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Measurement of scintillation and ionisation yields in ZEPLIN-III

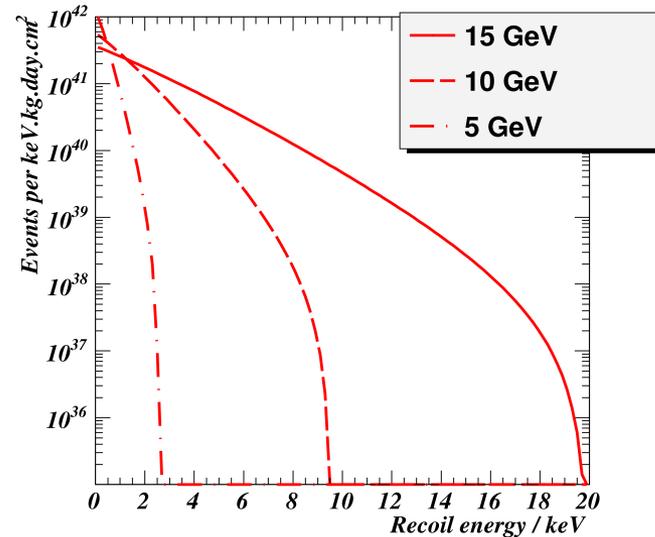
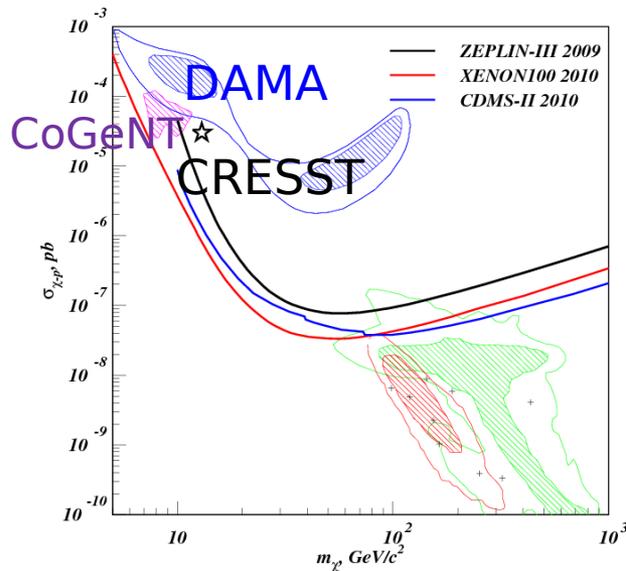
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Outline

- The WIMP signal in xenon
- Energy estimators: light and charge
- Spectrum-matching of neutron MC
- Efficiency and uncertainties
- Results, consequences

WIMP signal in xenon

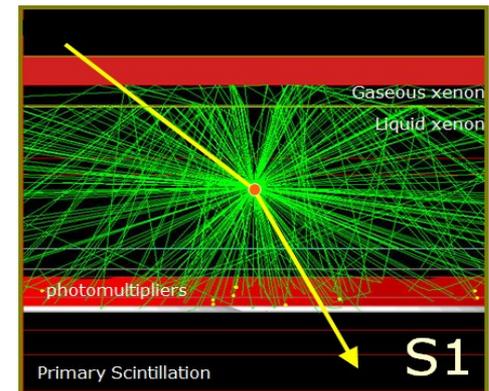
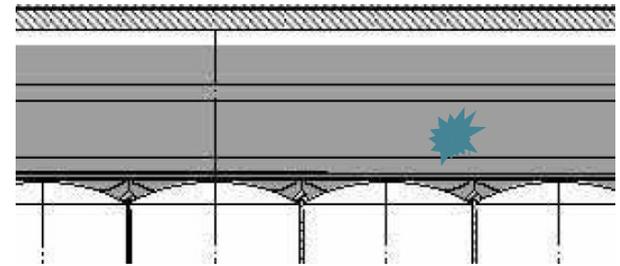


- Exponentially falling nuclear recoil spectrum
- Light WIMPs could explain DAMA, CoGeNT

Scintillation channel

- S1: reconstructed scintillation
- Determines threshold
- For nuclear recoils:

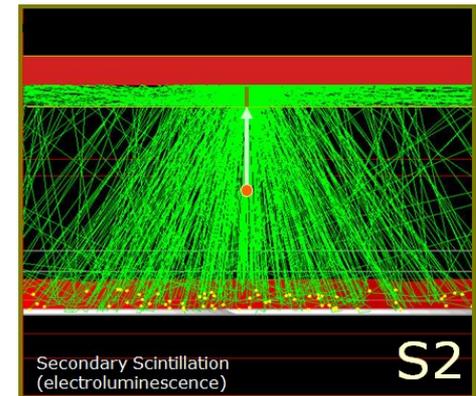
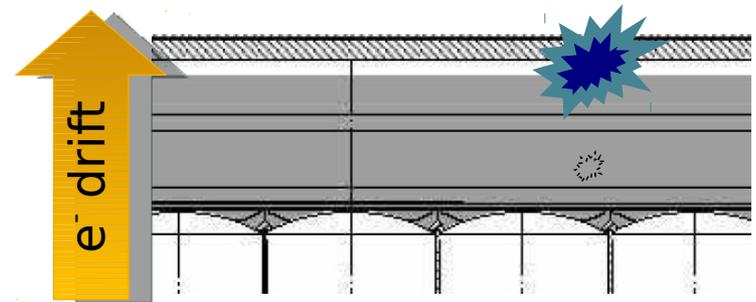
$$\langle S1 \rangle = \frac{S_{nr}}{S_{er}} \cdot L_{eff}(E) \cdot E$$



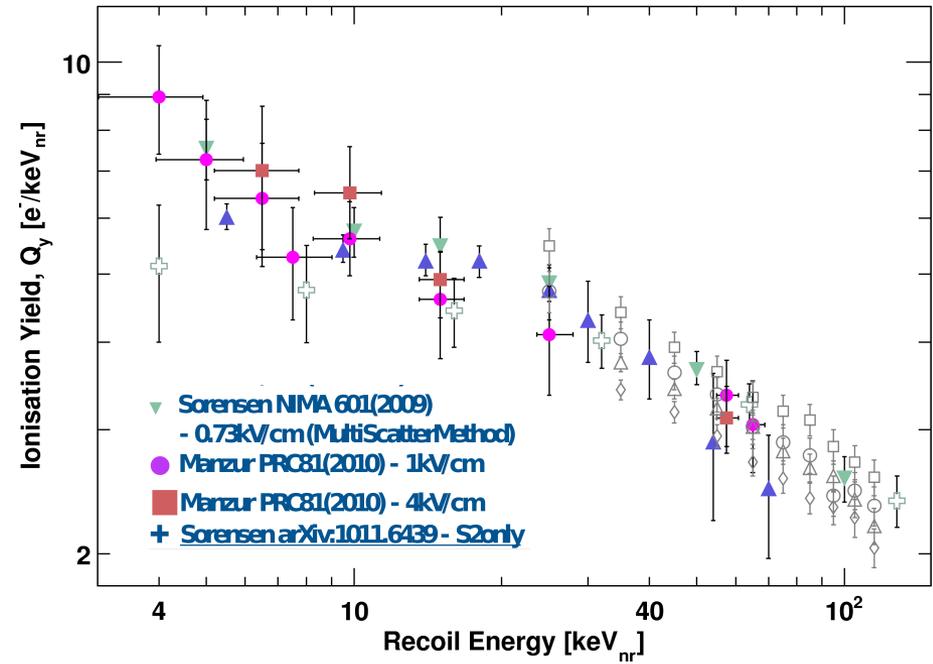
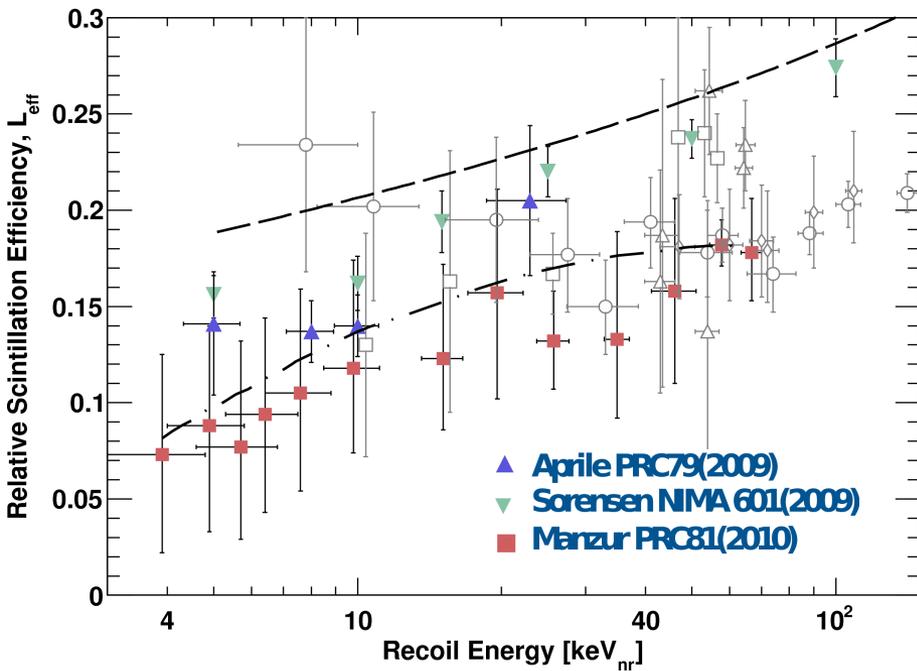
Ionisation channel

