

Current status of dark matter searches at the Boulby facility

Boulby Programme
Boulby Facility
NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

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CCLRC Rutherford Appleton Laboratory
On behalf of Boulby DM Collaboration*

Boulby Programme

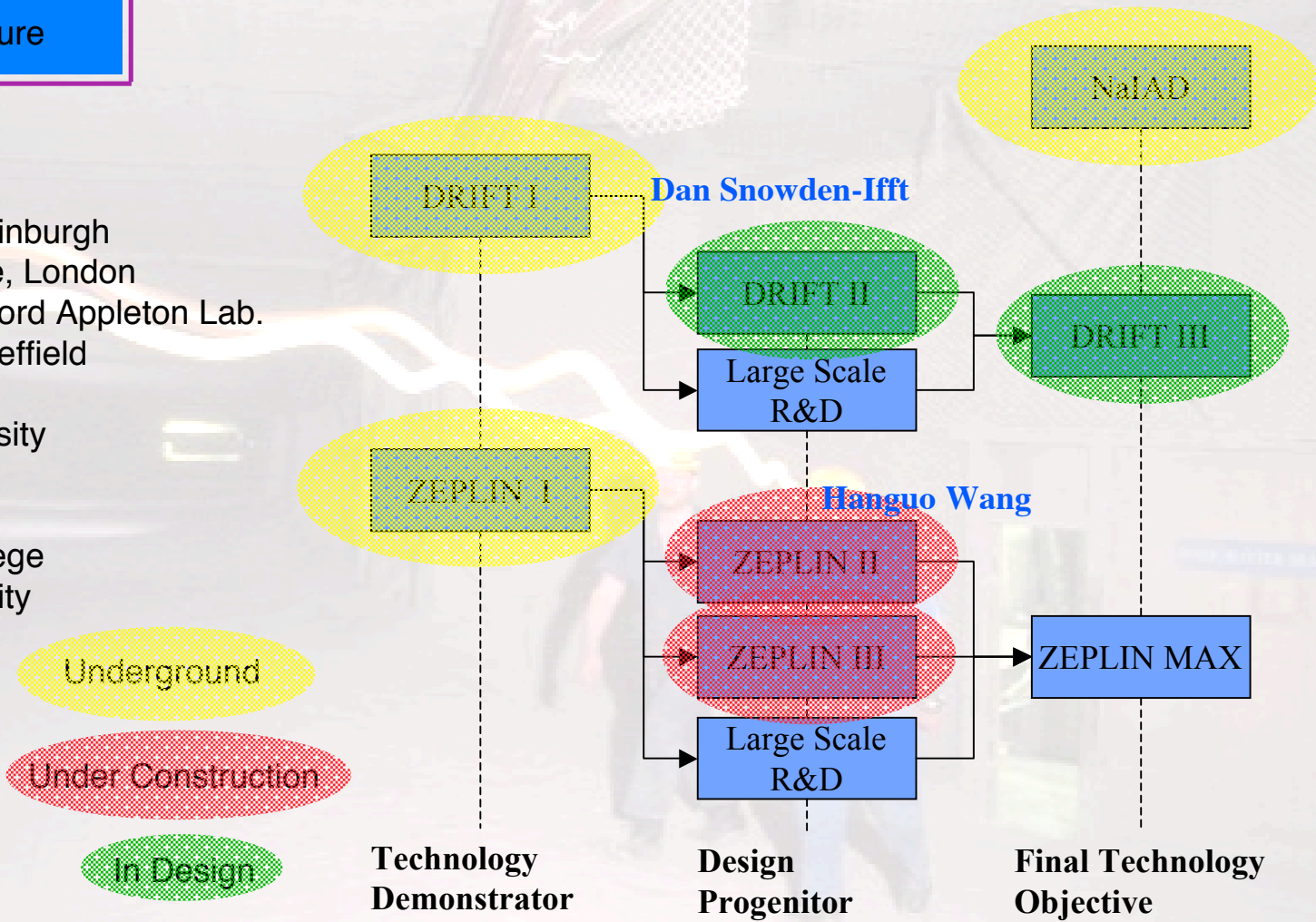
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Boulby DM Programme

Collaboration

University of Edinburgh
Imperial College, London
CCLRC Rutherford Appleton Lab.
University of Sheffield

Coimbra University
ITEP
LLNL
Occidental College
Temple University
Texas A&M
UCLA



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ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

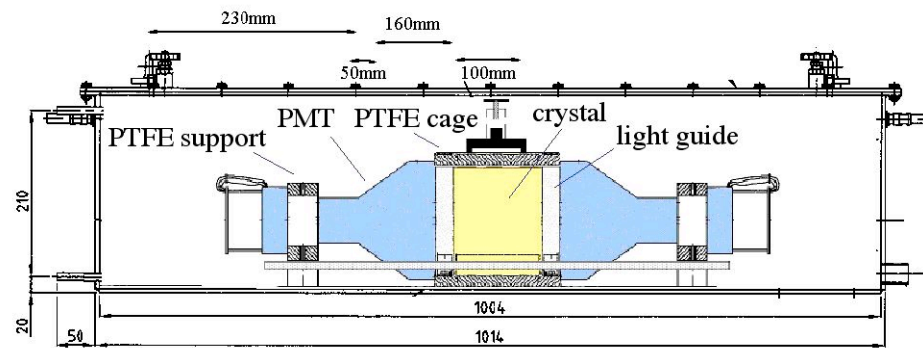
A place to find WIMPs

- Surface facilities
 - **Workshop, offices, etc.**
- Underground facilities
 - **New clean area, upgrade existing**
- Opened April '03 by Lord Sainsbury
 - **With a place in the Sun**



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ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

NaIAD Array



- NaIAD: 8 NaI(Tl) crystals totalling 65kg
 - **6 unencapsulated, 2 encapsulated**
 - **Light yield 5 - 9 p.e./keV**
 - **Temperature stabilised to 0.1°C**
 - **Threshold 1-1.5 keV**
 - **DAQ based on Acquiris C-PCI 100MHz digitisation (replaced Lecroy DSO)**
- Unencapsulated crystals
 - **Removal of fast anomalous events (radon induced low energy alphas)**
 - **Operated in dry nitrogen, 1cm PTFE cage, quartz light guides**

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 ZEPLIN I Status
 ZEPLIN III Status
 ZEPLIN MAX Future

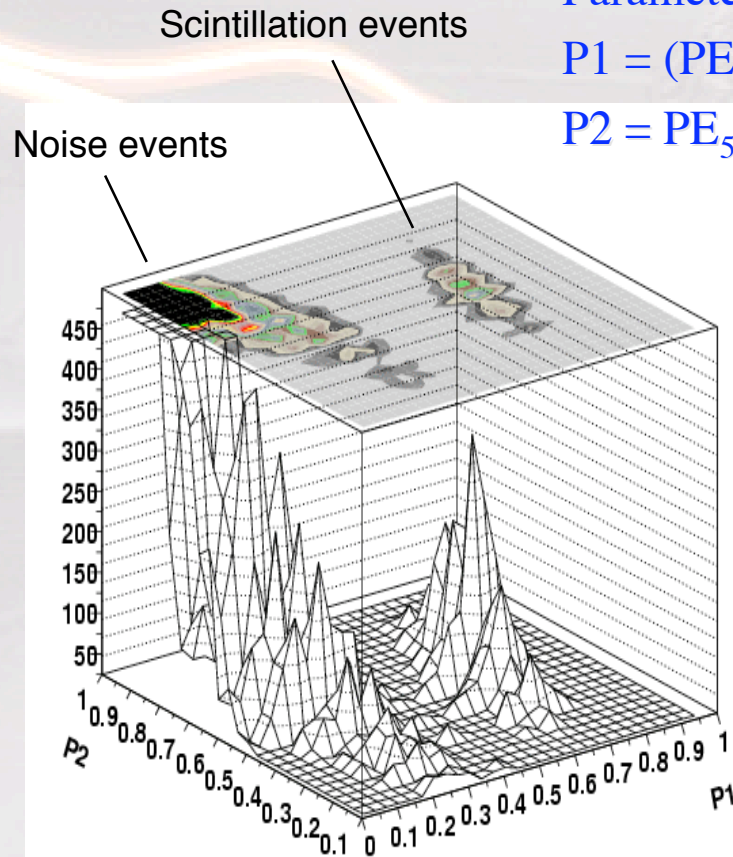
NaIAD: full noise suppression

- Asymmetry cuts in PMT amplitude and Δ (2 PMT systems)
- Use of 'DAMA' type cuts on pulse shape
- Surface plot of events (all energies) in DM74 data run. Parameters P1 and P2 are as follows:

