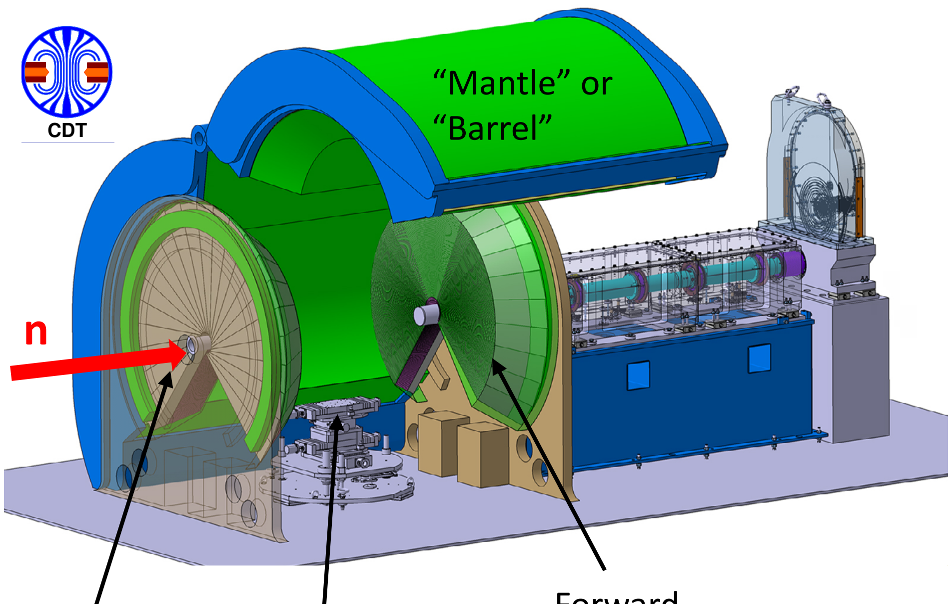
- Agreed budget for the “competitive configuration”: 13.7 M€, of which 3.4 M€ is allocated to the detector system and beam monitors.



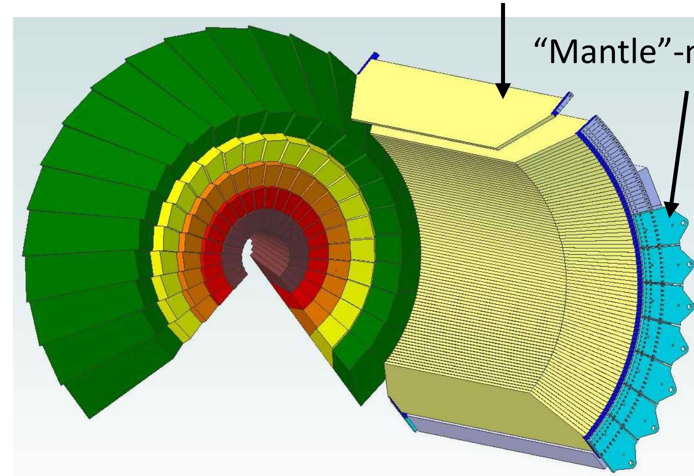
The DREAM detector

Detector technology based on stacked MWPC with ^{10}B-coated cathodes. Designed by CDT Heidelberg for the POWTEX instrument at the FRM2 research reactor.

CDT



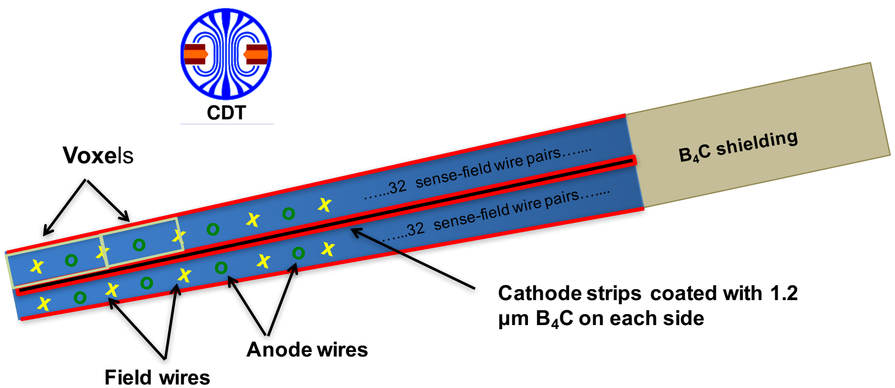
Mantle detector: θ=45°-135°, ϕ~2π;
Backward: θ=135°-168°;
Forward: θ=12°-45°;



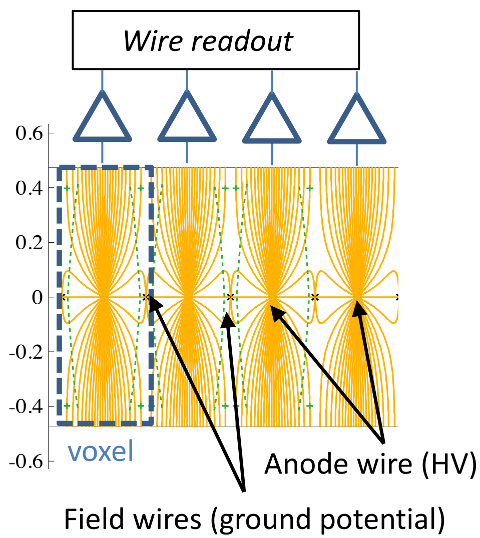
The mantel (barrel) detector consists of hundreds of segments with a trapezoidal shape.

