Response of the XENON100 detector to gamma and neutron radioactive sources

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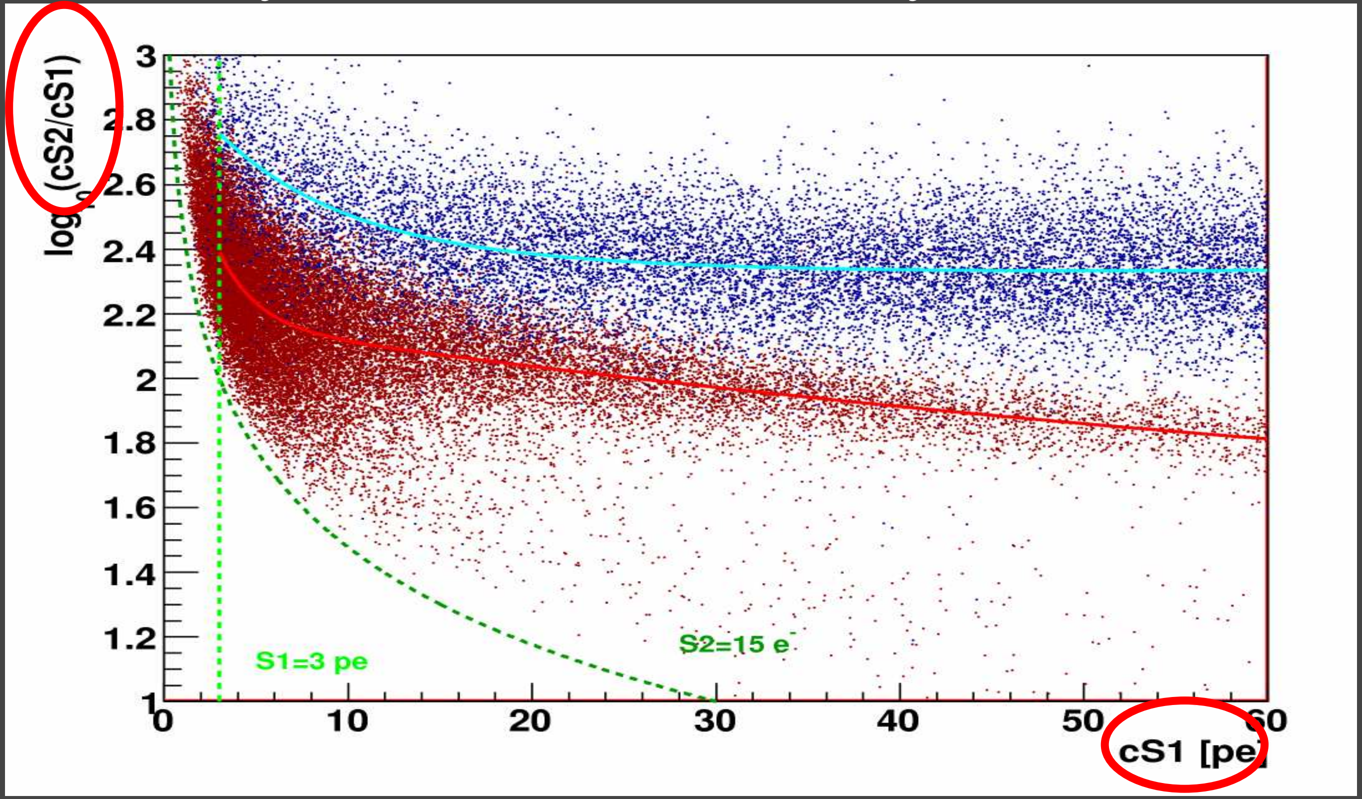
for the XENON collaboration

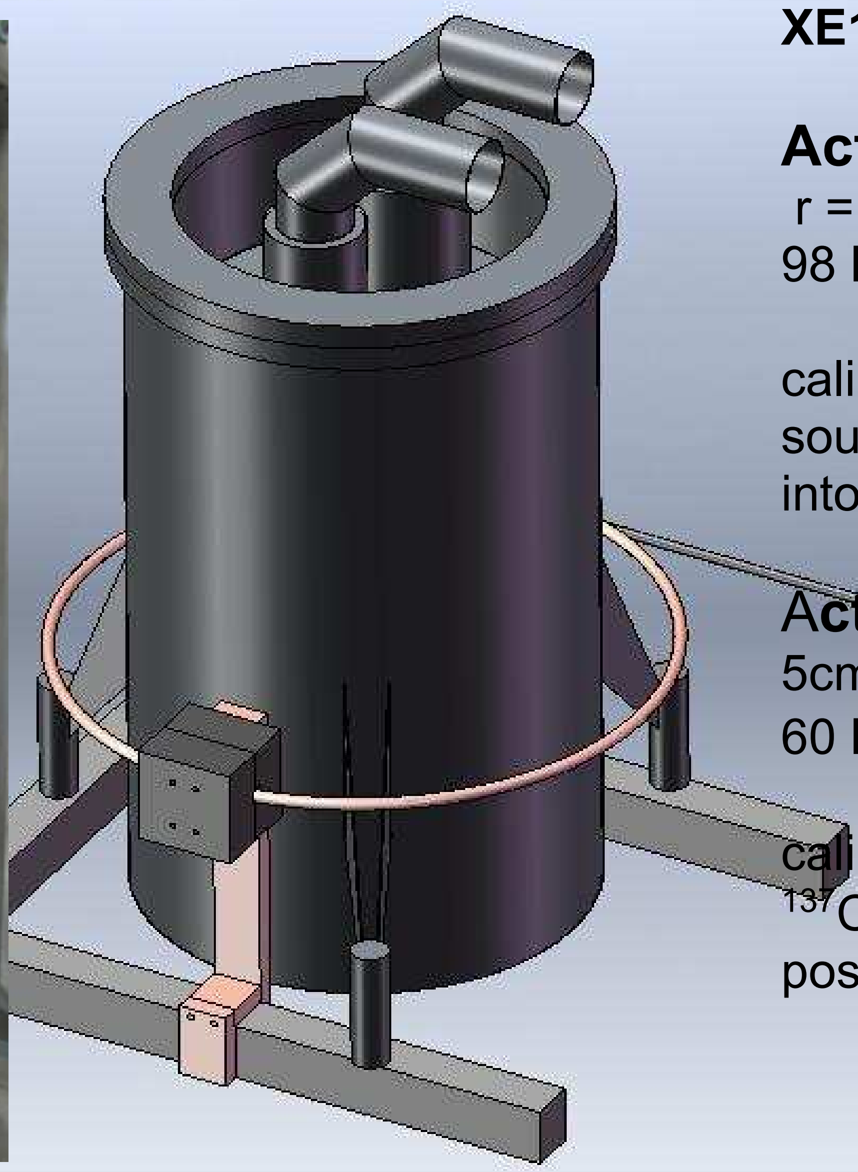
XE100 rejection power depends on position dependent corrections

Calibration of detector is needed to define its background rejection power but large scale detectors show inhomogeneous response across the volume, which needs to be corrected for.