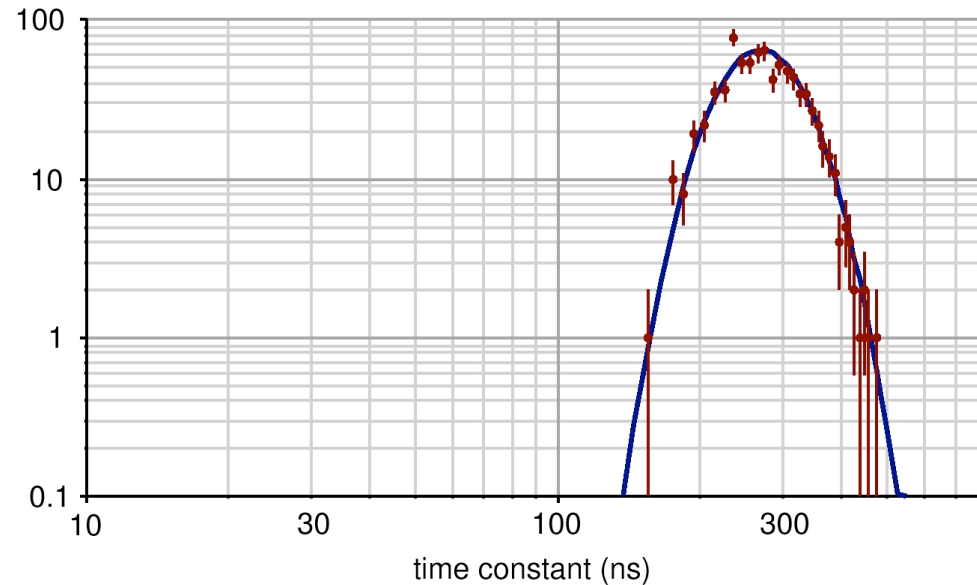
$$P1 = (PE_{600} - PE_{100}) / PE_{600}$$

$$P2 = PE_{50} / PE_{100}$$

Np.e. in 600ns



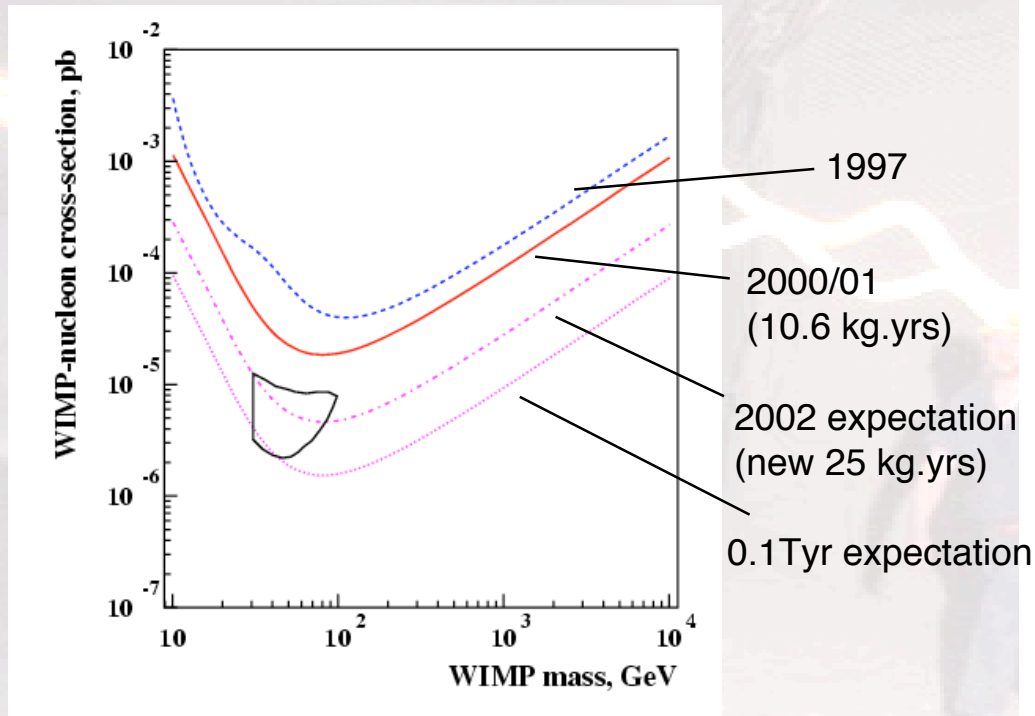
DM74 Time Constant Distribution 4-6 keV



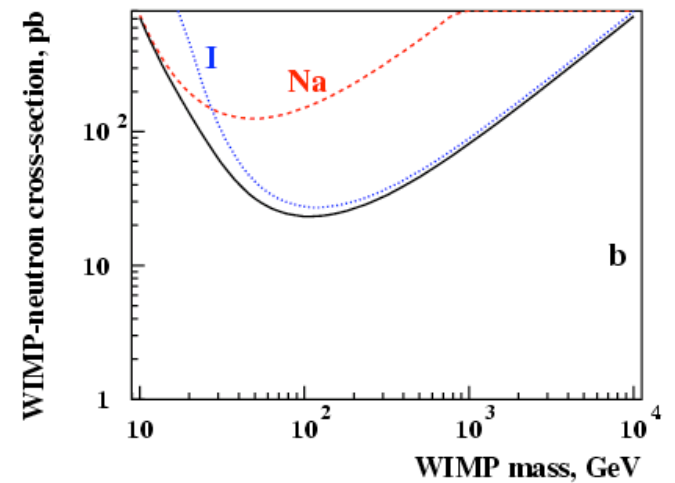
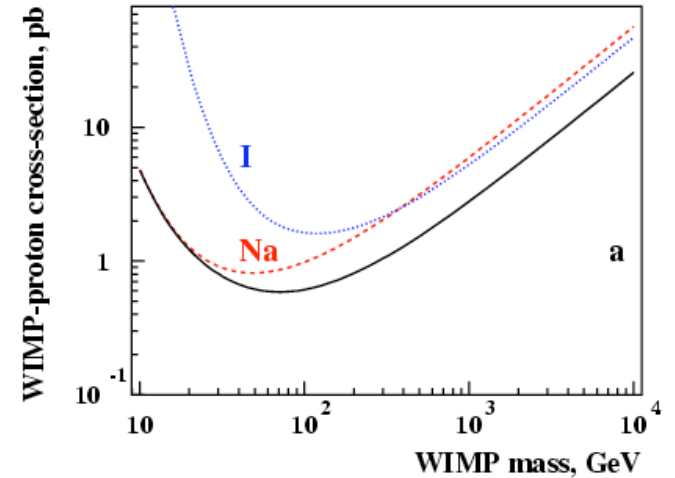
Time constant distribution after noise rejection

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 ZEPLIN I Status
 ZEPLIN III Status
 ZEPLIN MAX Future

NaIAD: Limits



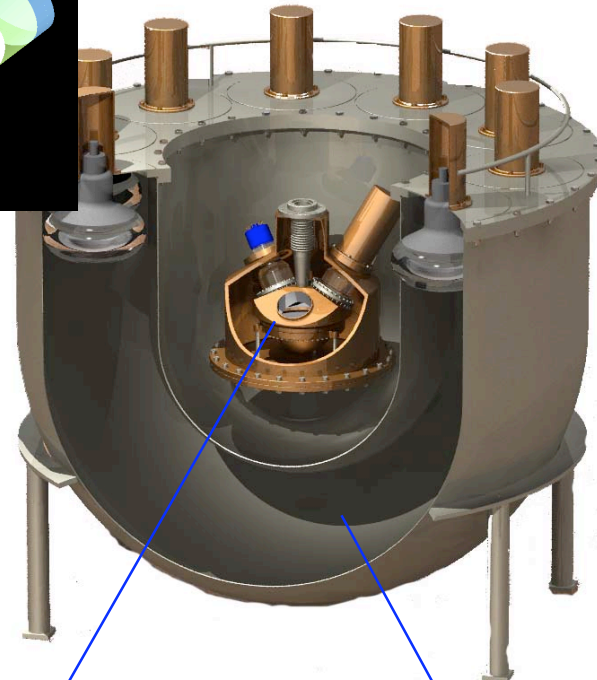
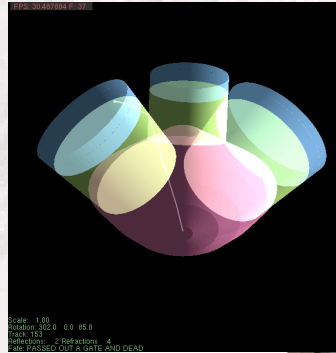
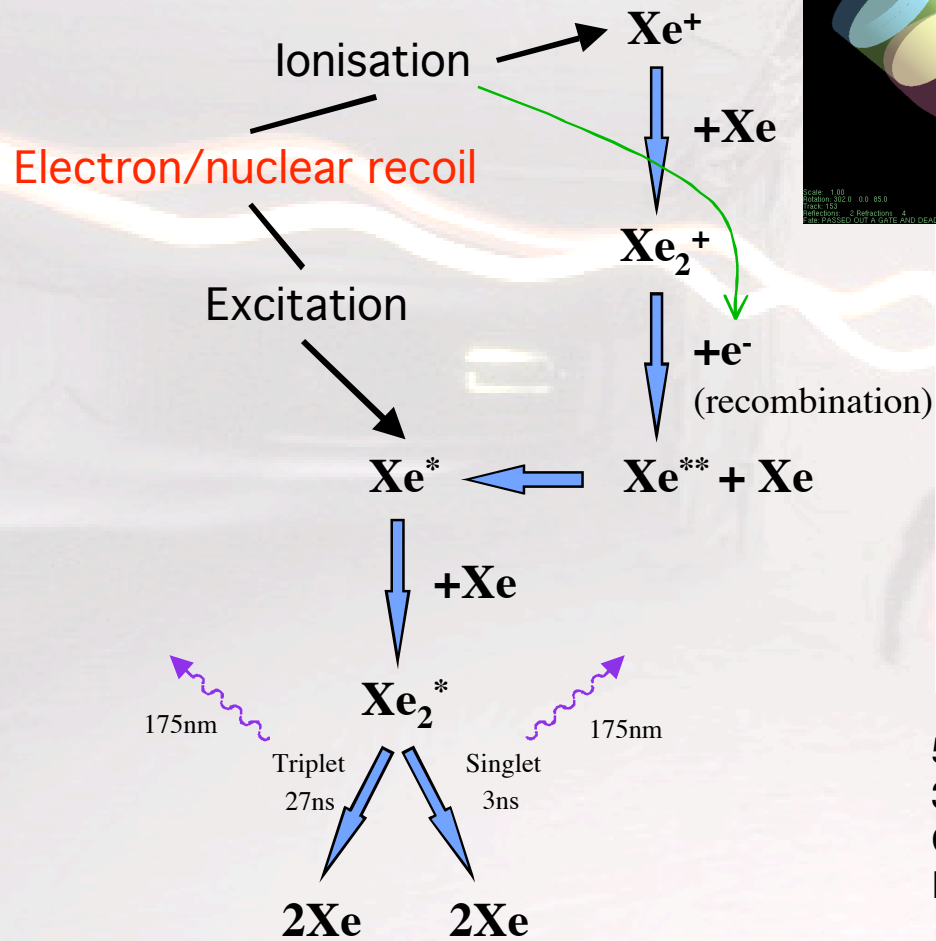
Scalar cross section