- S2: reconstructed ionisation
- BG discrimination, position
- For nuclear recoils:

$$\langle S2 \rangle = \frac{\eta}{E_{ee, SE}} \cdot Q_y(E) \cdot E$$



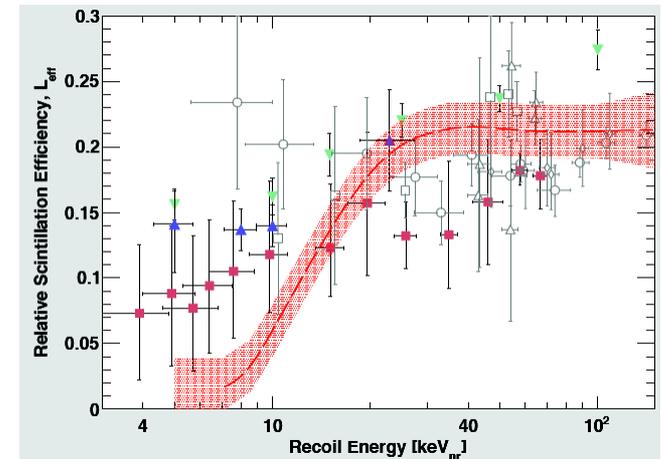
Existing yield measurements



- Mainly neutron beam measurements
 - Tag outgoing neutron: known E_{recoil}

Spectrum matching method

- Vary yield function to match neutron MC with observation (Sorensen *et al.* NIM **A601** 339, 2009)
- Was applied to ZIII FSR scintillation.
- Present work: SSR and re-analysed FSR; scintillation and ionisation.