extensively discussed in main talk by G.Plante



Calibration of XENON100 detector



XE100 Total 170 kg

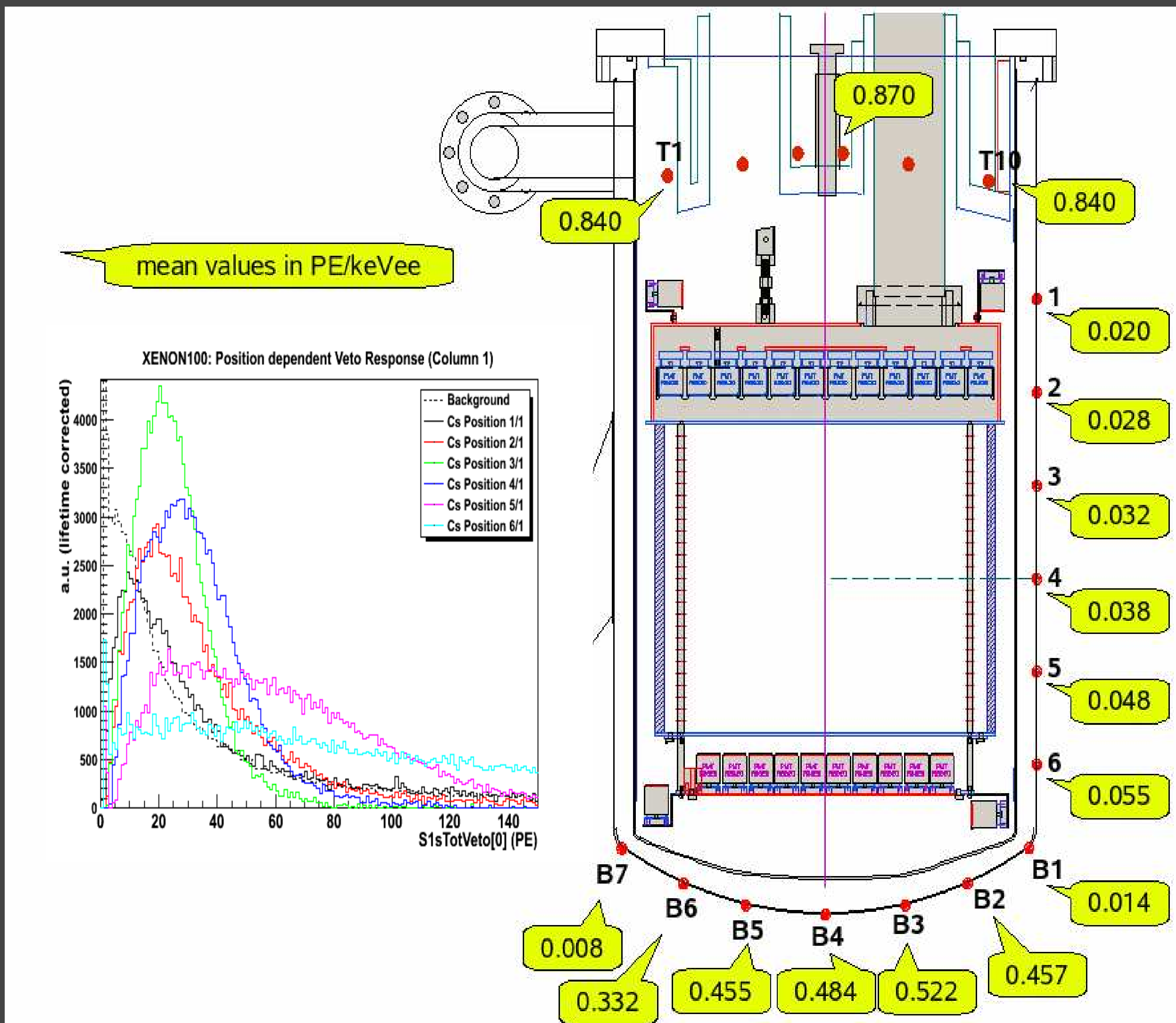
Active LXe 65 kg
r = 15 cm, z = 30 cm
98 PMTs top, 80 PMTs bottom,

calibration with external sources is done via insertion into a cooper pipe

Active LXe veto 105kg ~3.5cm thick
60 PMTs

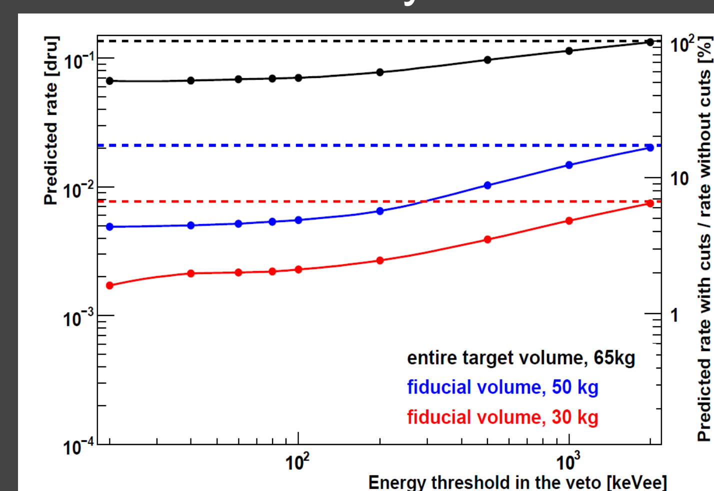
calibration done with collimated ^{137}Cs source at different positions

Collimated source for LXe active veto calibration



- from measured light yield averaged veto threshold is estimated to be better ~100 keVee.
- threshold of ~100keVee already in the region where background reduction is starts to flatten.
- with the fiducial and the active veto cut background reduction by 2 orders of magnitude.

see talk by A.Kish



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Gamma and neutron calibrations for spatial dependence characterization

Need for : source line distributed across the detector volume.

ONGOING ANALYSIS ON

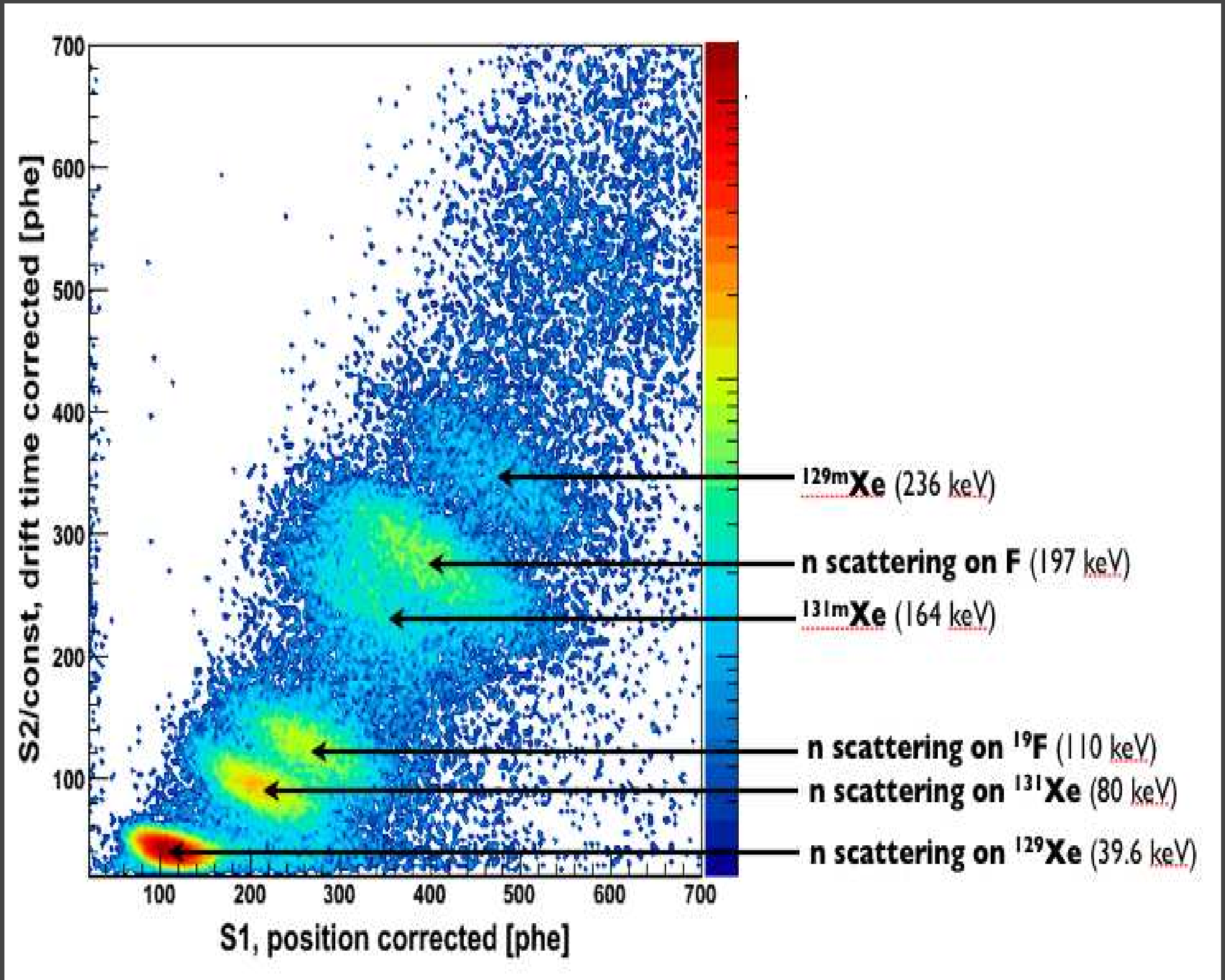
662keV line (Cs-137)

activated Xenon lines
164keV (^{131m}Xe) and **236keV** (^{129m}Xe)

inelastic lines
40keV (^{129}Xe) and
80keV (^{131}Xe)