2000/01 Spin dependent cross section

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ZEPLIN I



5kg LXe target (3.1kg fid)
 3 PMTs
 Cu construction
 Polycold cryogen cooling

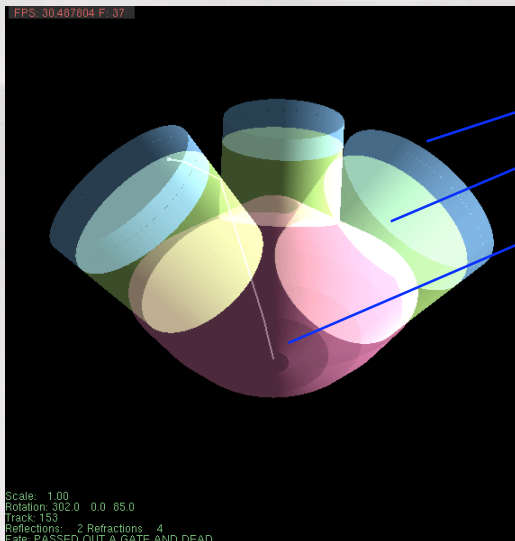
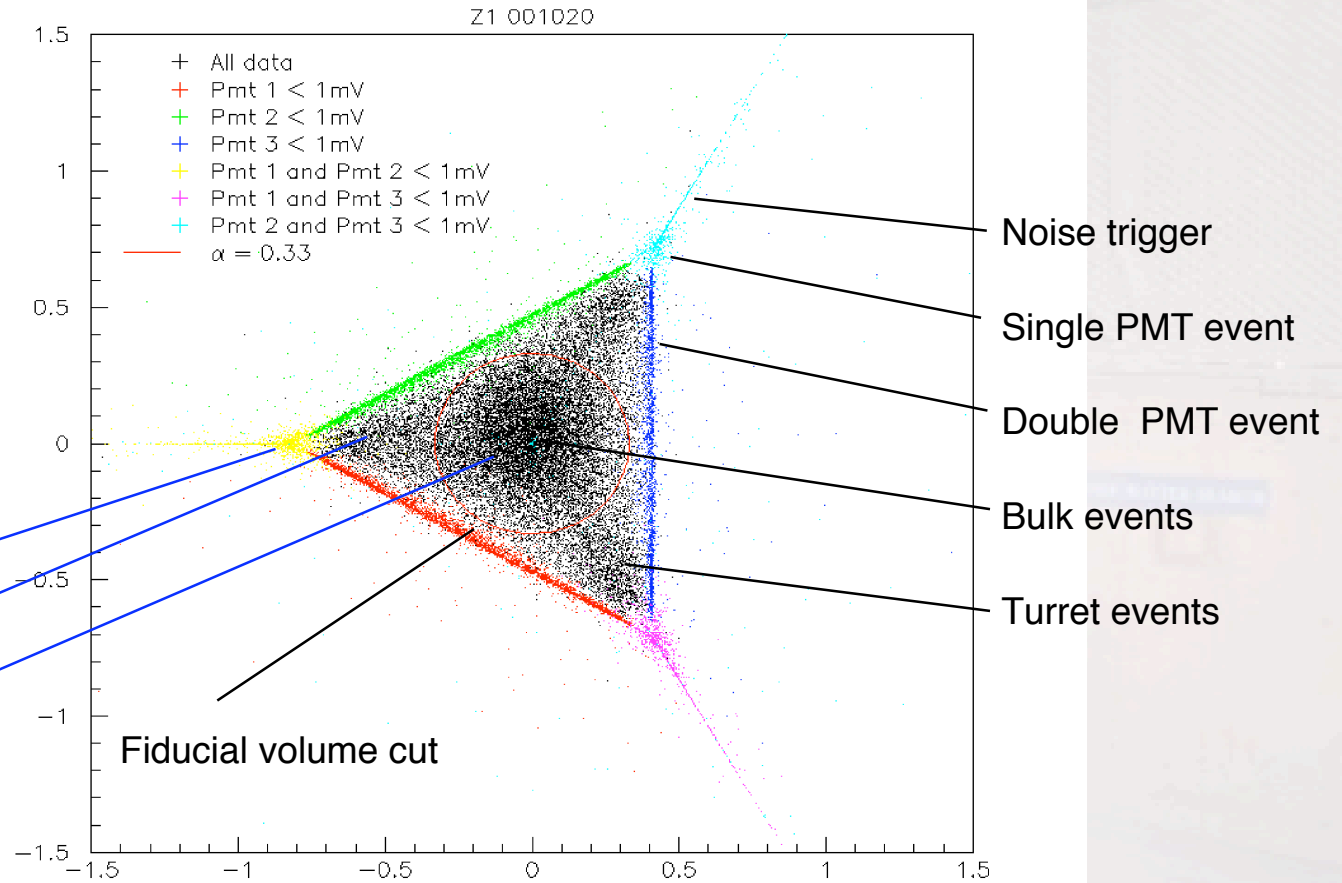
1 tonne Compton veto
 PMT background tag
 Gamma calibration
 Neutron monitor

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ZEPLIN III Status
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S3 Fiducial volume cut

Reduce the background

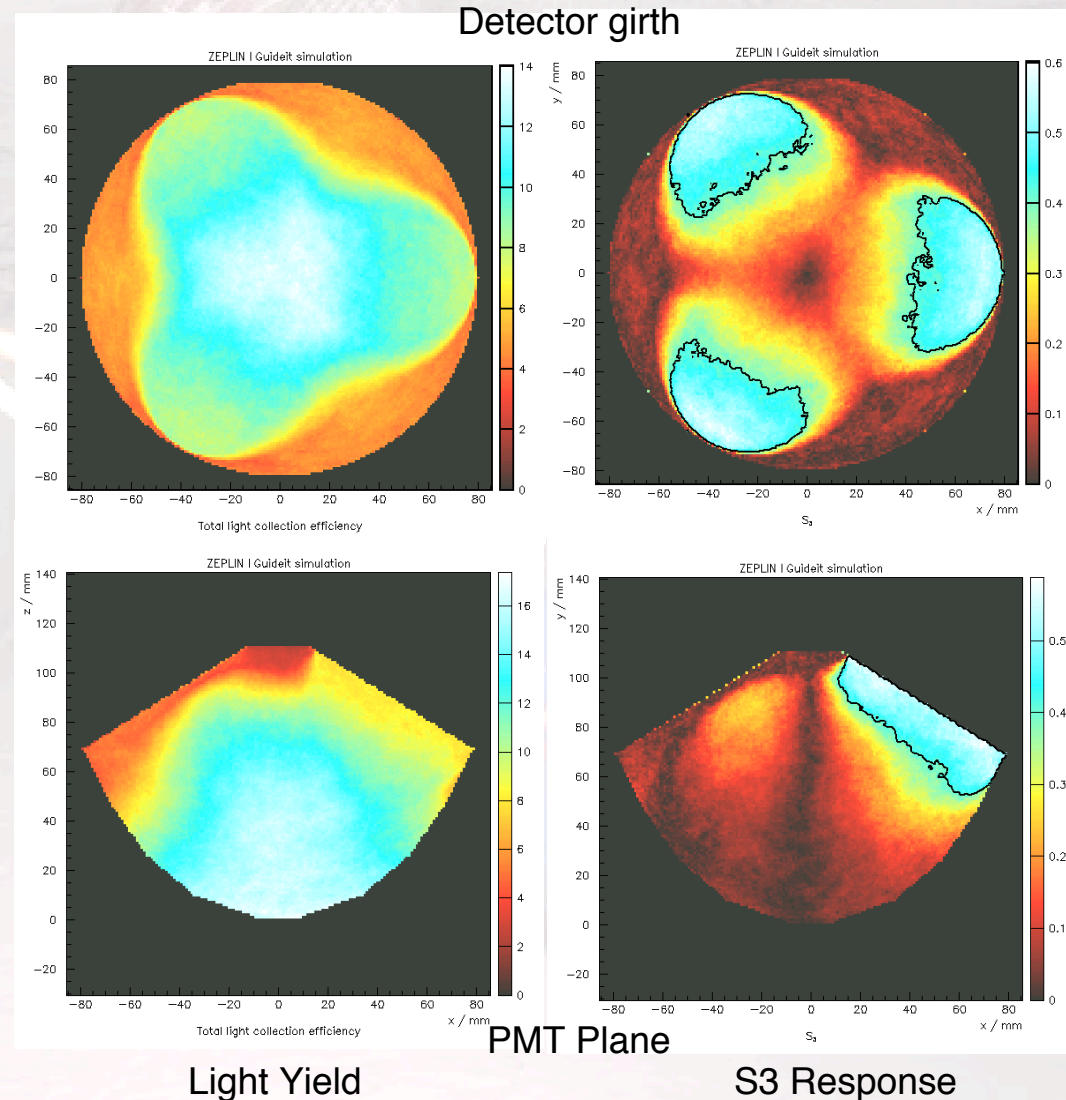
Project normalised amplitudes PMT1,2,3 onto plane - S3