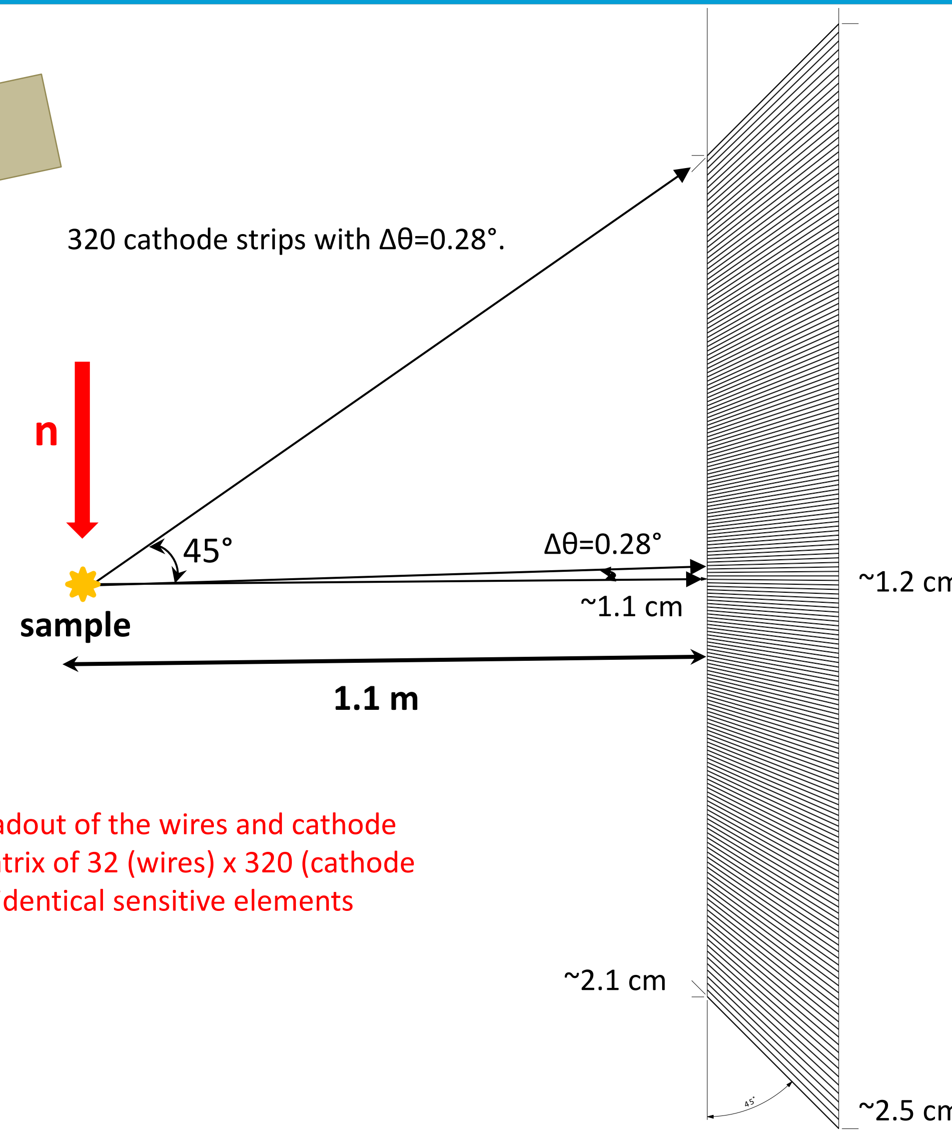
Segment length=2.2 m,
depth=35 cm, height ~ 2 cm.

The DREAM detector
preliminary technical characteristics



One detector segment = two MWPCs
Each wire and strip independently readout





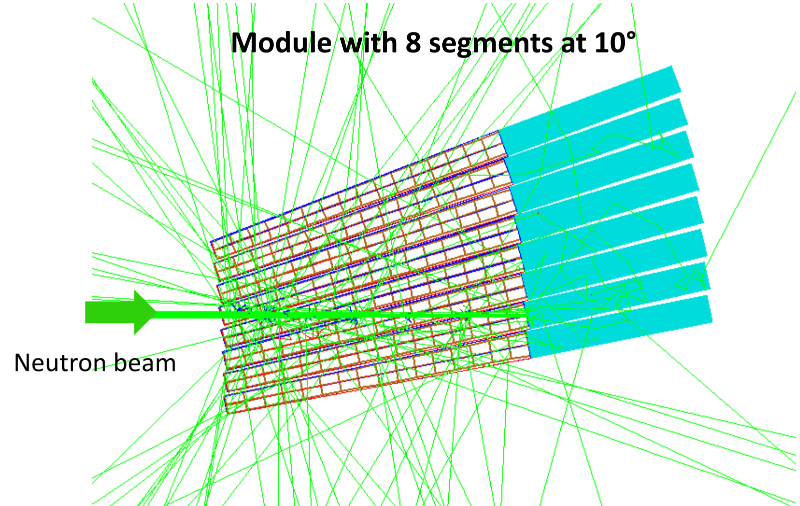
The independent readout of the wires and cathode strips forms a 3D matrix of 32 (wires) x 320 (cathode strips) = 10240 non-identical sensitive elements (voxels).

The DREAM detector

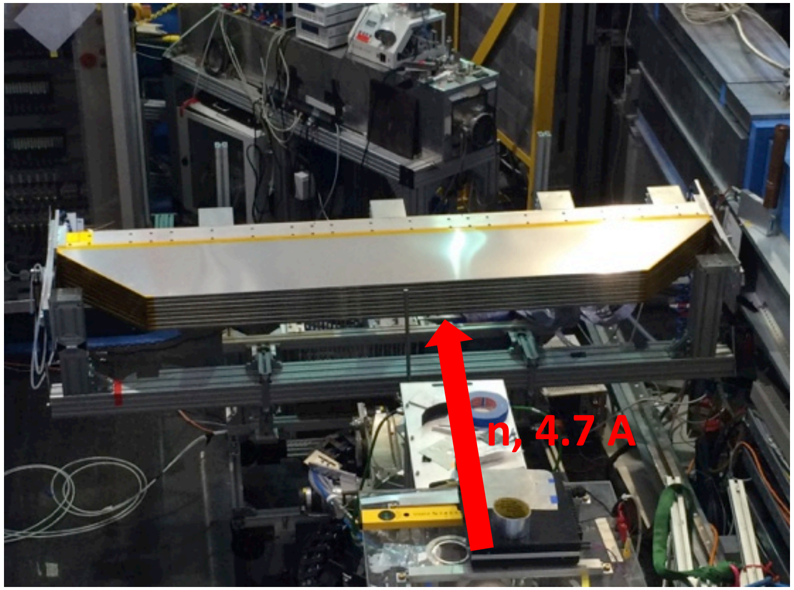
6 segments will be mounted in a common frame = detector module

The modules will be installed in the detector frame such that the angle between the incoming beam and the Boron layers is 10°.