ONGOING R&D ON

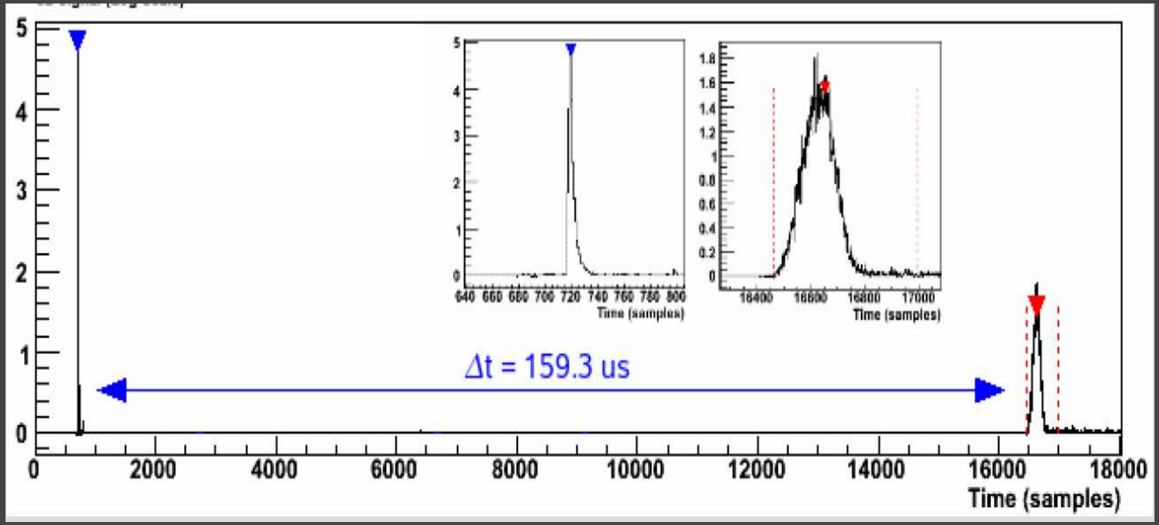
9keV, 32keV and 41keV lines :
Gamma calibrations with ^{83m}Kr source internally distributed low energy and short lived

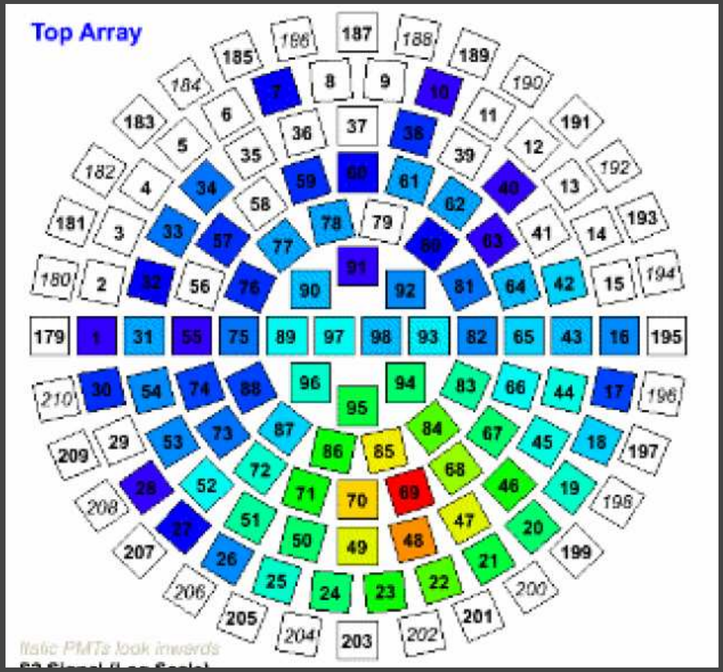


3D Position Reconstruction

To determine the spatial response of XE100 precise position reconstruction is needed.

- z coordinate is determined by the drift time = the time between the S1 and S2 signal, and known drift velocity.
- z coordinate resolution ~ *o* (1mm)





- x,y and r positions are reconstructed from the S2 signal distribution on the top PMT array.
- three different position reconstruction algorithms developed independently: chi^2 minimization, neural network and support vector machine.
- first validation via MC shows that radius of an event can be predicted with an average resolution of <1.5 mm for all algorithms.

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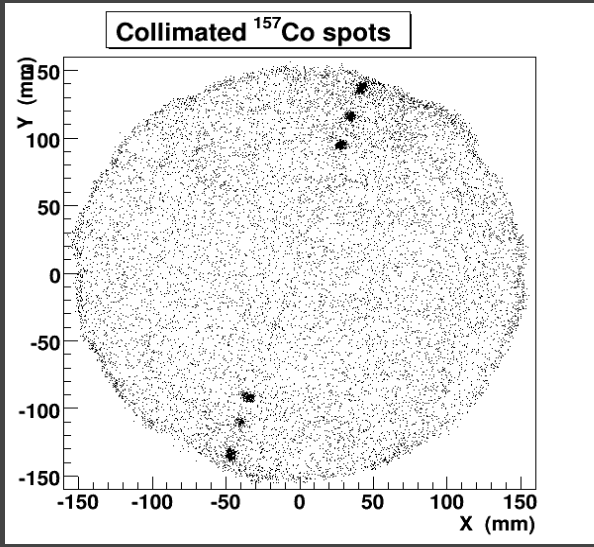
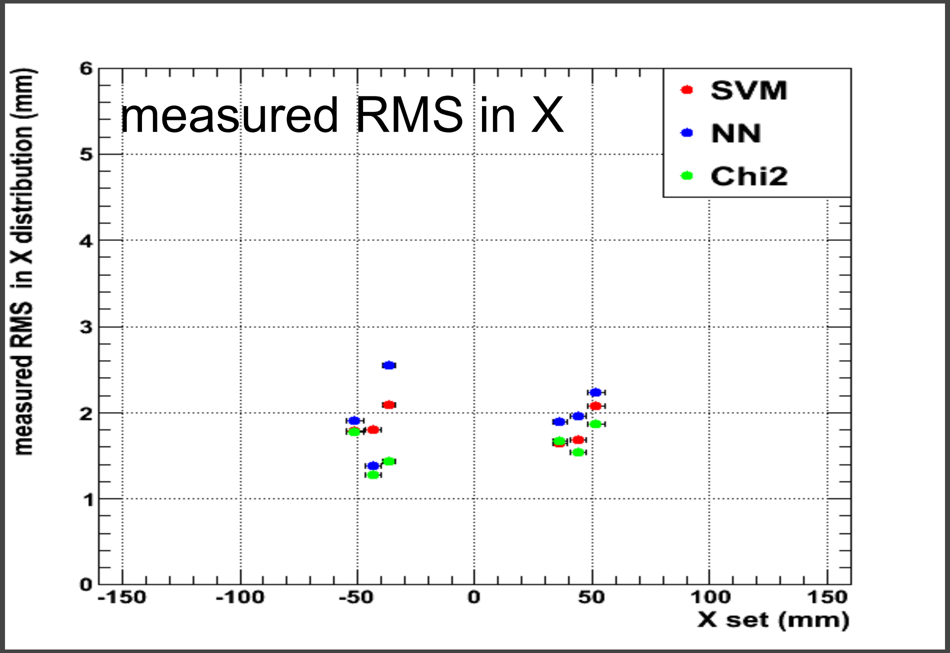
Collimated source for position calibration

- Long (16cm) lead collimator with an opening of 2mm was used to collimate gammas from ^{57}Co source.
- Collimator was installed on top of the detector and several measurements were taken at different radii. No LXe in top veto.
- Position of the collimator spot was set with a precision of 3 mm.