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ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

Uniformity, light collection

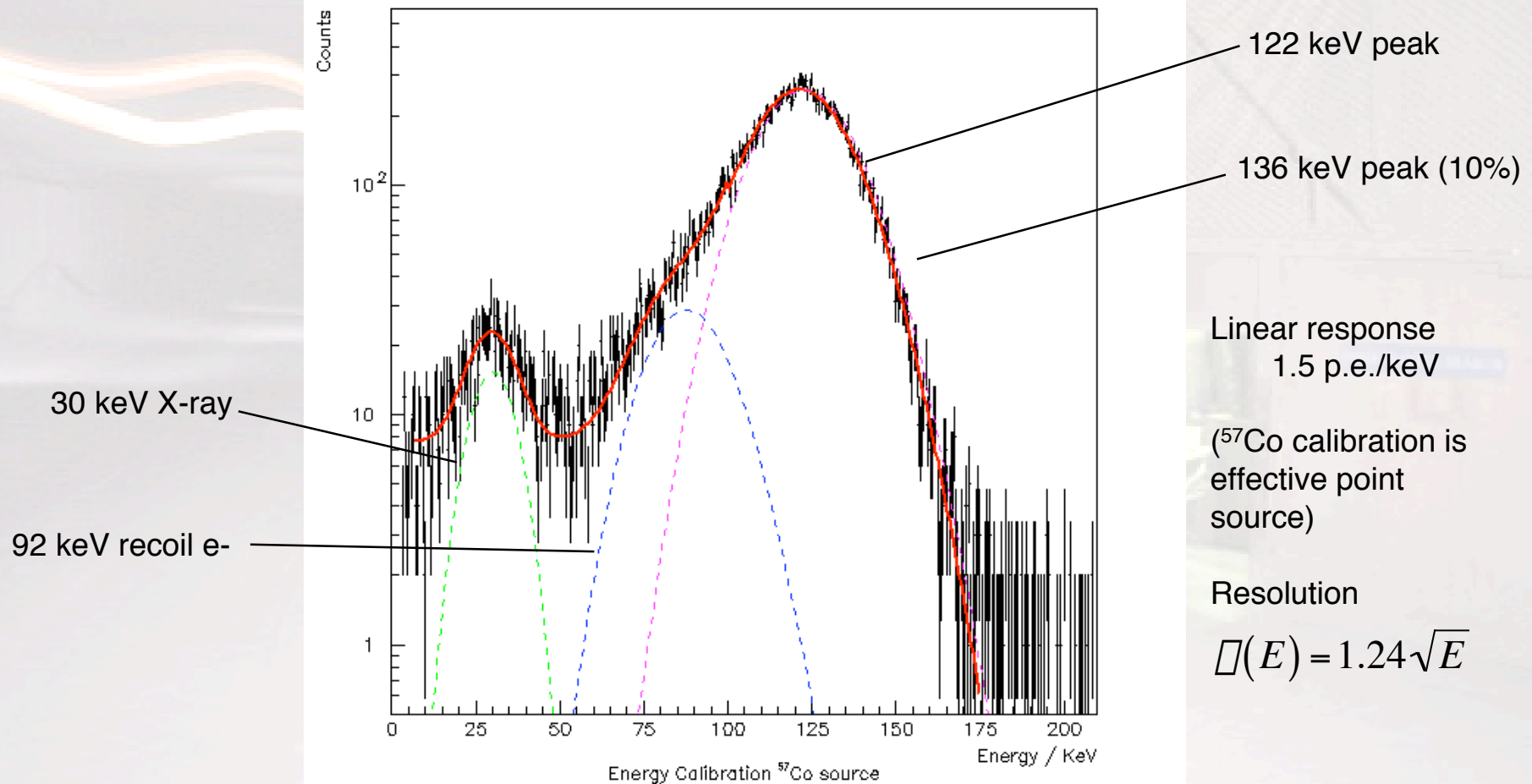
- Part of detector response matrix
 - **17% best, 14% bulk**
 - **Falls to 4% below Xe delivery pipe**
- Light collection simulations allow S3 calculations
- S3 cut < 0.408
 - **(66% on 1: $0.5 + 0.5/3$)**
- Fiducial volume 3.1kg
 - **(excluding turrets + ~1cm below)**



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ZEPLIN III Status
ZEPLIN MAX Future

ZEPLIN I Energy Resolution

57 Co Calibration

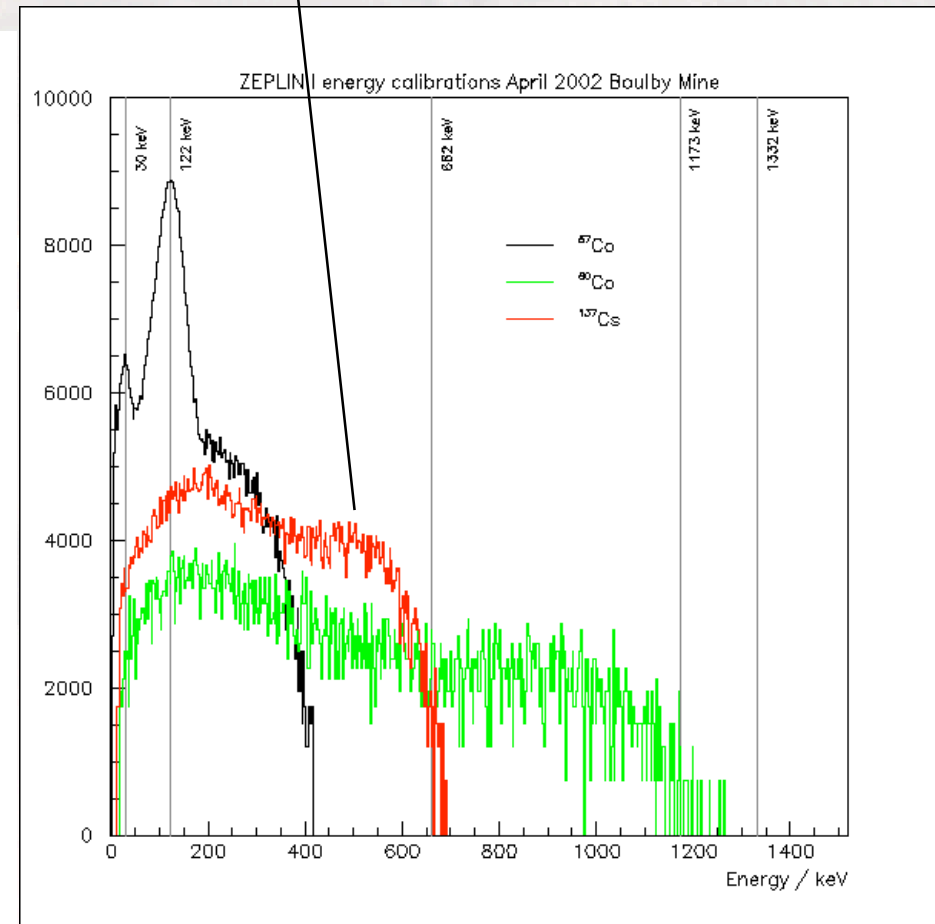
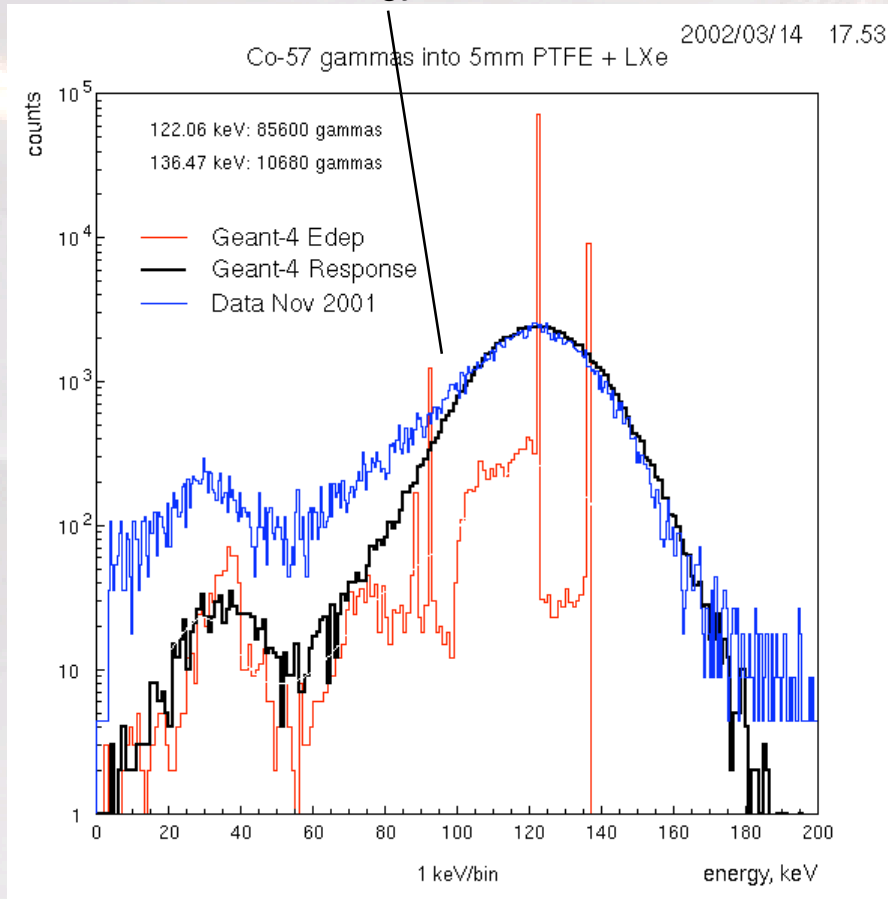