Spectrum matching stages

MC spectrum in
recoil energy

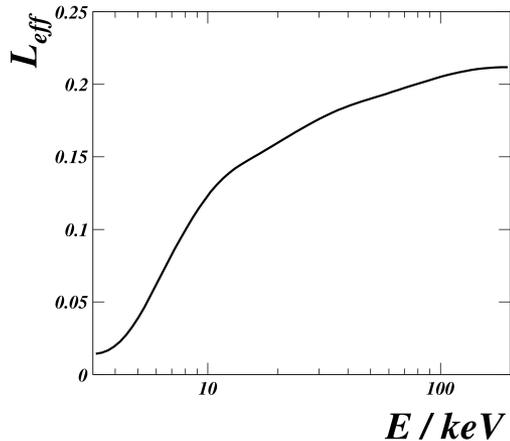


MC spectrum in
scintillation

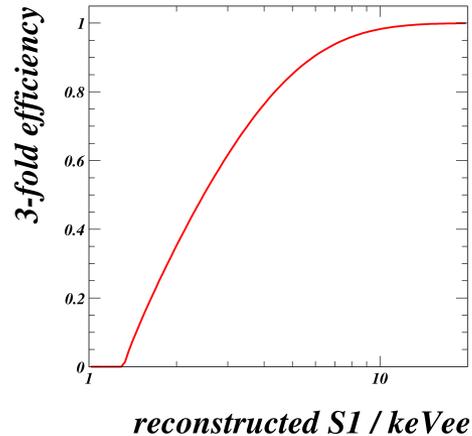


MC spectrum in
observed S1

Yield



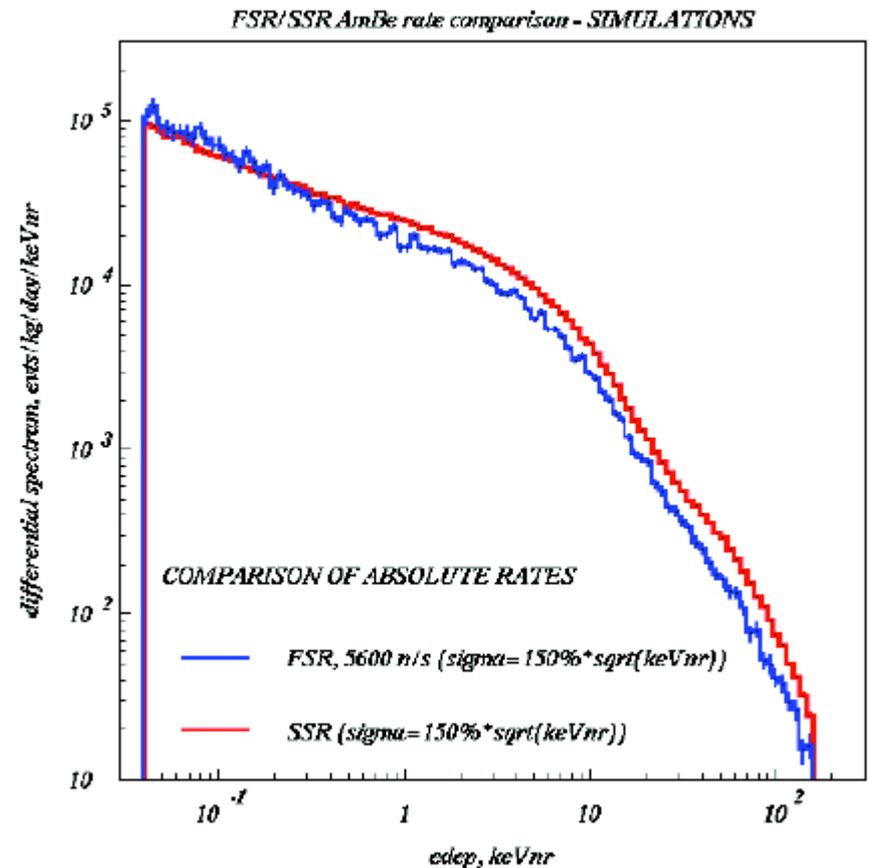
Resolution,
efficiency



Using SSR scintillation as example...

Simulation of recoil energies

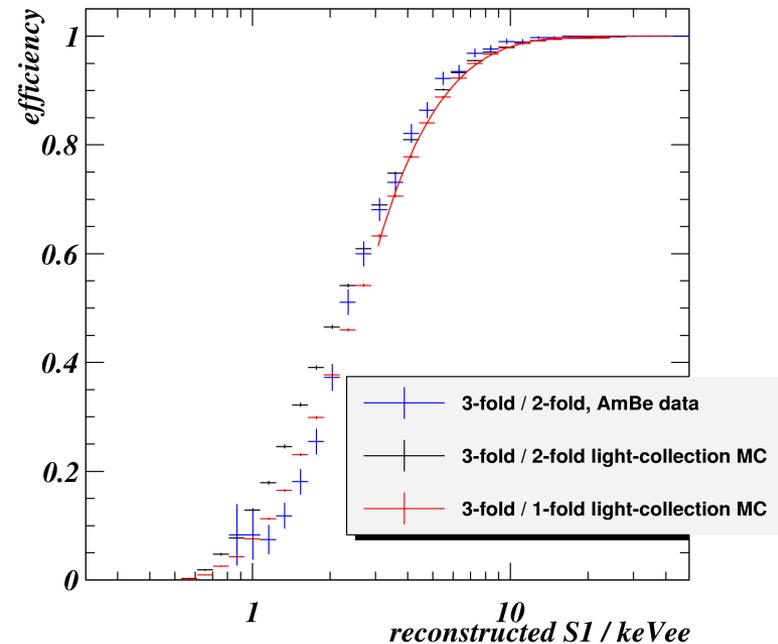
- Calibration with AmBe source
 - mean neutron energy ~ 4 MeV
- Geant4 9.3 with ENDF/B.VII
- Single-scatter, elastic