Counting gas: Ar-CO_2 (80-20) in continuous flow.

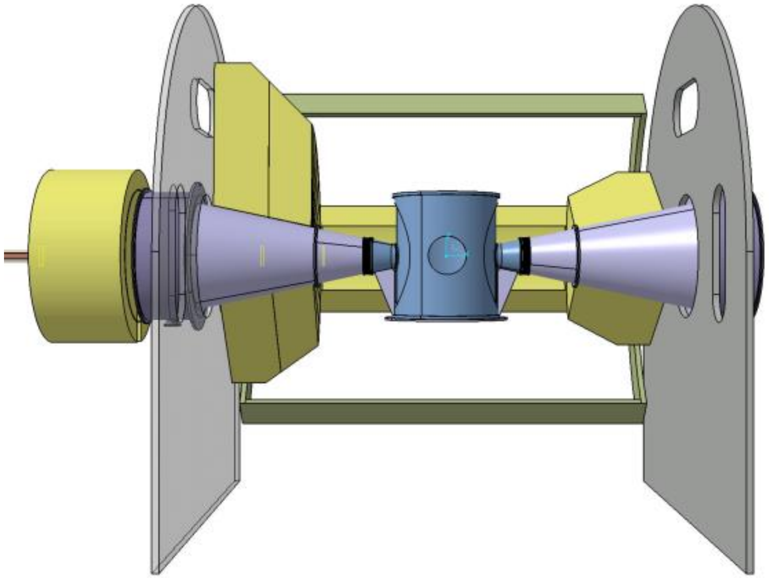


Simulation for Powtex@FRM2



Powtex module (=8 segments) irradiated at TREFF@FRM2 in Dec. 2016.

The DREAM detector
preliminary technical characteristics



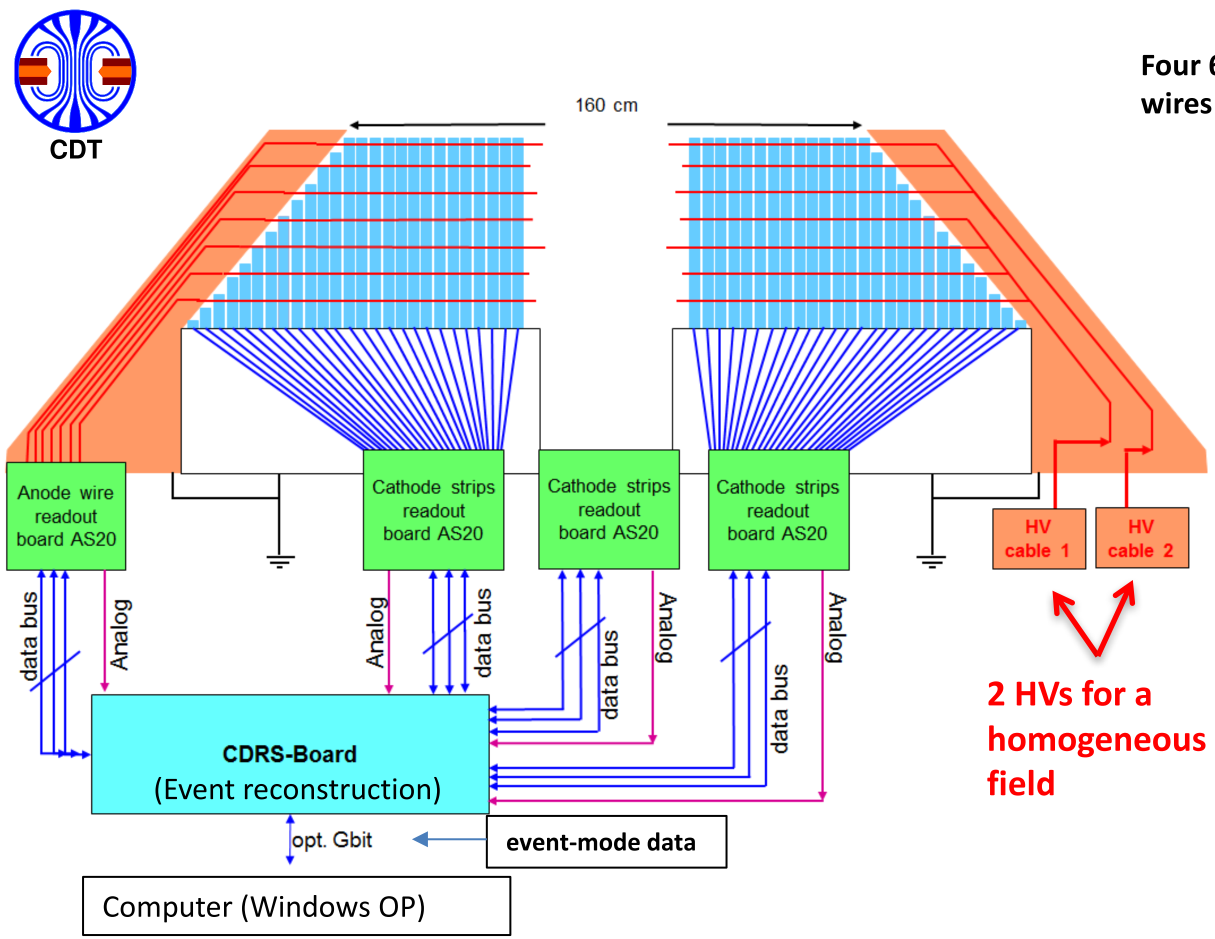
6 x 2 x 32 x 320 voxels per detector module
= 122 880 electronics channels/module

4 mantel modules (24 segments) should be available for hot commissioning

Detector config.	V0	V1	Full Scope
Detector banks	dΩ (sr)	dΩ (sr)	dΩ (sr)
HR Forward 0.6°-12°	0	0	0.14
Forward 12° - 45°	0.06 (12°)	0.29 (60°)	1.30 (270°)
Mantle 45°-135°	0.46 (18°)	0.77 (30°)	2.23 (91°)
Backward 135°-168°	1.02 (216°)	0.61 (132°)	1.30 (270°)
HR Backward >168°	0.14	0.14	0.14
Total coverage	1.68 (33%)	1.81 (35%)	5.11 (100%)

The POWTEX detector at FRM2

The readout/DAQ will be based on the current Powtex readout system, also developed by CDT.