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 ZEPLIN I Status
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Z1 Energy Calibration

Multi-source calibration
 Variation in yield commensurate with
 volume response matrix

Geant4 Simulation of ^{57}Co calibration
 With/without energy resolution

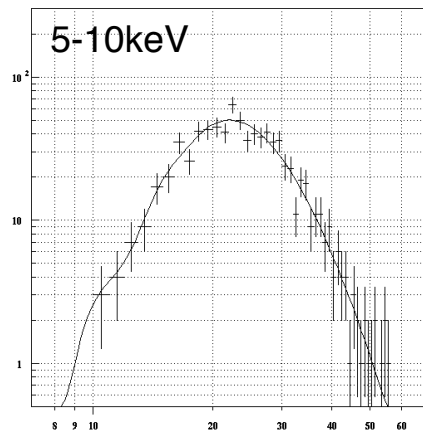
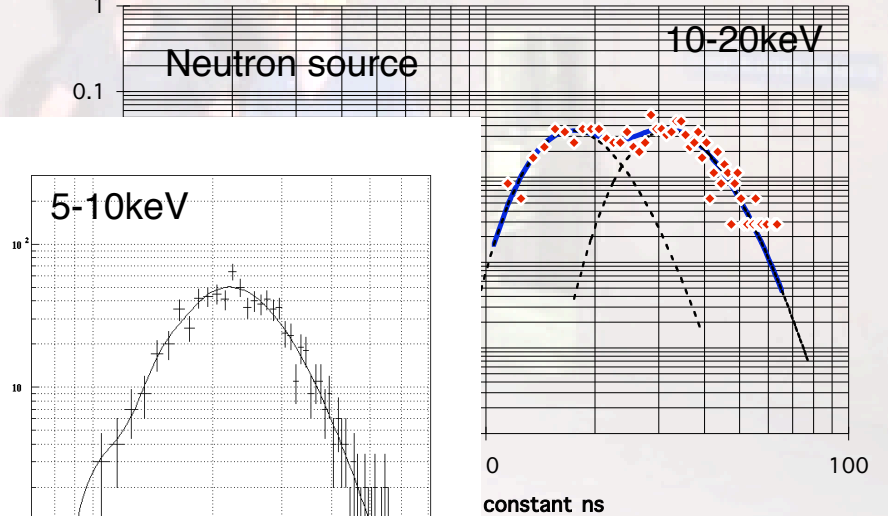
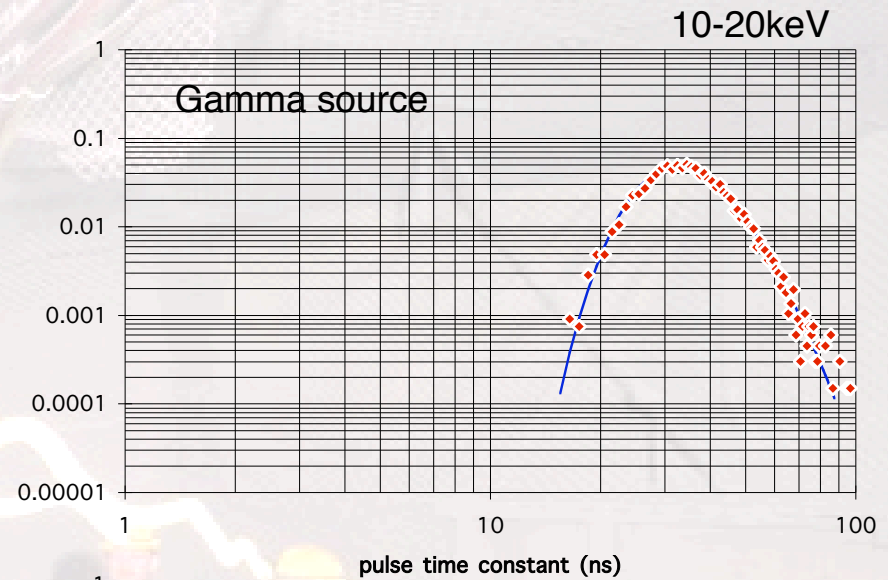
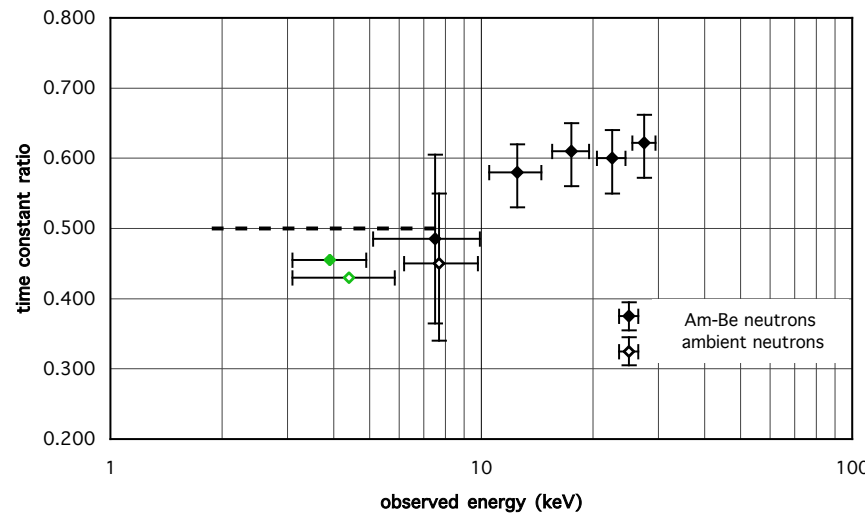


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 Boulby Facility
 NaIAD Status
 ZEPLIN I Status
 ZEPLIN III Status
 ZEPLIN MAX Future

ZEPLIN I Discrimination

Remove the background

- Surface neutron calibrations to 3keV_{ee}
- Surface ambient neutrons below 10keV_{ee}
- Ratio held at $0.5 < 7\text{keV}_{ee}$ (conservative)
- Fitted \square density function in $1/\square$
- Underground gamma calibration to 2keV
- Consistent with beam tests ($0.6@15\text{keV}_{ee}$)
- Check on efficiency of PMT noise cuts