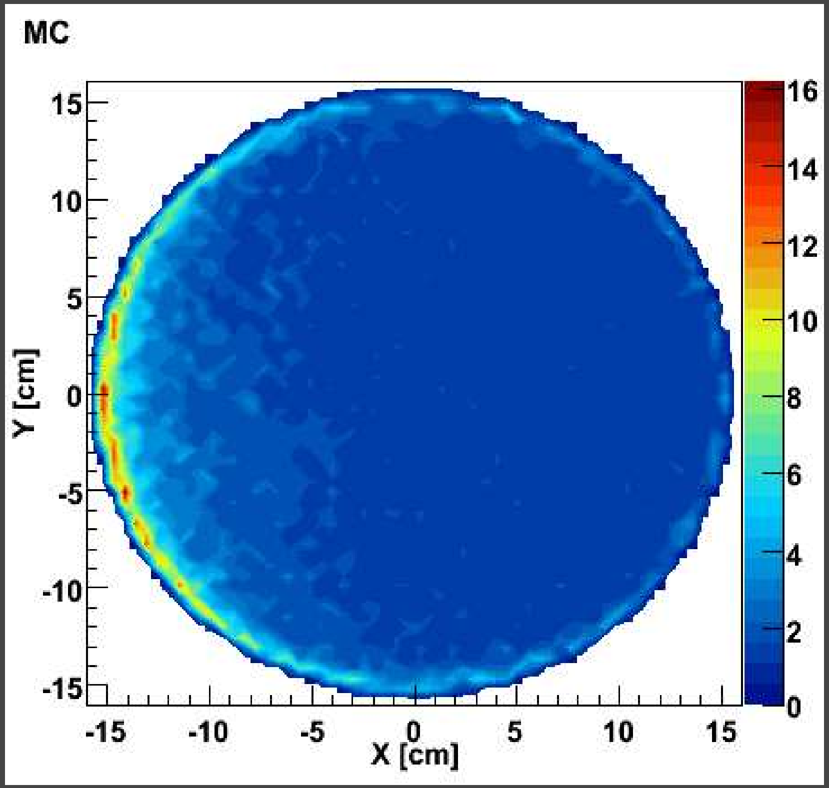


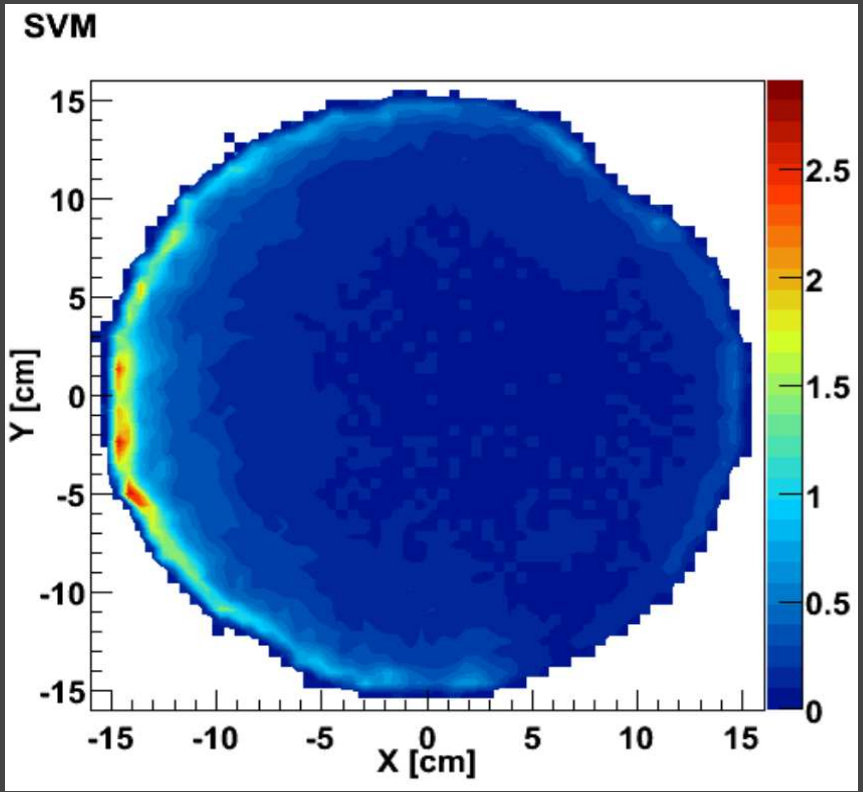


- Measured resolution has two contributions: spread due to the finite size of the collimator hole (~2mm) and spread due to the position resolution of the algorithm.
- Resolution of all position reconstruction algorithms <3mm (as expected from MC)

Comparison of position reconstruction algorithms - source position

Good agreement in source position reconstruction (SVM) with MC for ^{129}Xe 40kev inelastic line from AmBe calibration.

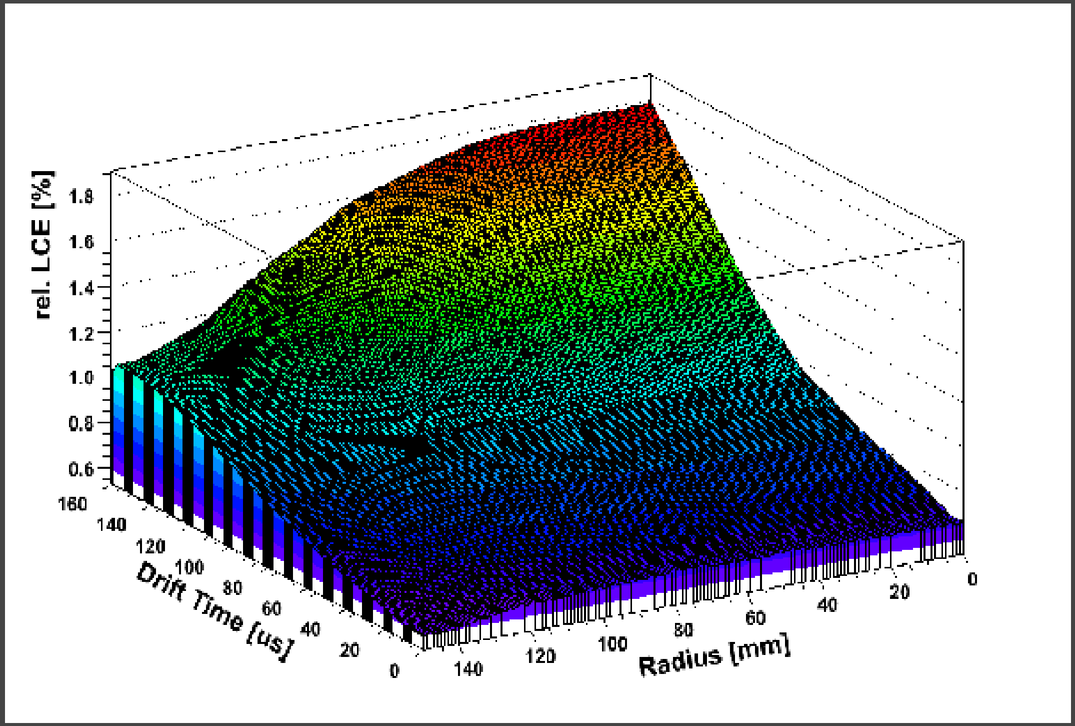


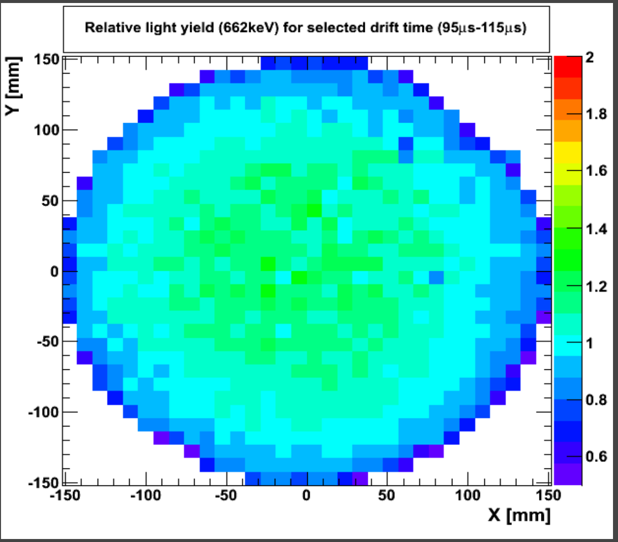


Position dependence of S1 signal

- 3D position dependent correction for S1 signal was determined using Cs-137 source line.
- S1 correction is parametrized for radius and drift time since detector has/shows azimuthal symmetry
- Ongoing analysis for inelastic and activated Xe lines.