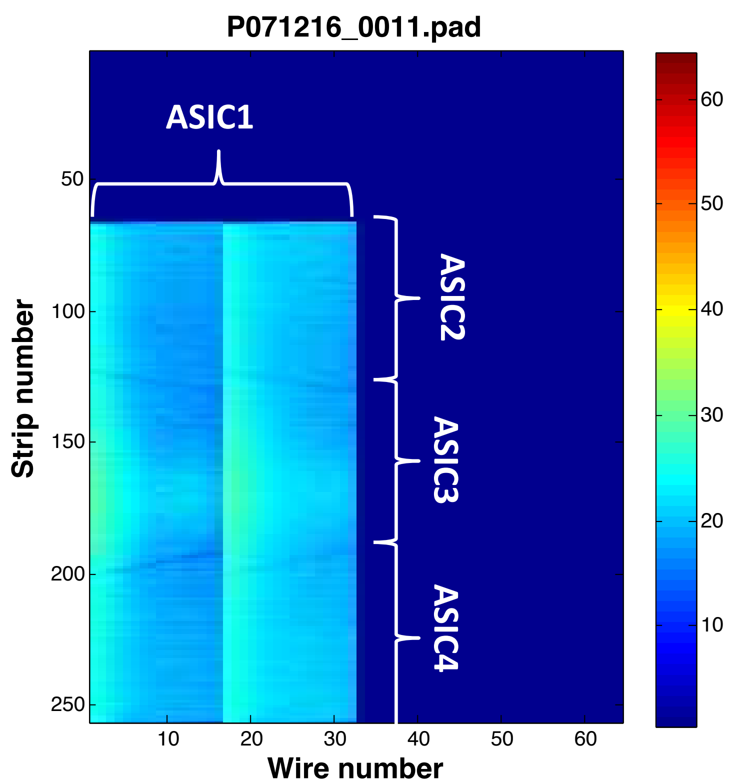
Four 64-ch CIPx cards (AS20) : 1 for the anode wires (32), 3 for the cathode strips (192).

2 HVs for a homogeneous field

Der Powtex Jalousie Mantelflächendetektor, Betribshandbuch, Montageanleitung, Stromlaufplan, 2015 CDT GmbH, www.n-cdt.com

The DREAM detector
preliminary technical characteristics

- Users have access to the 1D and 2D histograms in ASCII format; use the software of choice for graphical representation.
- Each ASIC has a analog output that can provide the PHS for a specific channel (wire, strip)

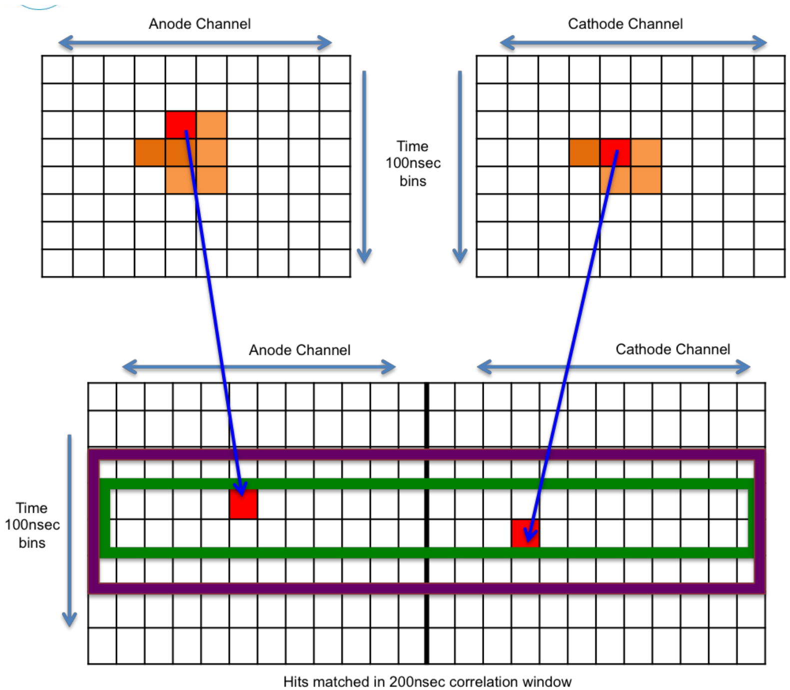


Matlab representation of the 2D data from Powtex

The DREAM detector
preliminary technical characteristics

- DREAM will use five ASIC boards for the cathode strips and one for the wires per detector segment = 6 64-ch ASICs/detector segment

- A larger FPGA might be needed by the more demanding DREAM data flow.



- The ASIC operates at 10.4 MHz ➔ time bin = 100 ns. Neutron pulses in up to 3 time bins and 3 voxels.

- Event reconstruction: valid neutron event if an anode event (x) exists with a cathode event within 200 ns.

Readout electronics for DREAM, Internal document, CDT-ESS, June 2016.

Status of the DREAM detector project

- The DREAM instrument is currently in phase 2.
- TG3 scheduled before the end of the year.
- Hot commissioning planned by mid 2021.

- Technical Annex for work with a duration of 18 months was signed in July 2017.
- Early procurement approved funding for the design, construction and experimental verification of a mantel module (6 segments) and a 12°-sector for the forward/backward detector, hardware development for readout electronics (new FE ASIC card, FPGA board, compatible clock/timing implementation) and adaptation of the detector readout firmware.

- Same detector technology selected by the MAGIC (Tranche 1) and Heimdal instruments (Tranche 2).

- The principal risk of the DREAM detector WU is of a delay and labor cost overrun due to the complexity of the project and the capability of the CDT company to deal with several projects that are in various stages of execution but running in parallel.

- We follow closely the development of the POWTEX detector, which is in an advanced stage of execution/testing.

Geant4 simulations for the Powtex Jalousie detector

EUROPEAN SPALLATION SOURCE

Powder diffraction studies are about being able to measure diffraction patterns from complex crystals.