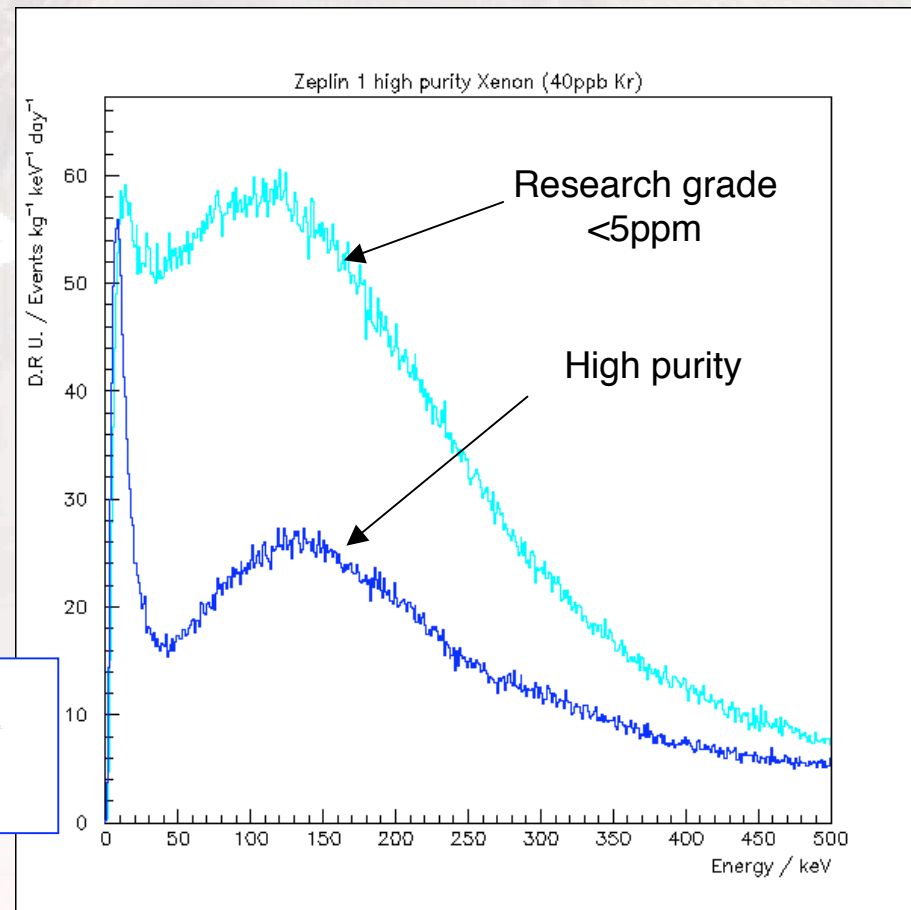


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Boulby Facility
NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

ZEPLIN I low Kr level

- Background with standard Xe:
estimated $^{85}\text{Kr} < 10^{-17}$
atoms/atom, spec: 5ppm
- Now using Xe with 40ppb Kr
impurities (specification).
- 16 d of high light yield data
2.5 pe/keV (vs 1.4-1.8 before)

- Background reduction
- Source of remaining?

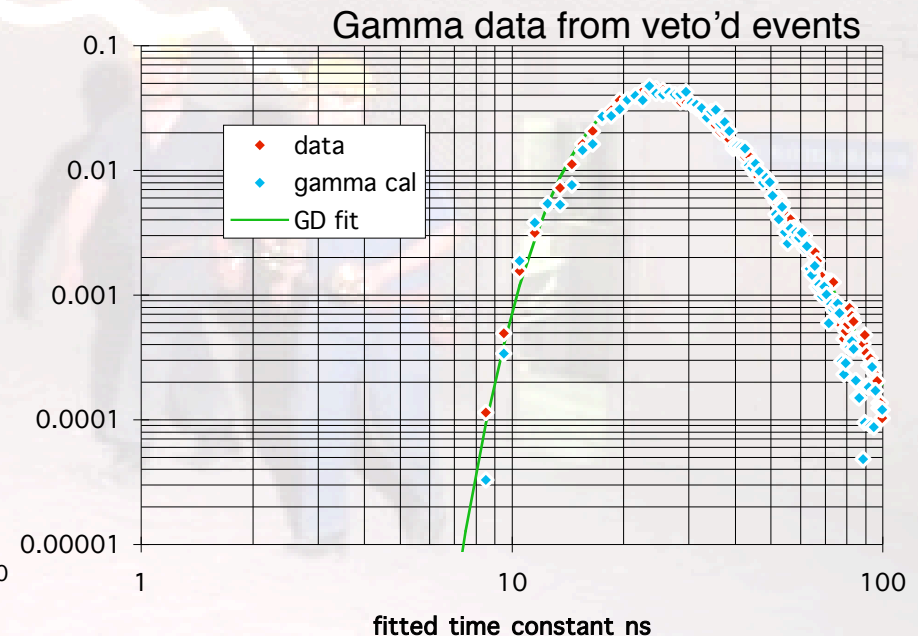
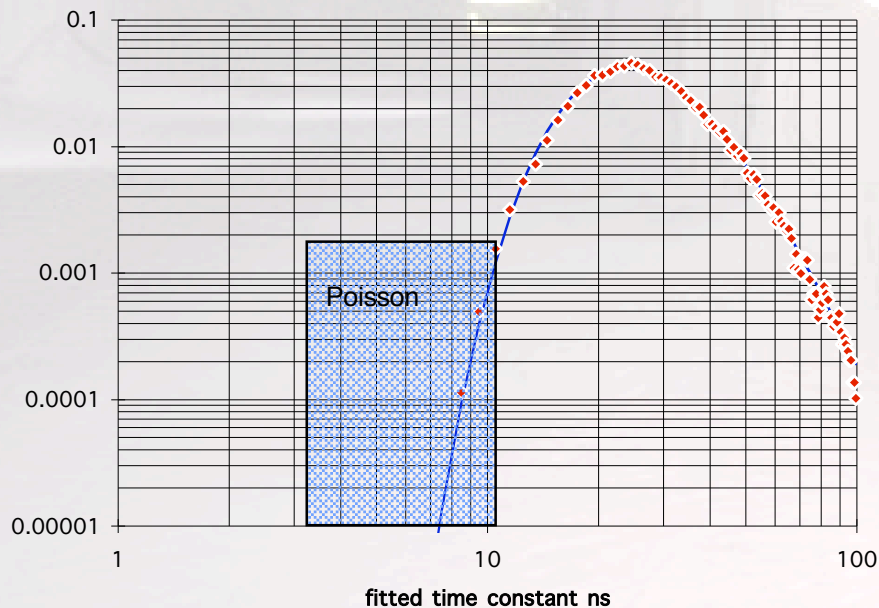


No Cuts

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ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

ZEPLIN I Data Runs

- 3 data sets, 91 day livetime, 290kg.days
 - Light yield >1.5 p.e./keV (2.5 p.e./keV best)
 - Gamma calibration data from contemporaneous veto events and extended source calibration
 - Neutron calibration from surface data
- Analysis: look for deviation at end of tail

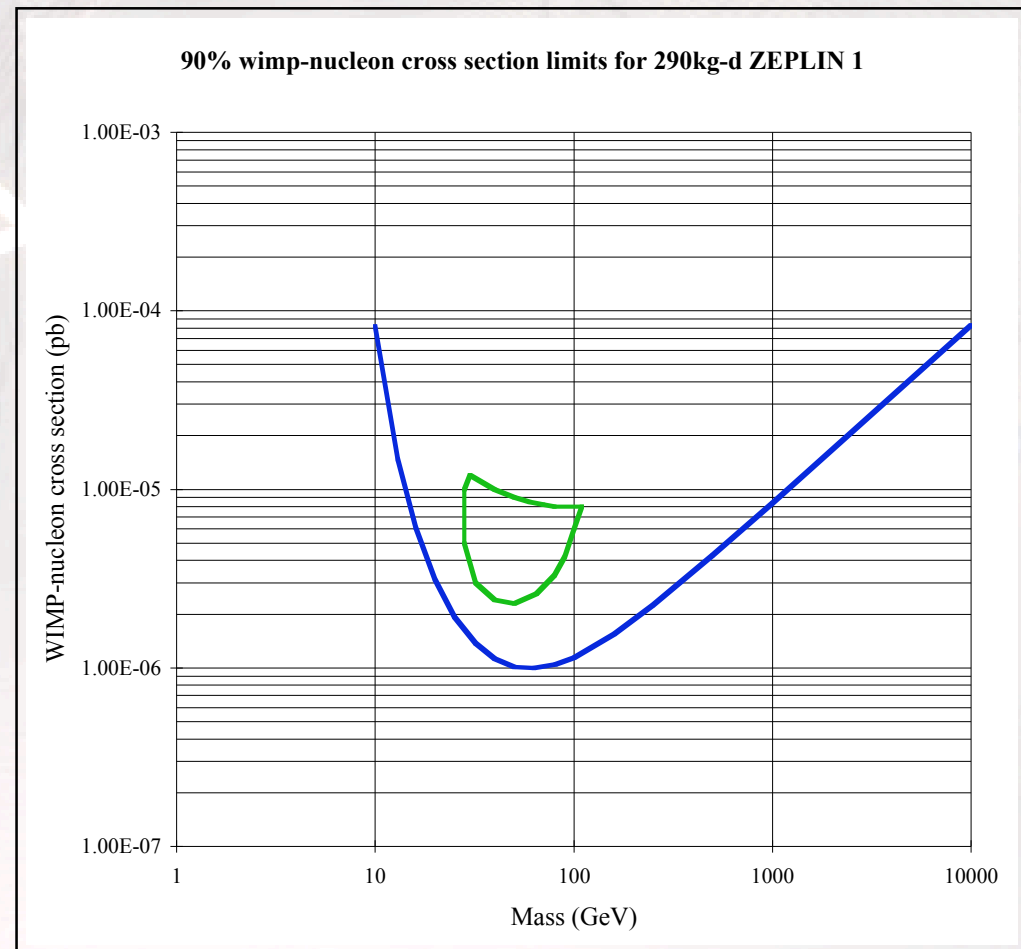


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ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