Parametrization of S1 spatial dependence



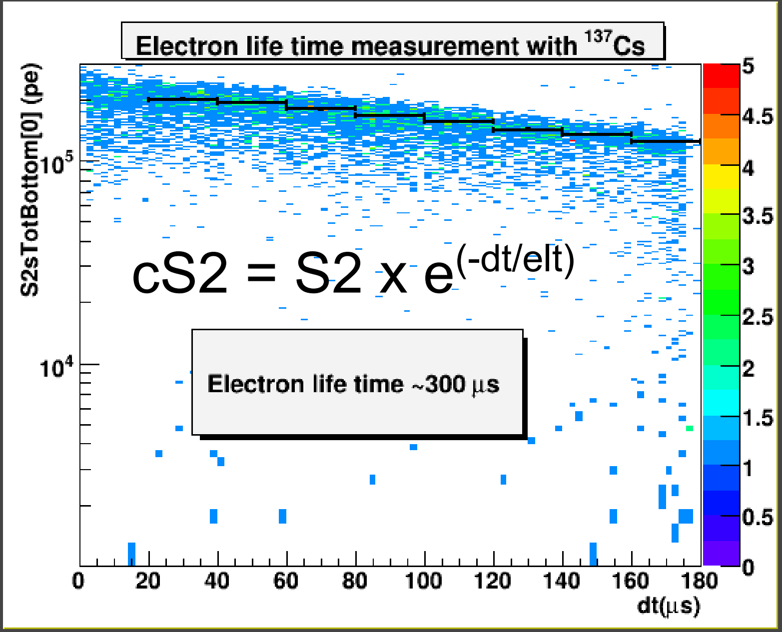


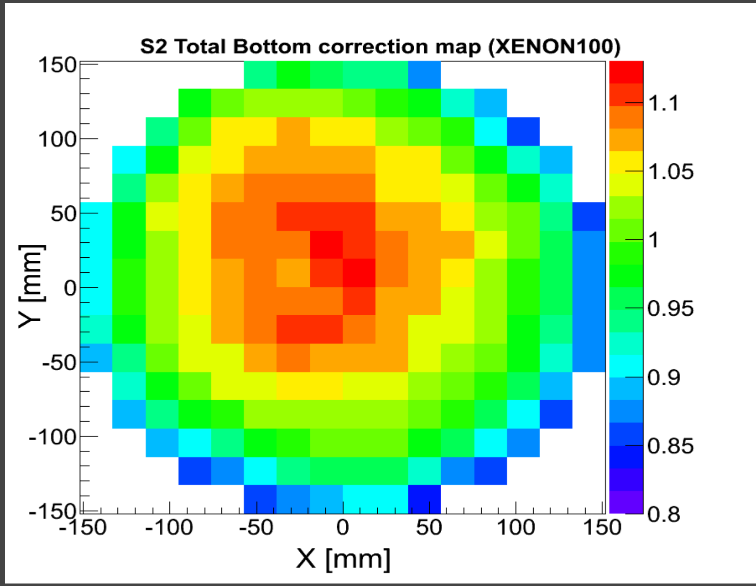
Volume averaged light yield@662keV with field is ~1.65pe/keVee.

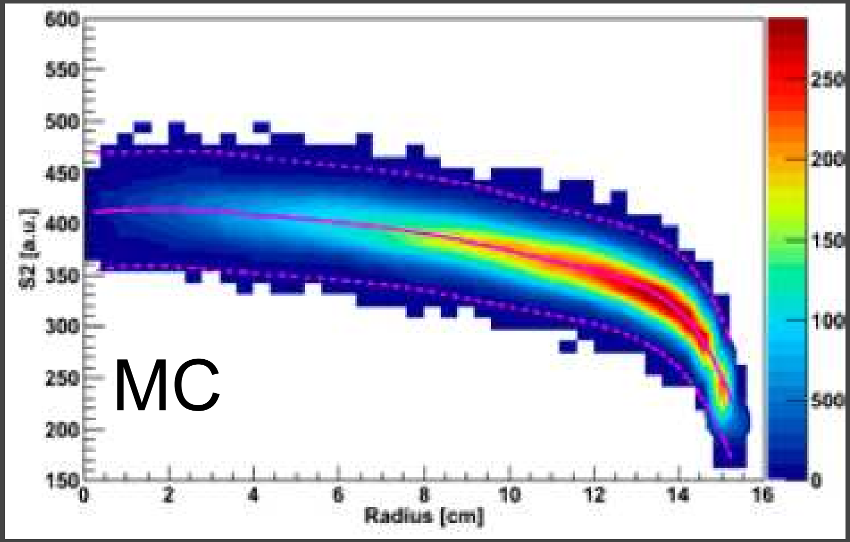
Position dependence of S2 signal

- Drift time correction for S2 signal is performed using electron life time measured regularly in Cs-137 calibrations.

- 2D position dependent correction for drift time corrected S2 signal was determined using Cs-137 line.
- Observed variation of the S2 signal is mainly due to worsening of S2 light collection towards the edge of the TPC. MC radial distribution of the S2 signal shows similar behavior.