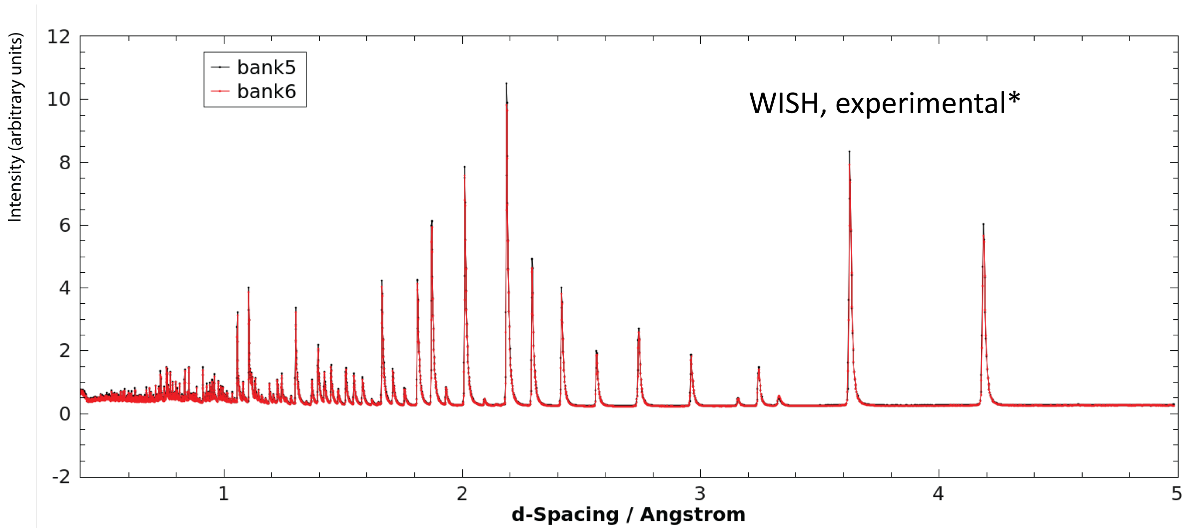


Figure 10. Bragg reflections from a sample of $Na_2Ca_3Al_2F_{14}$ in the most back scattering panels.

Quality of the PD spectra determined by the instrumental resolution:

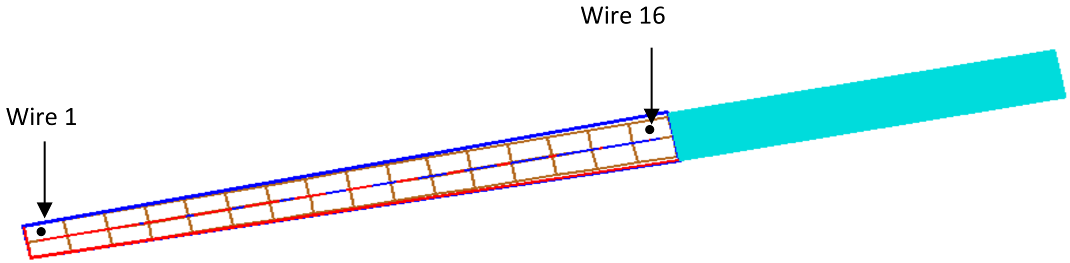
$$\frac{\delta d}{d}=\sqrt{\left(\frac{\delta t}{t}\right)^2+\left(\frac{\delta L}{L}\right)^2+(\delta\theta\cot\theta)^2}$$

**D. Duxbury et al., IOP JINST 9, C12008, 2014.*

Objectives of the simulation project: deliver a model of Jalousie that can be used to study the detector performance in terms of efficiency, time and position resolution, the background signal generated by the scattering of the neutrons in the various detector components, but also be able to simulate the diffraction pattern of a known diffraction sample.

Geant4 simulations for the Powtex Jalousie detector

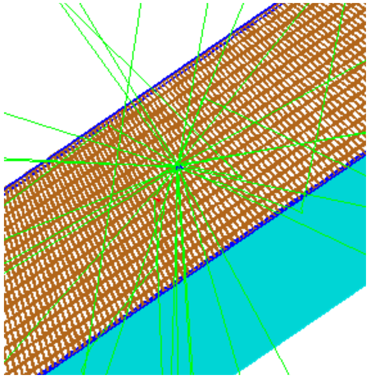
In a MWPC the position/time resolution is determined by the geometry of the counter, the physics of the media involved (neutron converter, counting gas) and the physics of the low-energy electrons produced in the ionization of the gas (drift, amplification).

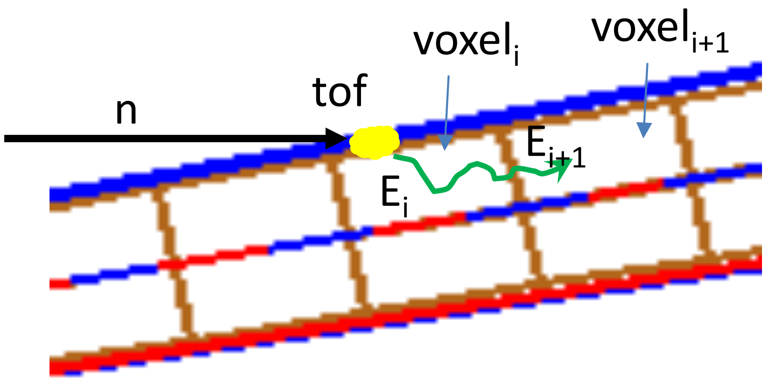


Simulation strategy: model the readout voxels as trapezoids made of Ar-CO_2 gas and place them side-by-side to fill the space between the cathode plane and detector housing.

Each gas voxel is centered on a sense wire and is located between field wires.