ZEPLIN I SI limit

Preliminary. Paper in preparation

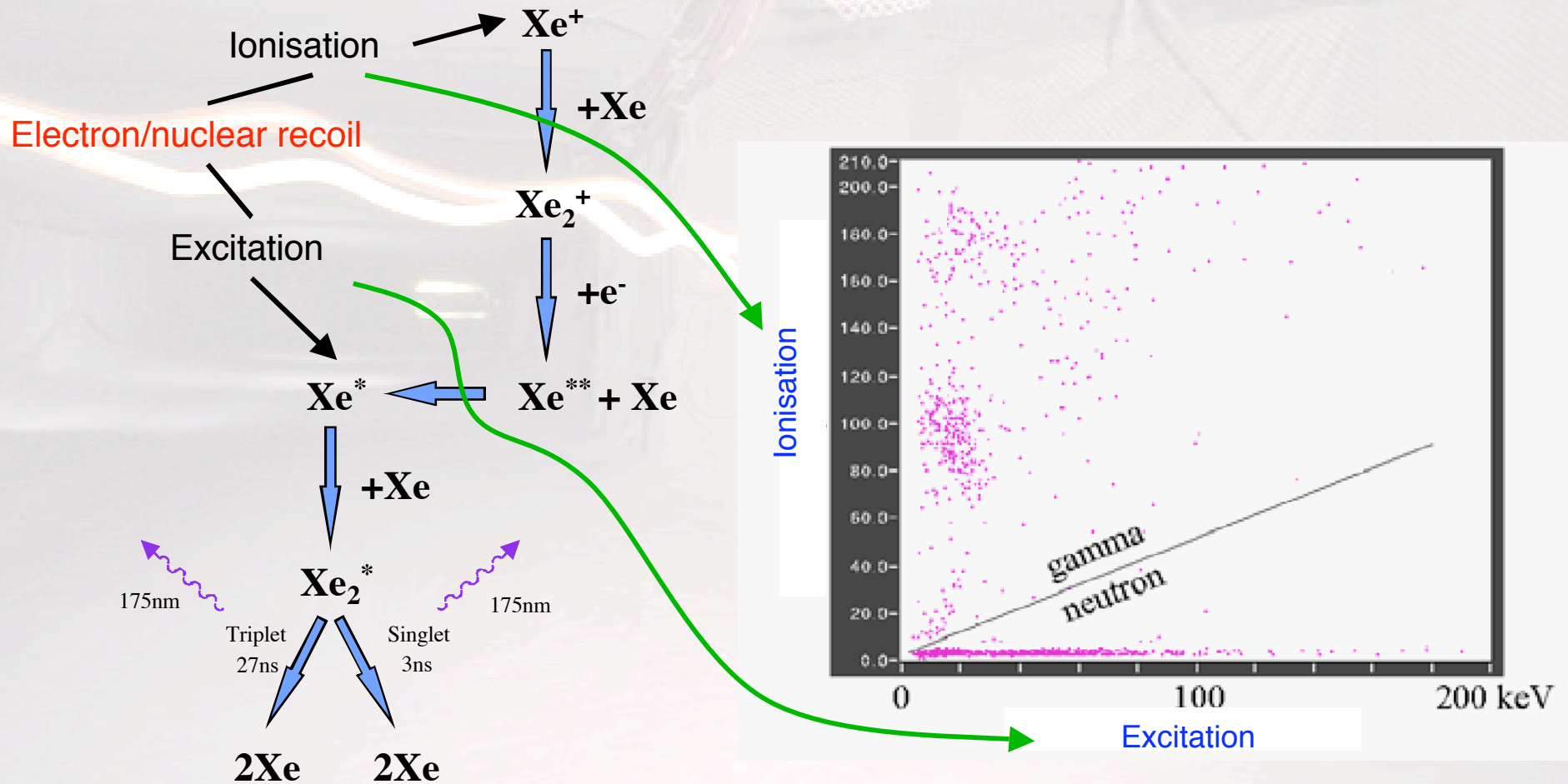
- Based on lab neutron discrimination
 - **To be re-done underground**
- Nuclear physics
 - **Quenching (0.2@8keV_{ee})**
 - **Form factor**
- Efficiencies incorporated
 - **Poisson trigger**
 - **Light collection response**
 - **Energy resolution**
 - **PMT noise cuts**
 - **Fiducial volume (S3)**
 - **Dead-time**
- ‘Standard’ DM model



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 NaIAD Status
 ZEPLIN I Status
 ZEPLIN III Status
 ZEPLIN MAX Future

Two phase discrimination

'Low' drift field in liquid bulk - recombination occurs for nuclear recoils

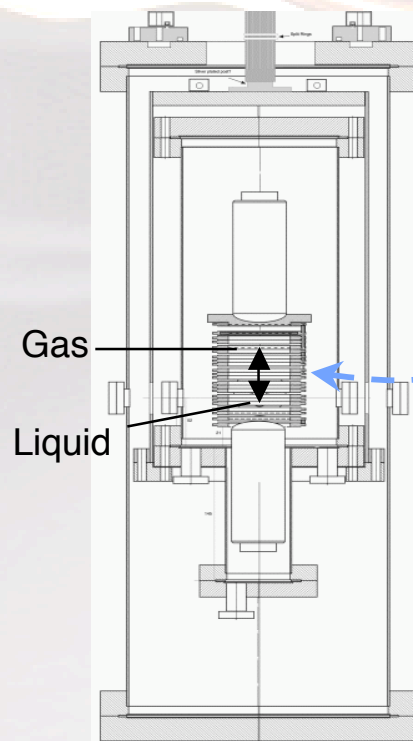


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Boulby Facility
NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