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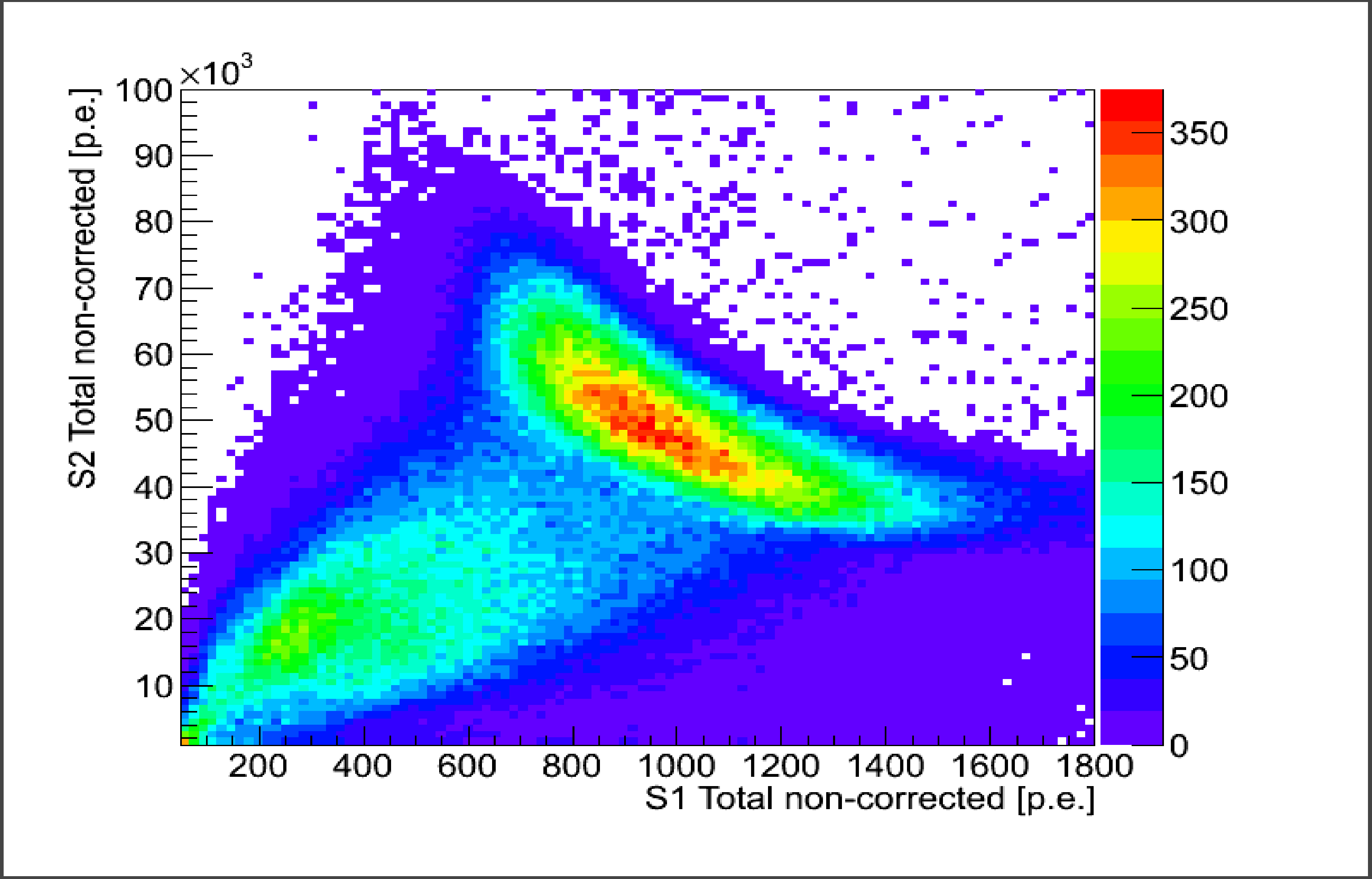
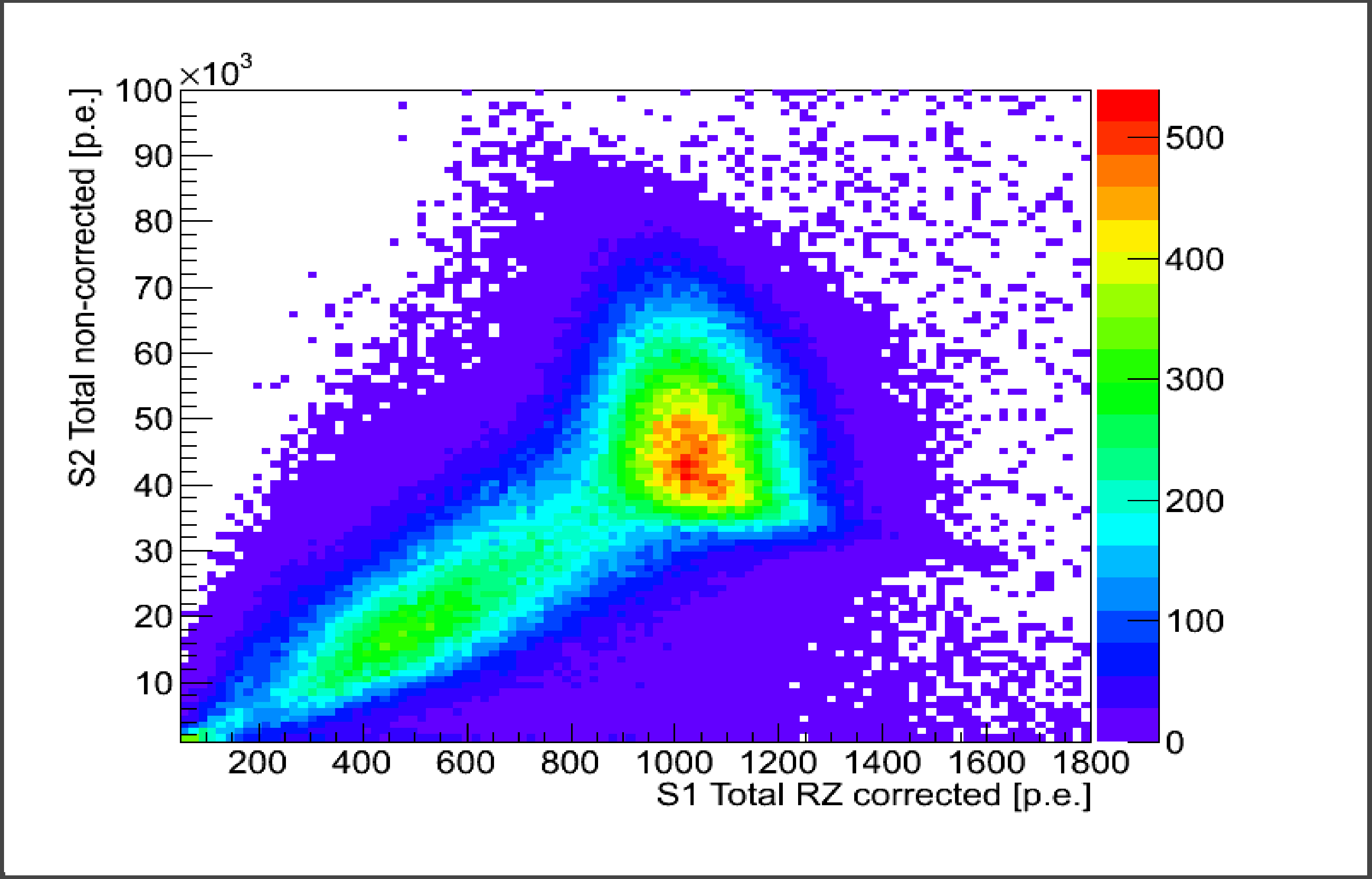
Position dependence correction - ^{137}Cs

S1 non-corrected S2 non-corrected



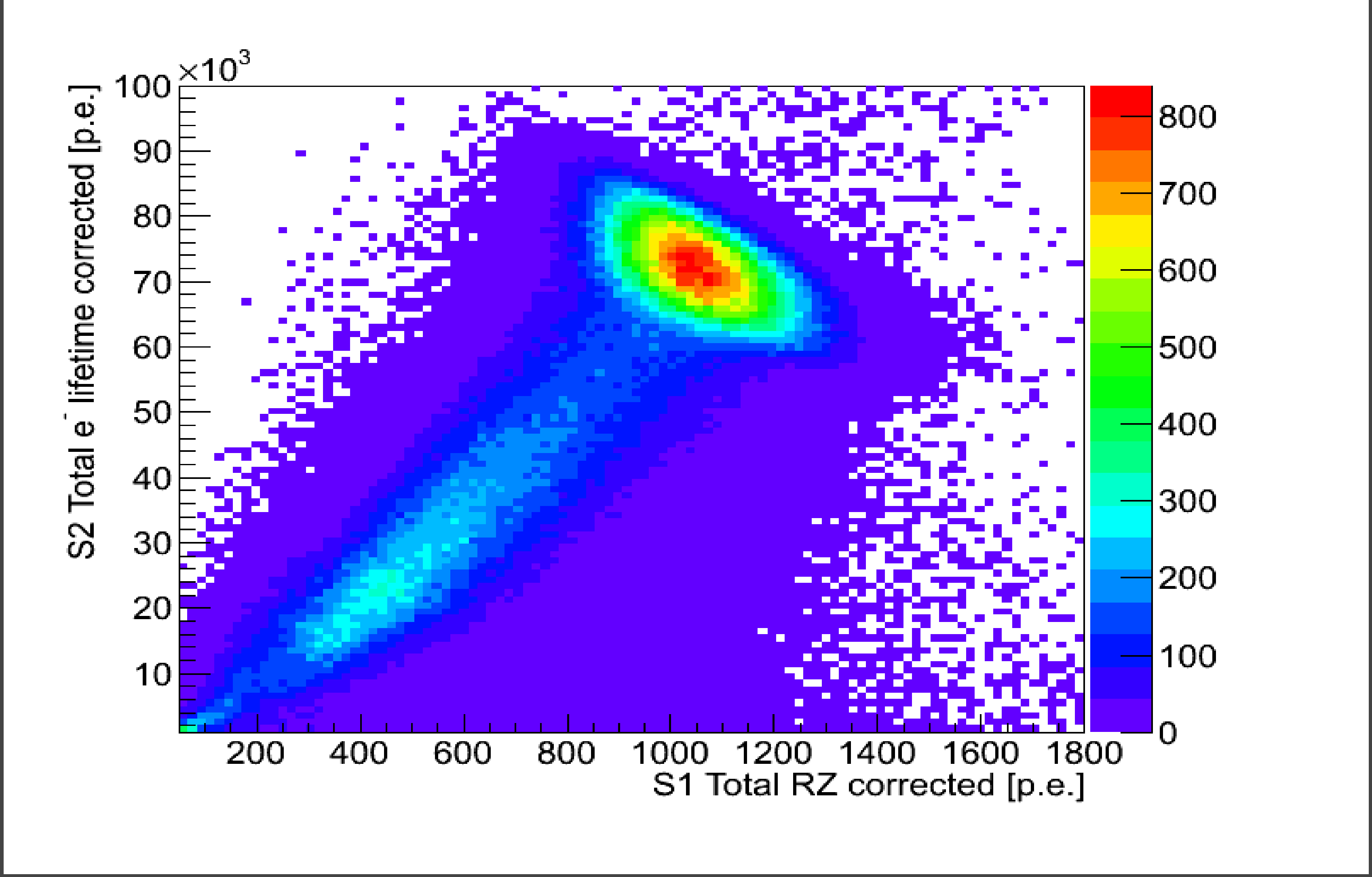
Position dependence correction - ^{137}Cs