16 x 192 gas voxels per counter = 16 x 192 readout voxels per counter





Geant4 simulations for the Powtex Jalousie detector

Validation of the simulation strategy: comparison between the calculated and measured strip resolution

Experimental

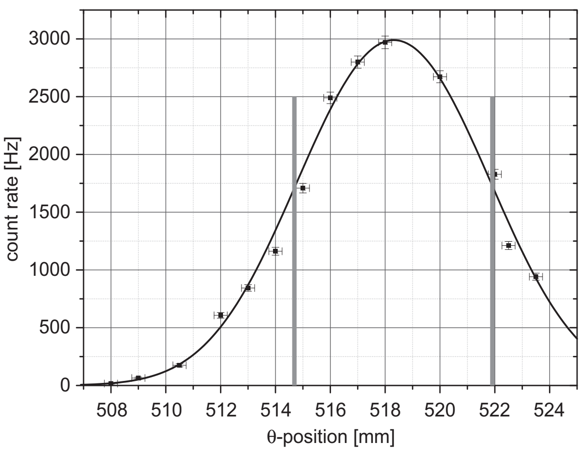
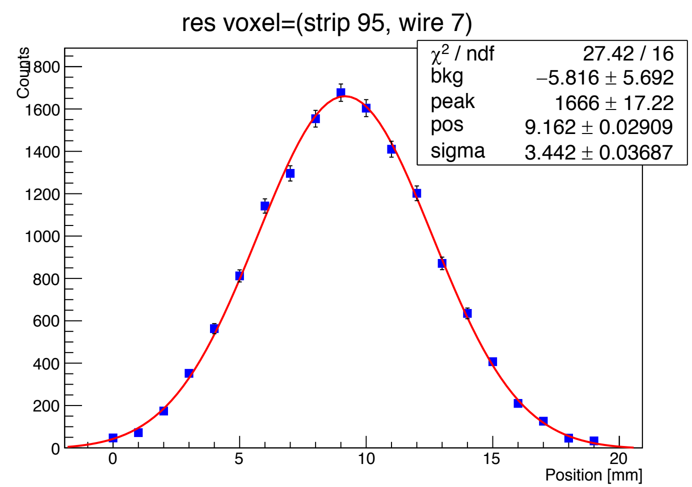


Fig. 9. Measured intensity on one cathode readout strip of 7.22 mm width (vertical lines). The error in θ-position due to the manual positioning was estimated to 0.25 mm. The Gaussian fit has a width of 7.85 mm (FWHM), which results in a position resolution of 6.0 mm (FWHM) when the beam width of 5.1 mm is quadratically subtracted. The intrinsic resolution of digitization alone would result in 4.9 mm FWHM, suffers additional broadening through the range of tracks in the counting gas of the primary fragmentation products.

Geant4

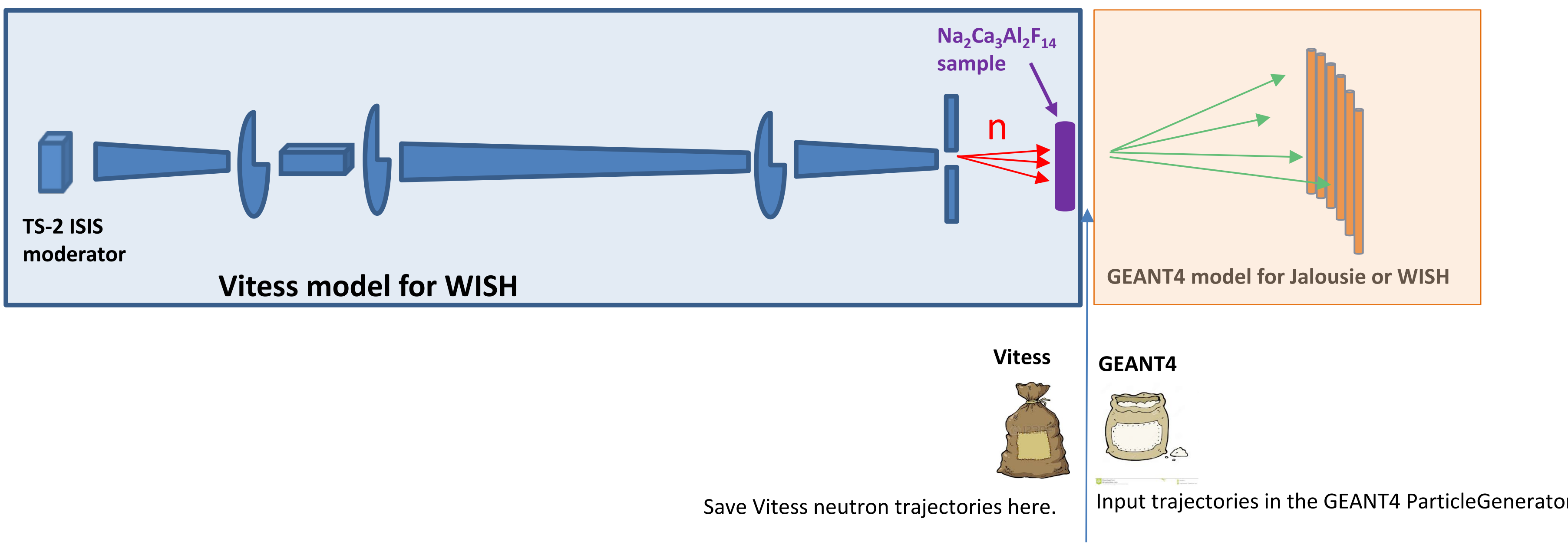


FWHM = 8.1 mm

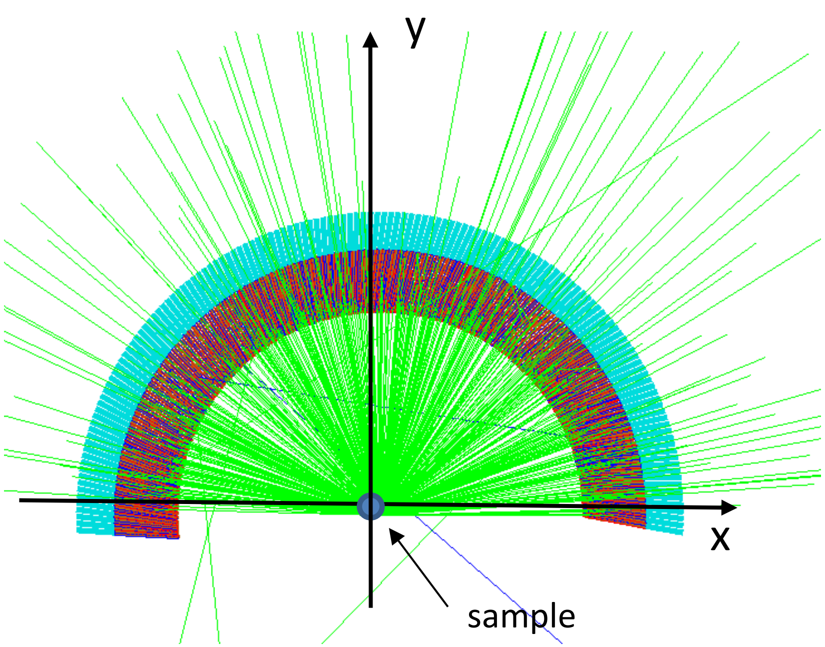
M. Henske et al. / Nuclear Instruments and Methods in Physics Research A 686 (2012) 151–155