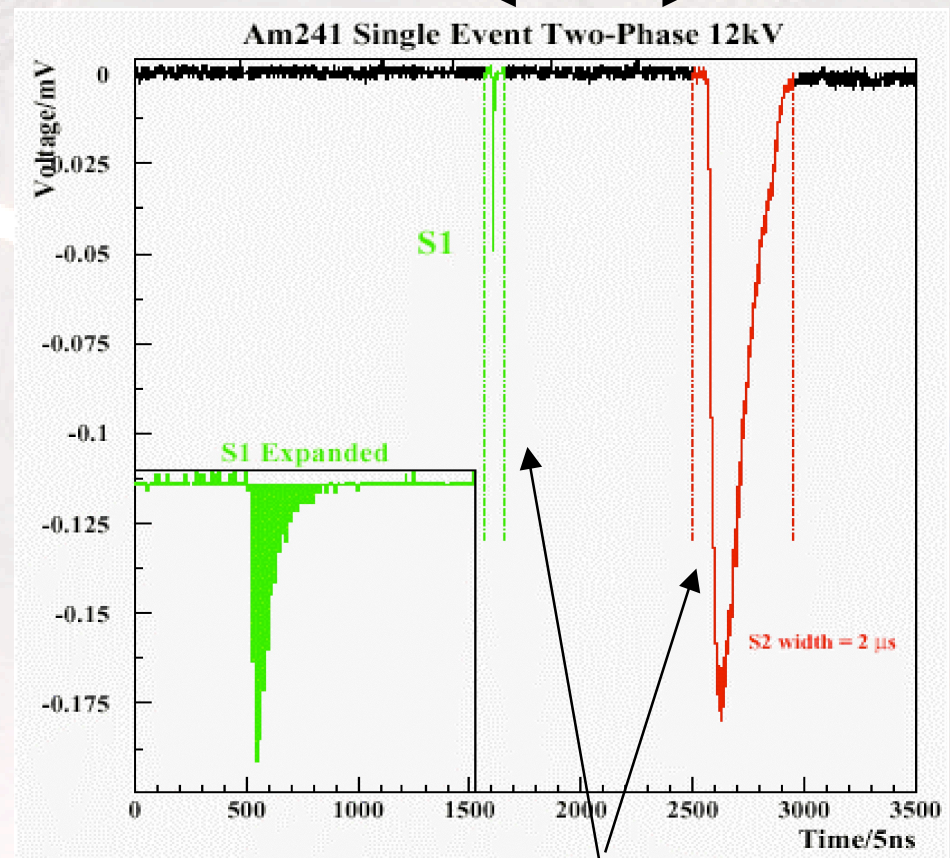
Two phase discrimination

'High' drift field in liquid bulk - charge separation occurs for nuclear recoils

- 1kg Prototype
- Alpha calibration



Depth Information
For given drift fields

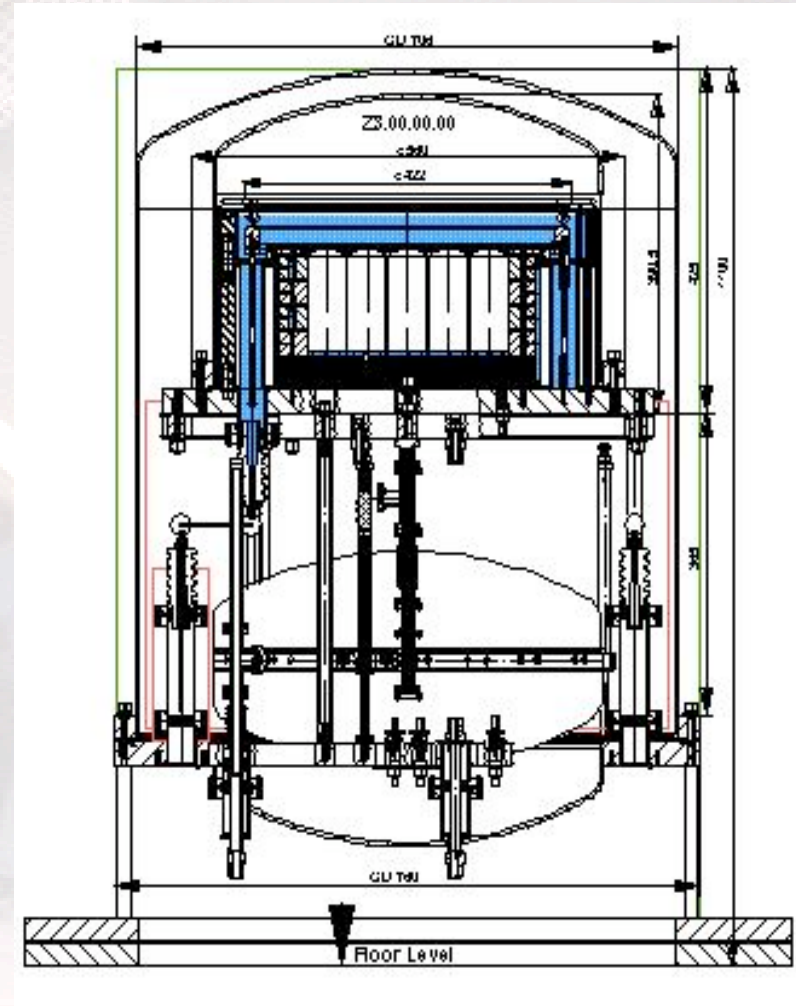


Relative size gives discrimination

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NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

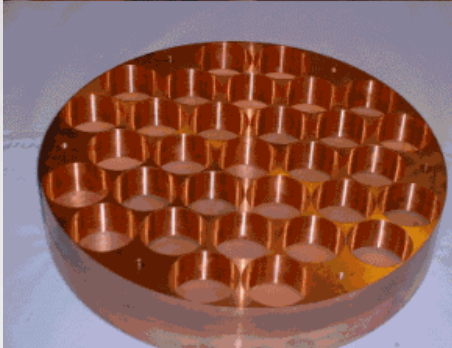
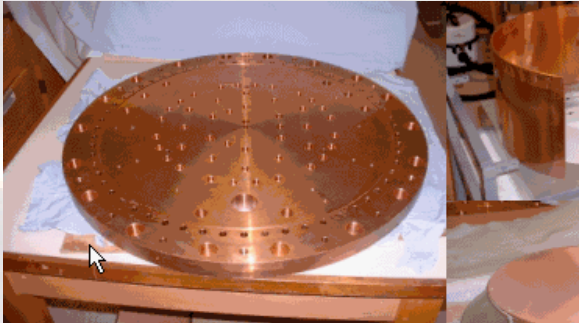
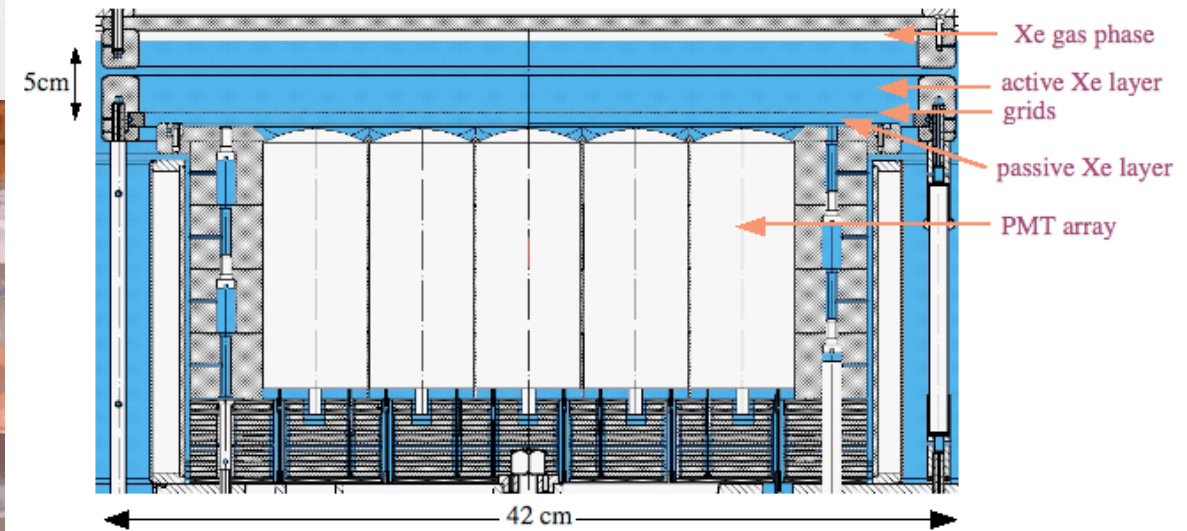
ZEPLIN III

- 2 phase detector, 31x 2" PMT
 - Reverse field for PMT Xrays
 - Position sensitivity
 - PMTs in liquid
- High E-field to extract ionisation from nuclear recoils
 - Nuclear recoil S1 and S2
- 7kg target under construction
- Deployment 2004
- Study for 1 tonne
 - Low threshold (S2 trigger)
 - High light yield
 - Fiducialisation, imaging



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NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

Zeplin III Status



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NaIAD Status
ZEPLIN I Status
ZEPLIN III Status
ZEPLIN MAX Future

ZEPLIN MAX and Future

- ZEPLIN MAX detector
 - 1 tonne active volume, target sensitivity 10^{-10} pb
 - Input from ZEPLIN I operational experience
 - ZEPLIN II/III progenitors for design info
- Issues
 - Operational mode
 - Readout technology (U/Th background)
 - Background suppression
 - active muon/neutron veto
 - passive shielding
 - detector design
 - purity requirement

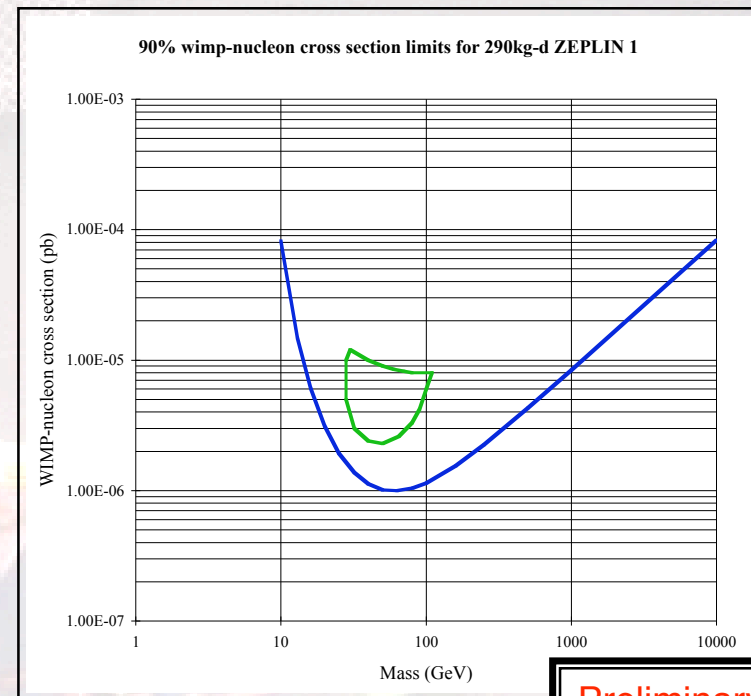


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Boulby Facility
NaIAD Status
ZEPLIN I Status
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Summary and Future

- Facility construction completed
 - **Neutron measurements underway**
- NaIAD array fixed operation
- ZEPLIN I
 - **Extended underground Compton calibration**
 - **Surface neutron calibration reanalysis**
 - **Additional 50kg.days from IDM02 data**
 - **Higher light yield**
 - **Efficiency calculation and simulations**
- Future ZEPLIN I Programme
 - **Underground n calibration**
 - **Full MC cross check of efficiencies**
 - **Low energy xenon quenching measurement**
- ZEPLIN II/III/MAX
 - **Commissioning/operation of progenitors**
 - **R&D+Design for tonne scale detector**



Preliminary