S1 rz-corrected S2 non-corrected



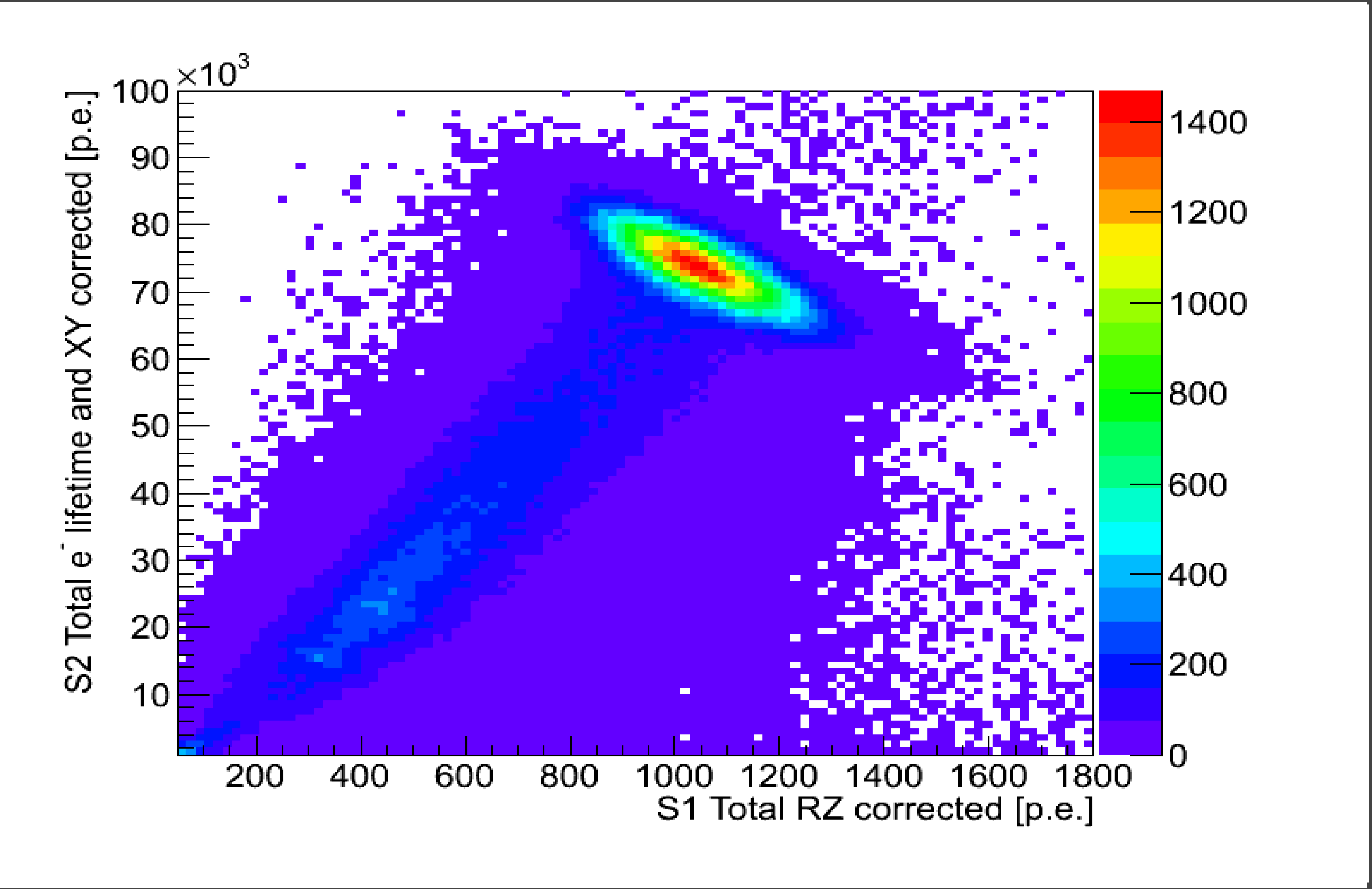
Position dependence correction - ^{137}Cs

S1 rz corrected S2 z-corrected



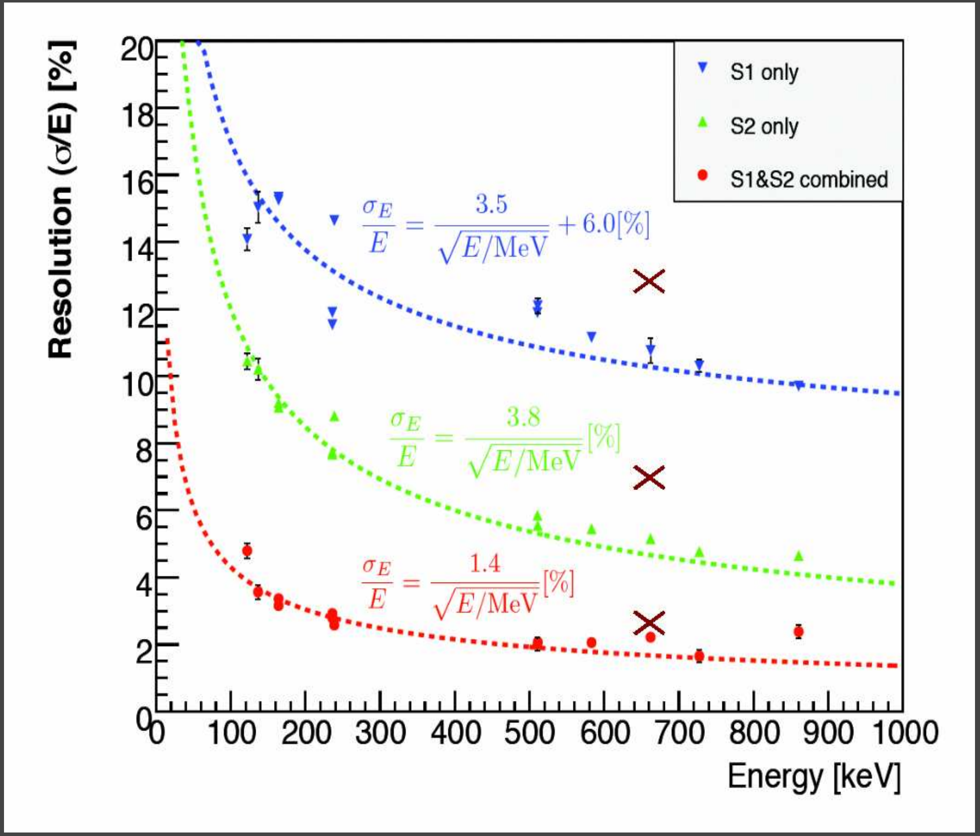
Position dependence correction - ^{137}Cs