Geant4 simulations for the Powtex Jalousie detector

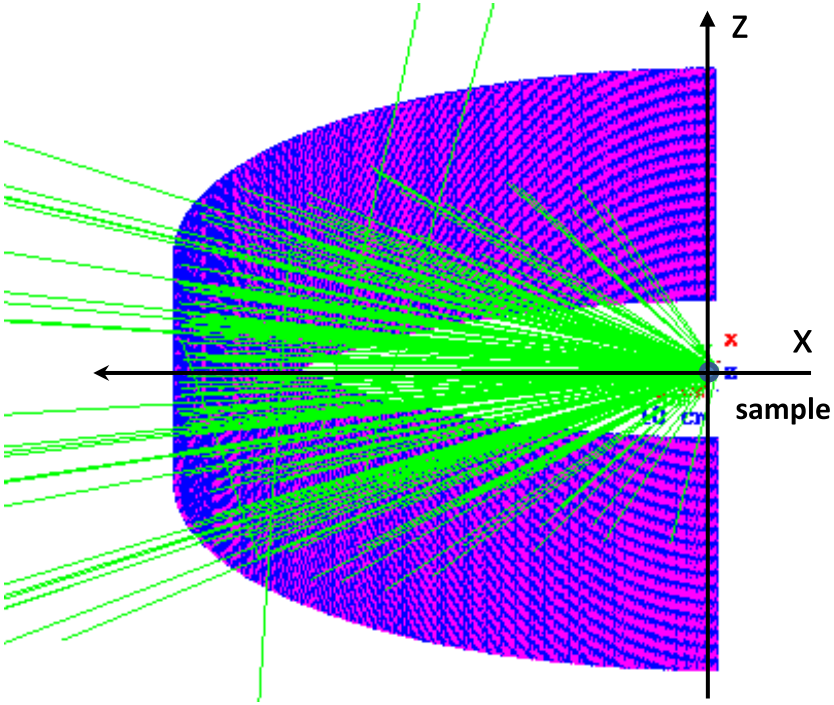
The trajectories of the neutrons scattered by the $Na_2Ca_3Al_2F_{14}$ sample obtained with the Vitess model for WISH.



Geant4 simulations for the Powtex Jalousie detector



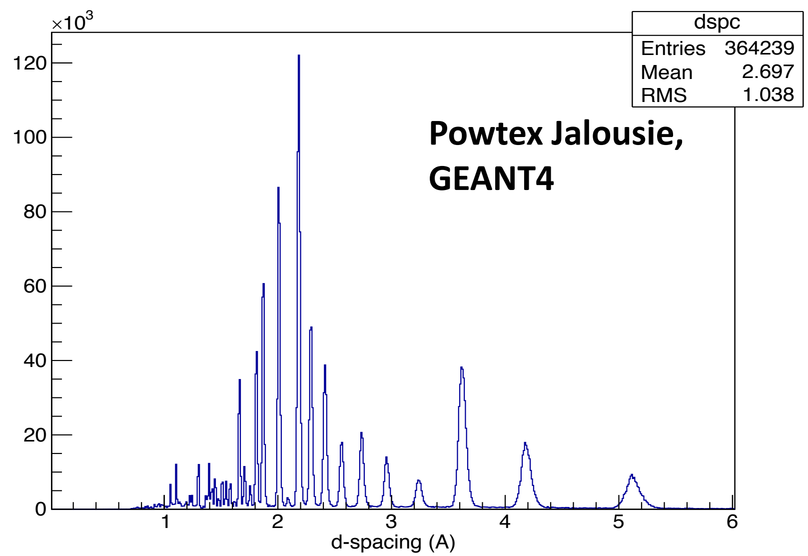
The Geant4 model for the Jalousie detector