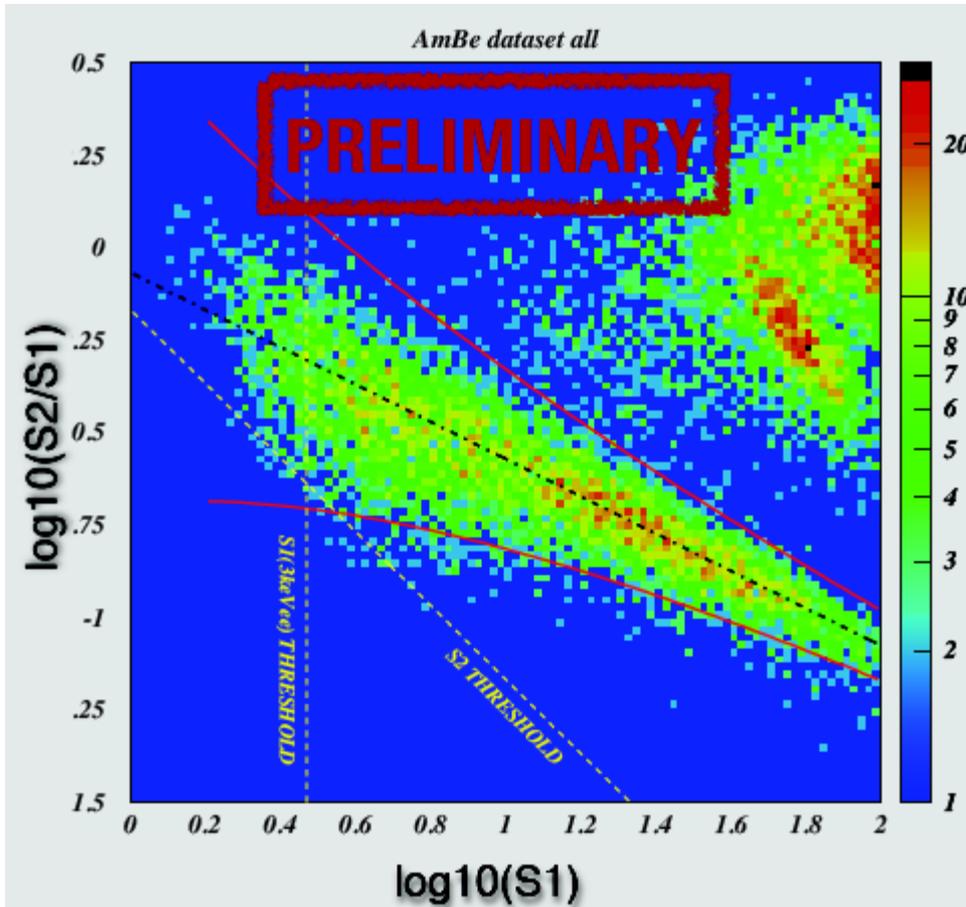
Energy-dependent efficiency

- Negligible S2 inefficiency above S1 threshold
- Light-collection simulation with AmBe spatial distribution
- Yield per keVee to match 4:3:2-fold coincidence in data

SSR efficiency(S1)