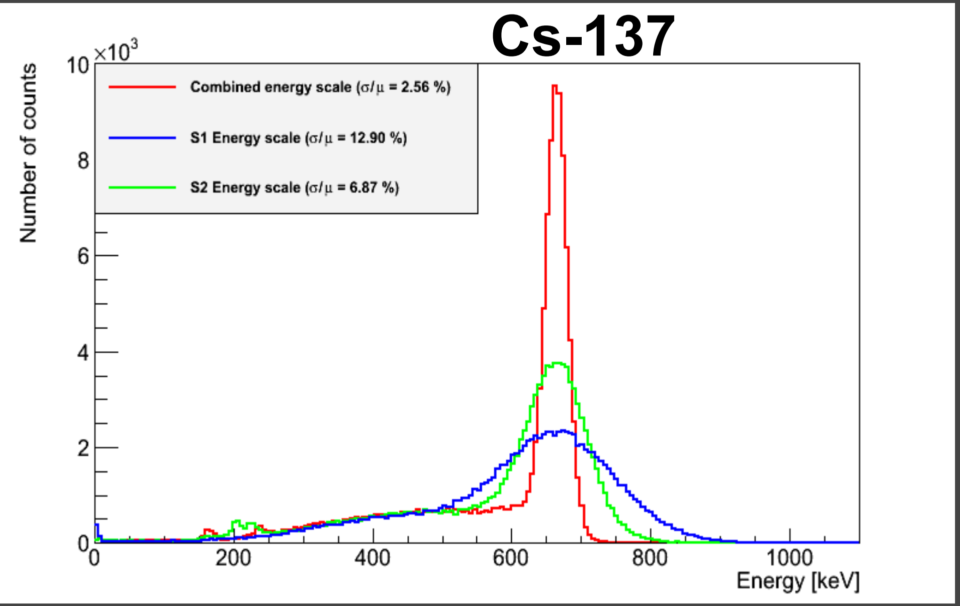
S1 rz-corrected S2 xyz-corrected

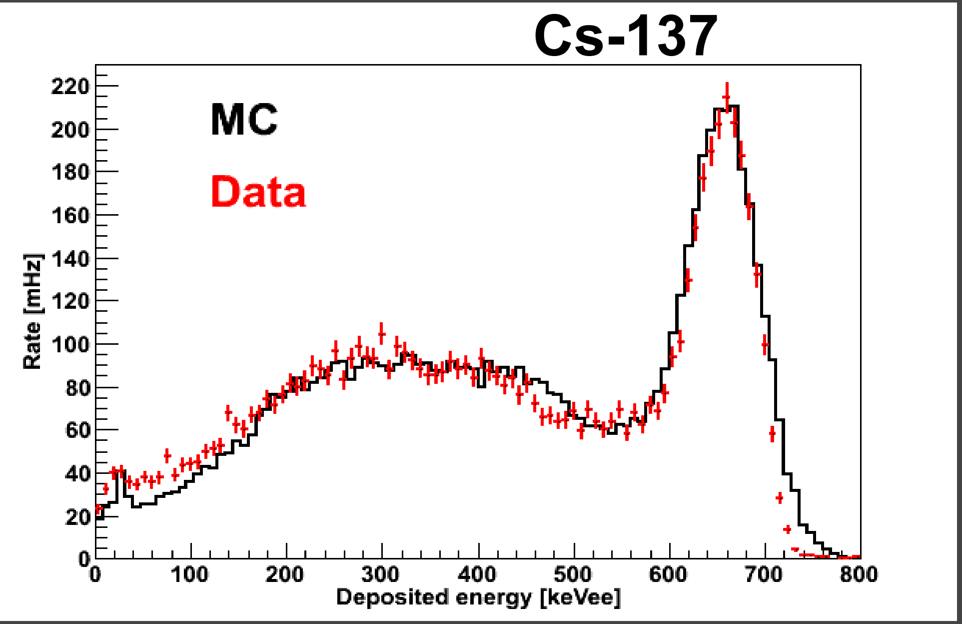


Energy resolution - ^{137}Cs

Preliminary results:
Resolution@E = 662keV
S1 ~12.9%
S2~ 6.9%
S1&S2 Combined ~ 2.6%







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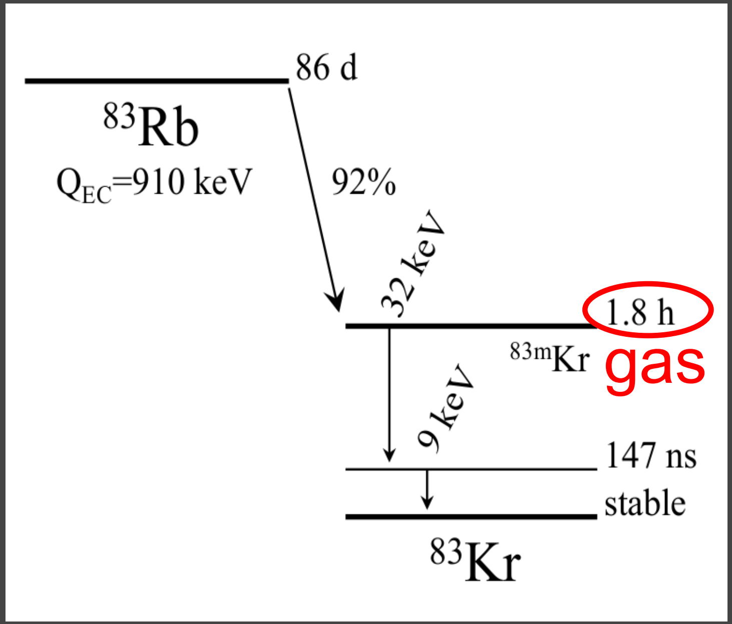
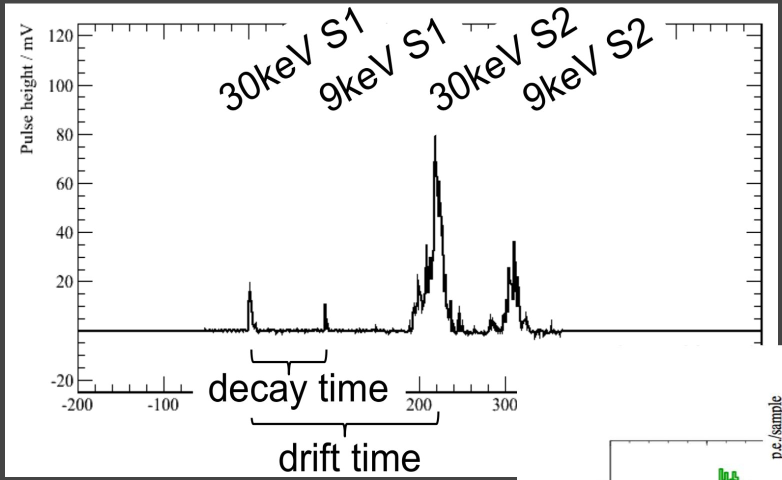
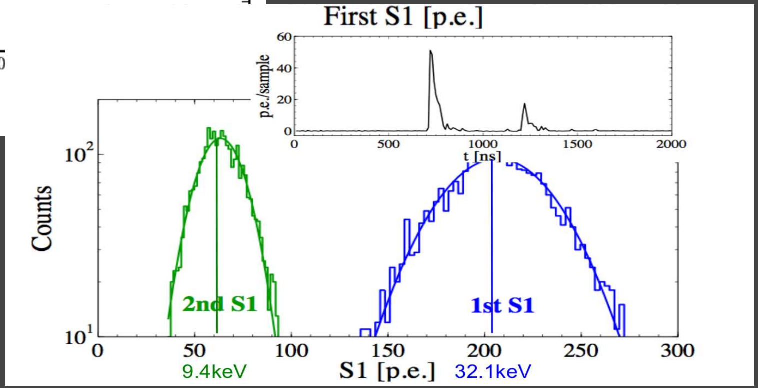
Future: Calibration with internally distributed short -lived low energy ^{83m}Kr source lines





^{83m}Kr has already been introduced in small test chambers and its lines observed



extensive R&D efforts with a wide range of methods
@ Columbia/Zurich/Muenster/Heidelberg on
needed source strength, integration of source in XENON100, diffusion & homogeneity, data acquisition software and data analysis procedures.

Conclusion

- 3 different position reconstruction algorithms for better estimate of any possible systematics and better event rejection. Position resolution better than 3mm for all of them.

- Light yield of LXe active veto characterized. Estimated veto threshold in average better than 100 keVee. Fiducial cuts and veto cut reduce background by two orders of magnitude.

- Corrections for spatial dependence of S1 and S2 signals are obtained from 662keV line. Ongoing analysis for lower energy lines (activated Xenon).

- Volume averaged light yield@662 with field is ~1.65pe/keVee.

- Two phase TPC allows improved energy measurement from combined light&charge signals. XENON100 energy resolution @ 662 keV from combined S1&S2 is 2.6% (sigma).