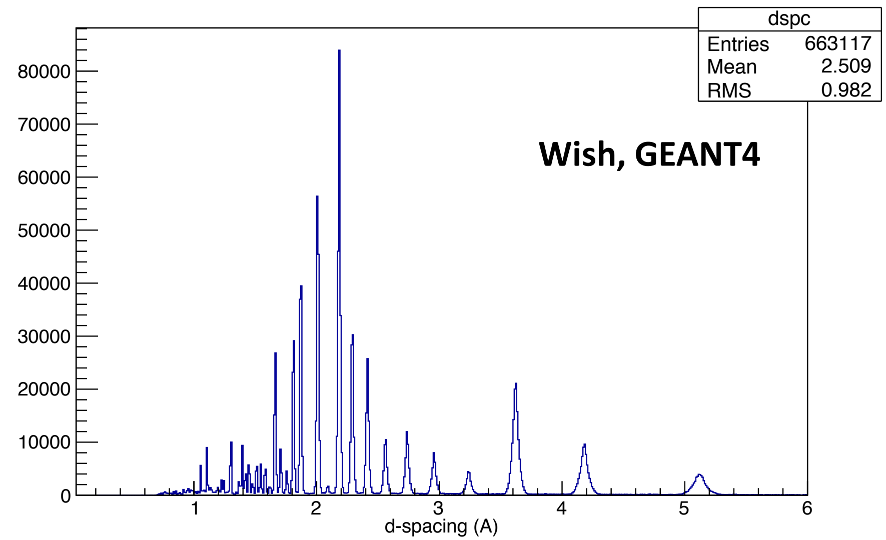


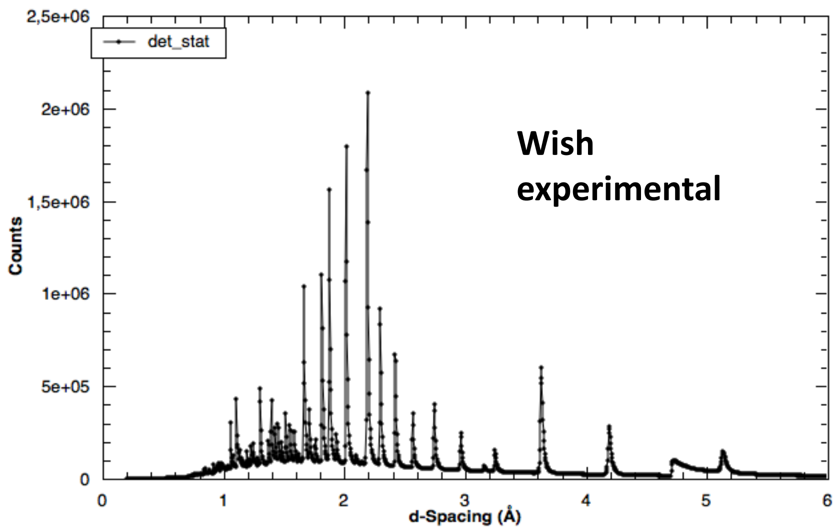
The Geant4 model for the WISH detector (760 ^{3}He-filled tubes with a diameter of 8 mm diameter and 1 m long).

Position resolution along the tube implemented by filling the tube with 8-mm high cylindrical gas voxels.

Geant4 simulations for the Powtex Jalousie detector







Comparison between the simulated and experimental $Na_2Ca_3Al_2F_{14}$ diffraction pattern

- good agreement for the peak density and position
- good agreement for the height of the peaks
- background not included in the calculation

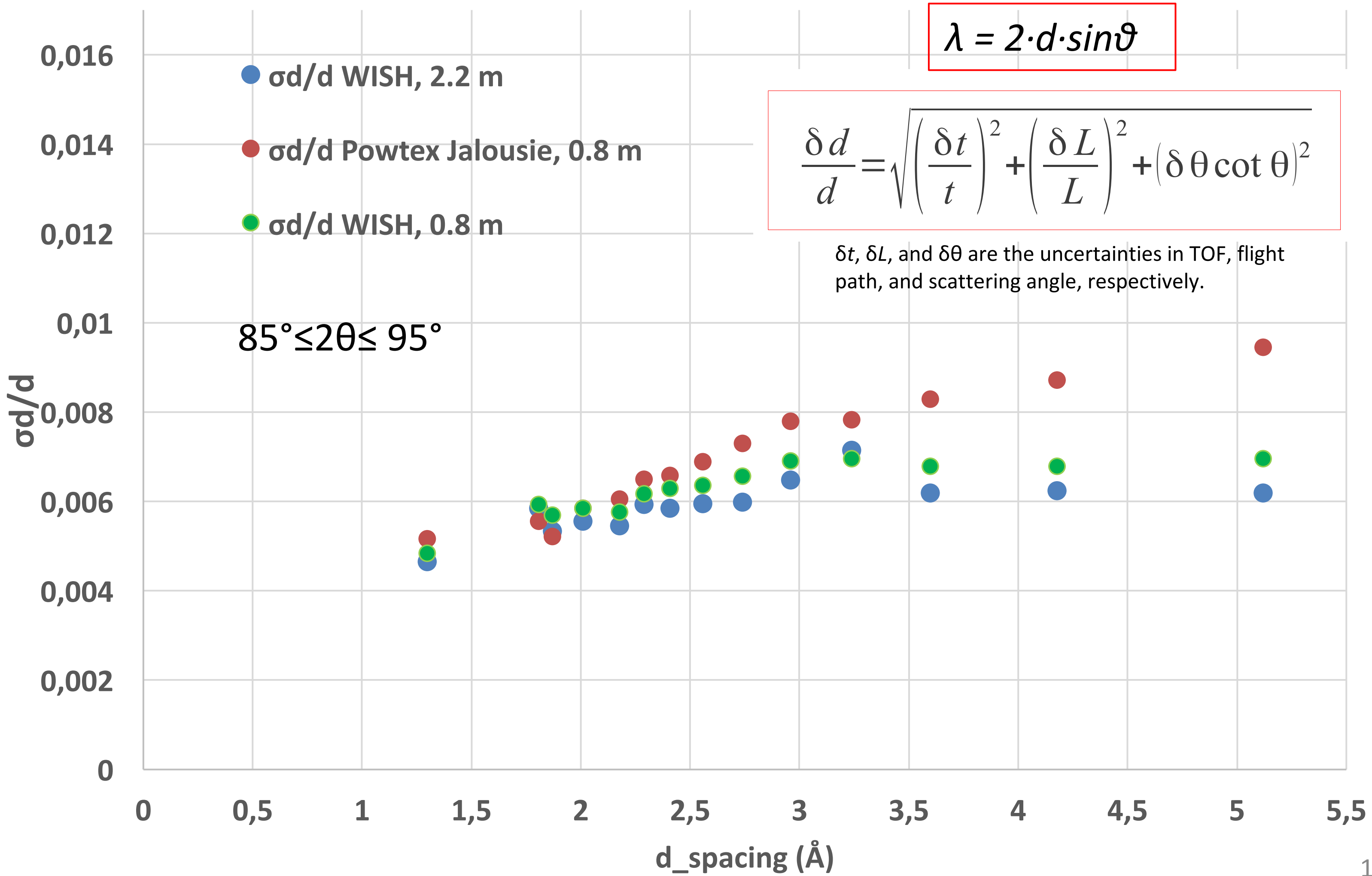
Geant4 simulations for the Powtex Jalousie detector

EUROPEAN SPALLATION SOURCE

$\lambda = 2 \cdot d \cdot \sin\vartheta$

$$\frac{\delta d}{d} = \sqrt{\left(\frac{\delta t}{t}\right)^2 + \left(\frac{\delta L}{L}\right)^2 + (\delta\theta \cot\theta)^2}$$

δt, δL, and $\delta\theta$ are the uncertainties in TOF, flight path, and scattering angle, respectively.



Conclusions

- I tried to give an overview on the current status of the DREAM detector project
- 1/3 of the detector must be ready by 2021, but the first TA was just signed ➔ this might indicate that the whole project is seriously late.
- However, the supplier, CDT Heidelberg, delivered some really nice stuff in the past (e.g., CASCADE detectors, beam monitors, etc.).
- Lods of experience gained and important lessons learned from the delivery of the Powtex detector. These put the DREAM detector project well ahead other detector projects at ESS.