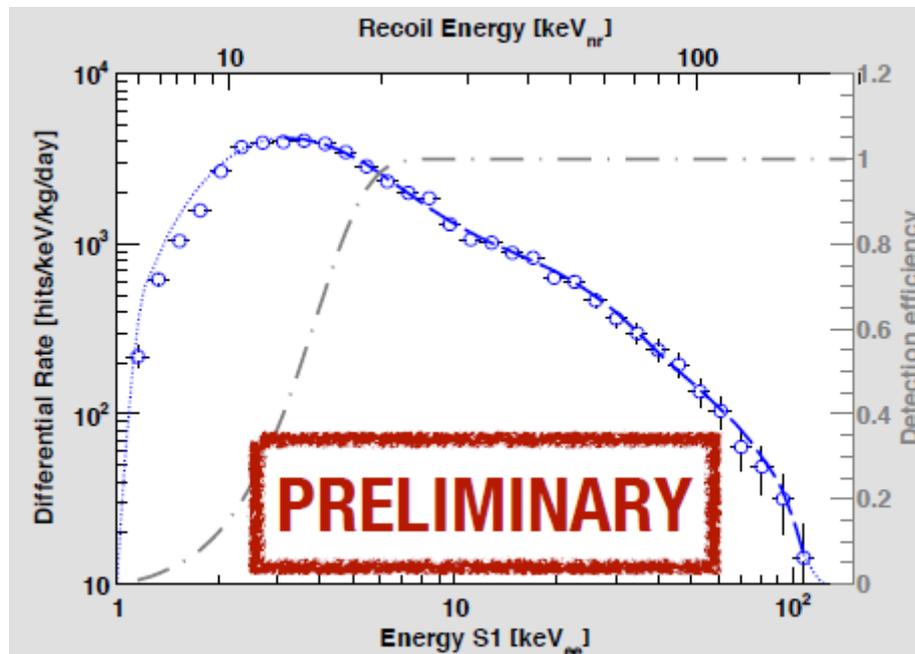
Event selection, normalisation



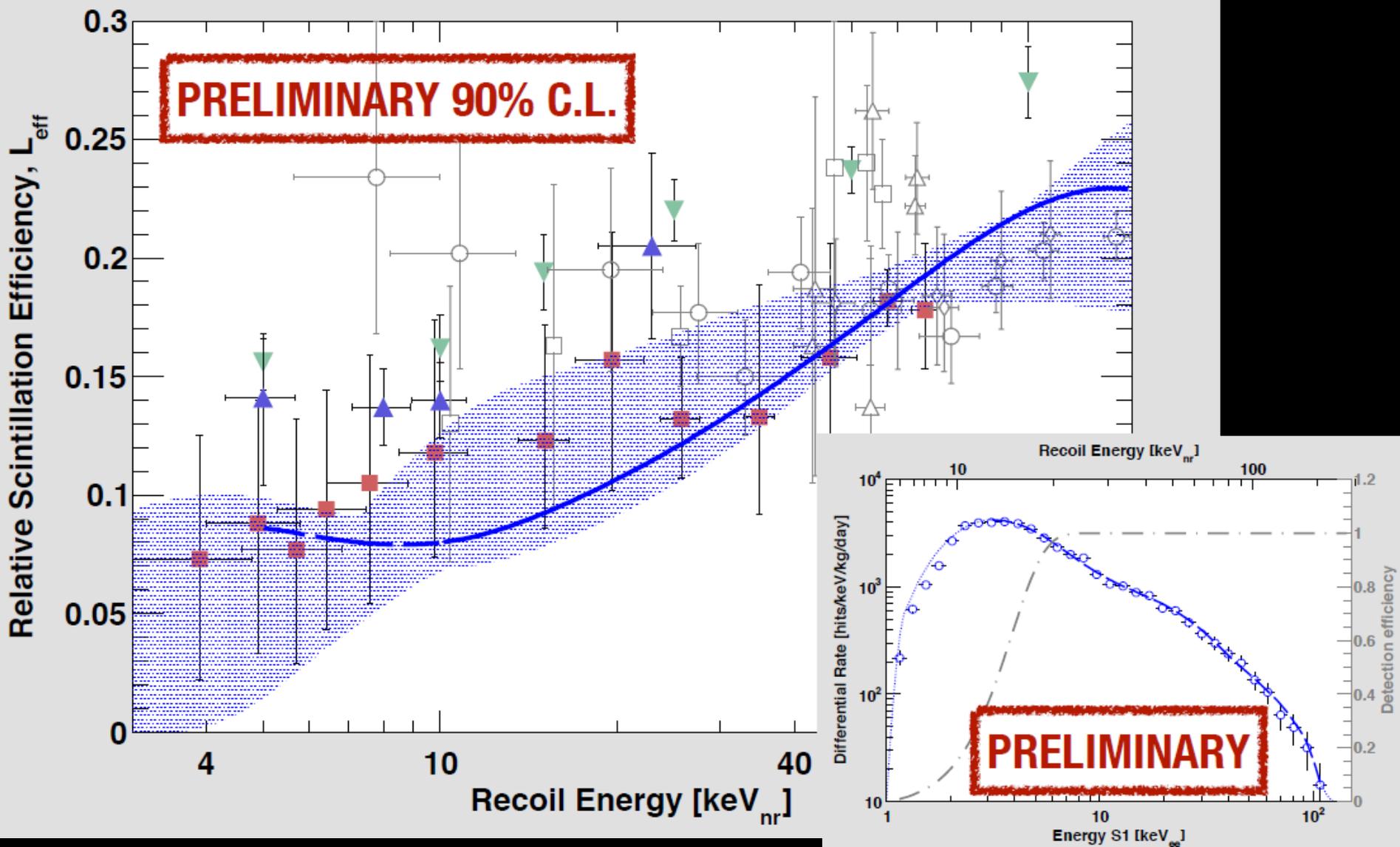
- Cuts for elastic single-scatter NR
- Dead time from DAQ and scalar trigger rate, delay times.
- Source activity calibrated to 1.1% (SSR)
- ~15% uncertainty in normalisation

Fitting, statistical uncertainty

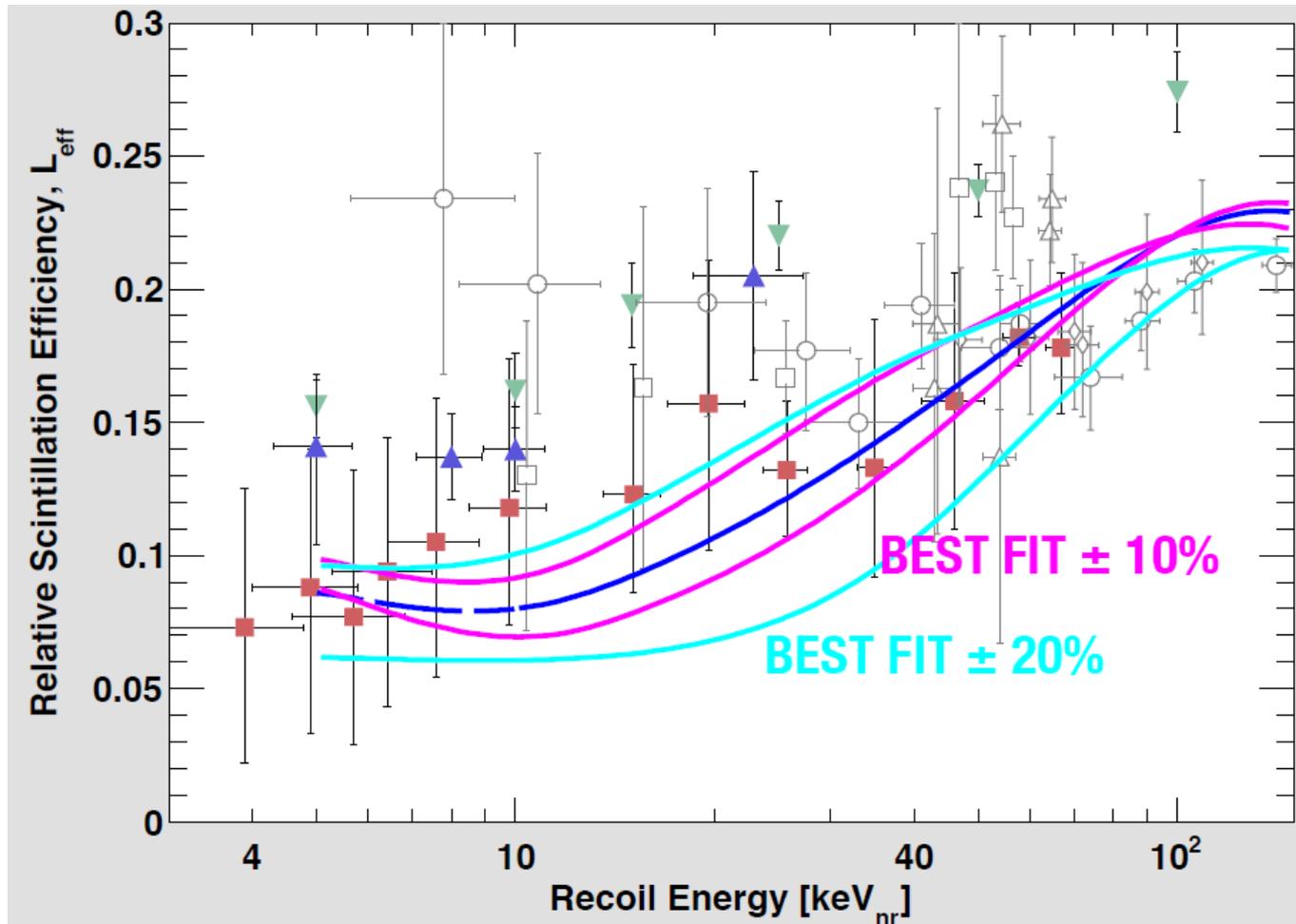
- Cubic spline to parametrise L_{eff}
- Confidence interval from ΔX^2 statistic



SSR scintillation results

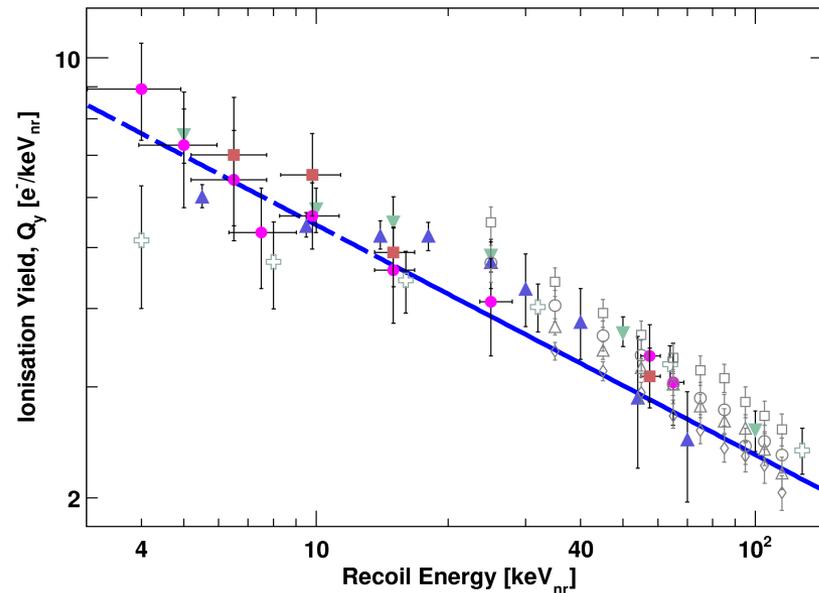


Normalisation systematics



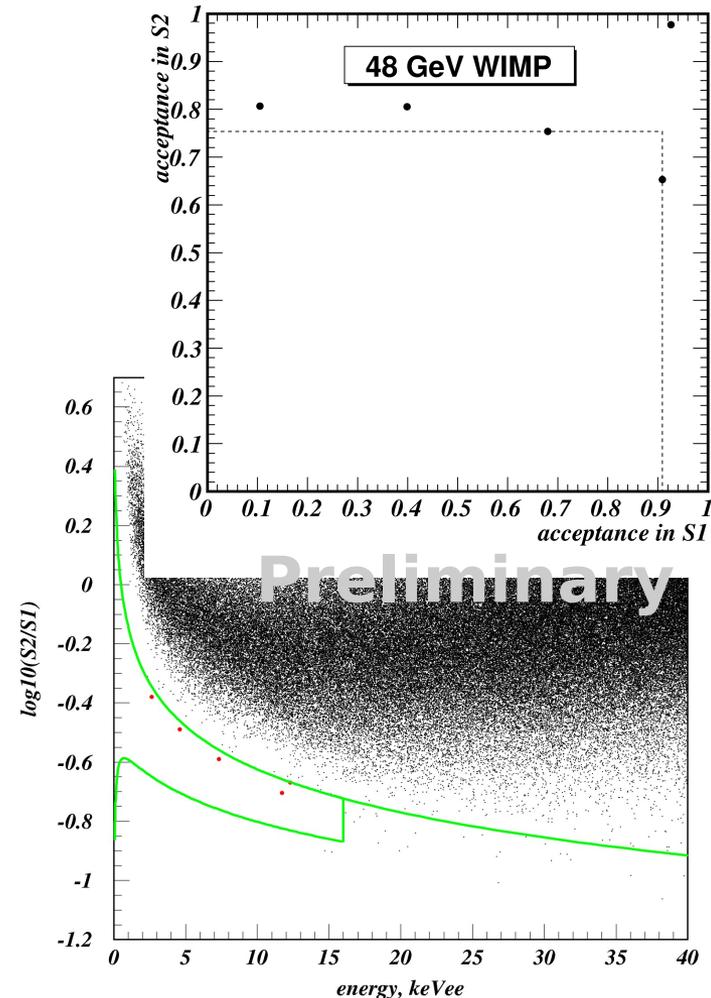
Charge yield results

- Similar approach to L_{eff} , with
 - Power law to parametrise Q_y .
 - Efficiency now $\eta(S1(S2))$.
- Recover median $S2/S1$, consistency with beam measurements

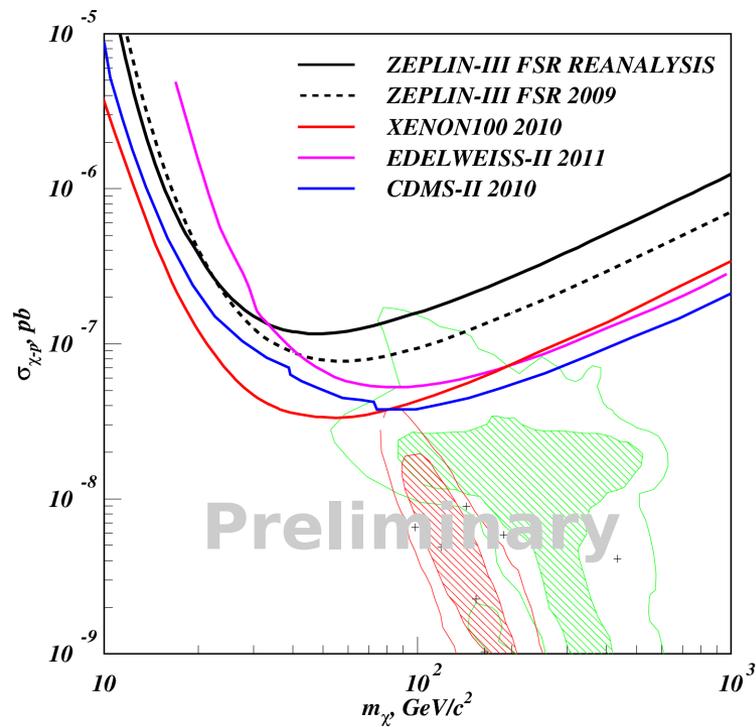


Consequences for FSR

- Efficiency recovered, improved reconstruction software → different events
- Threshold corresponds to lower recoil energy
- Maximum patch analysis
 - events mapped to plane of S1,S2 signal acceptance
 - empty rectangle of area e.g. $0.69 \rightarrow 6.5$ evts, 90% CL



Preliminary revised limit



Summary

- Scintillation yield determines low-WIMP-mass sensitivity (two-phase)
- New *in situ* MC-matching measurements in line with beam results; analysis not yet finalised.
- FSR threshold lower than previously thought.