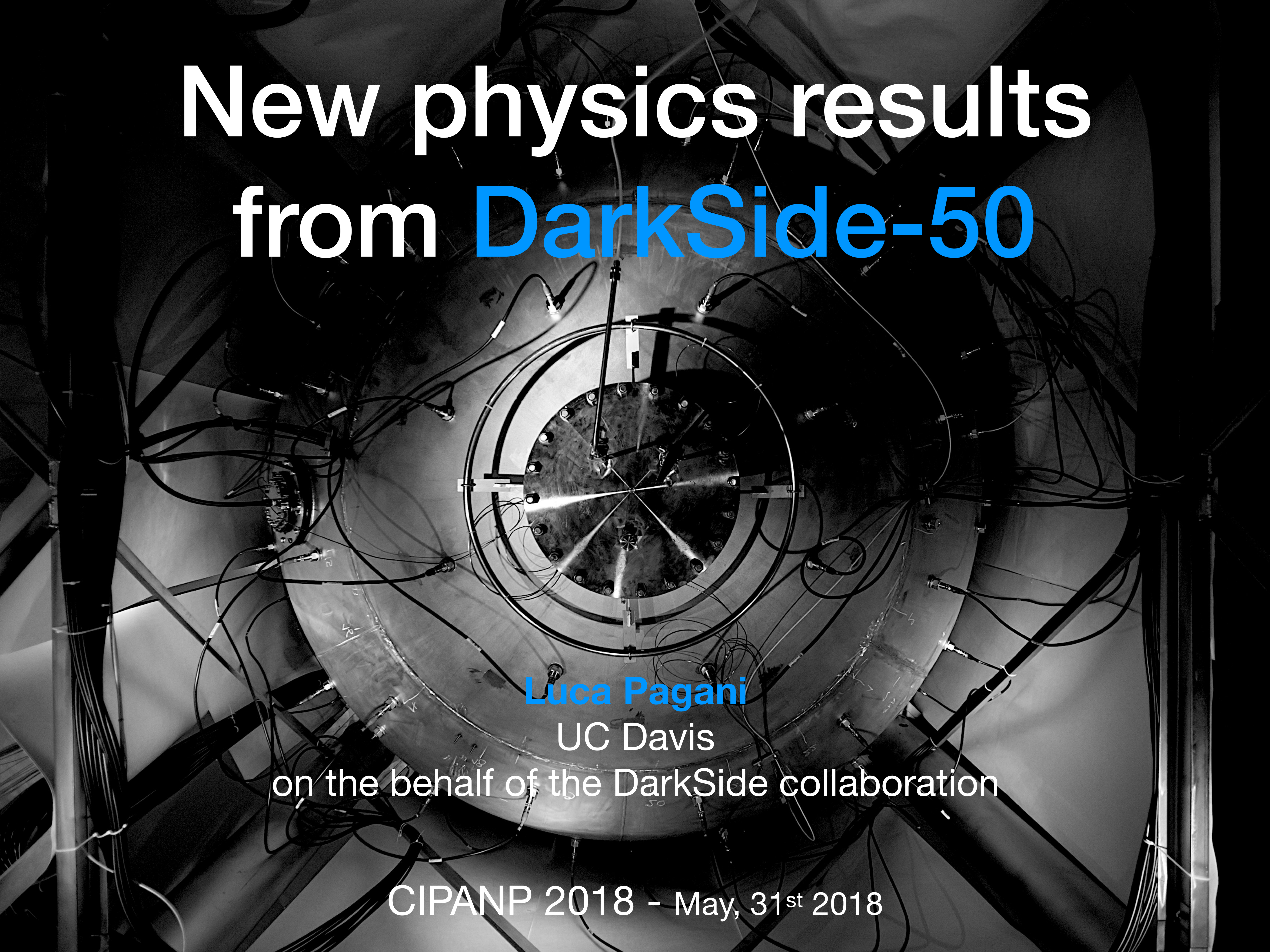


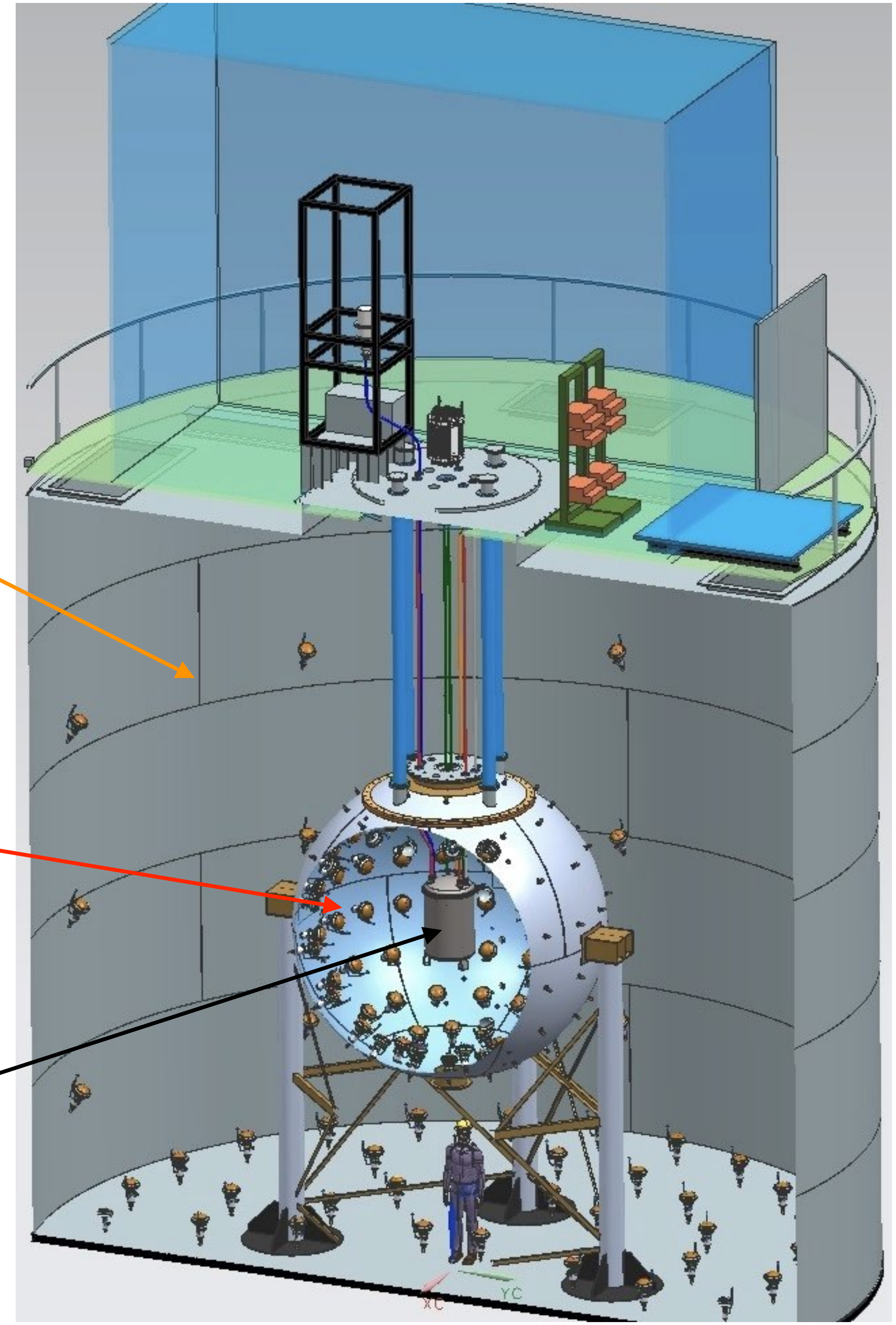
New physics results from DarkSide-50

Luca Pagani
UC Davis
on the behalf of the DarkSide collaboration

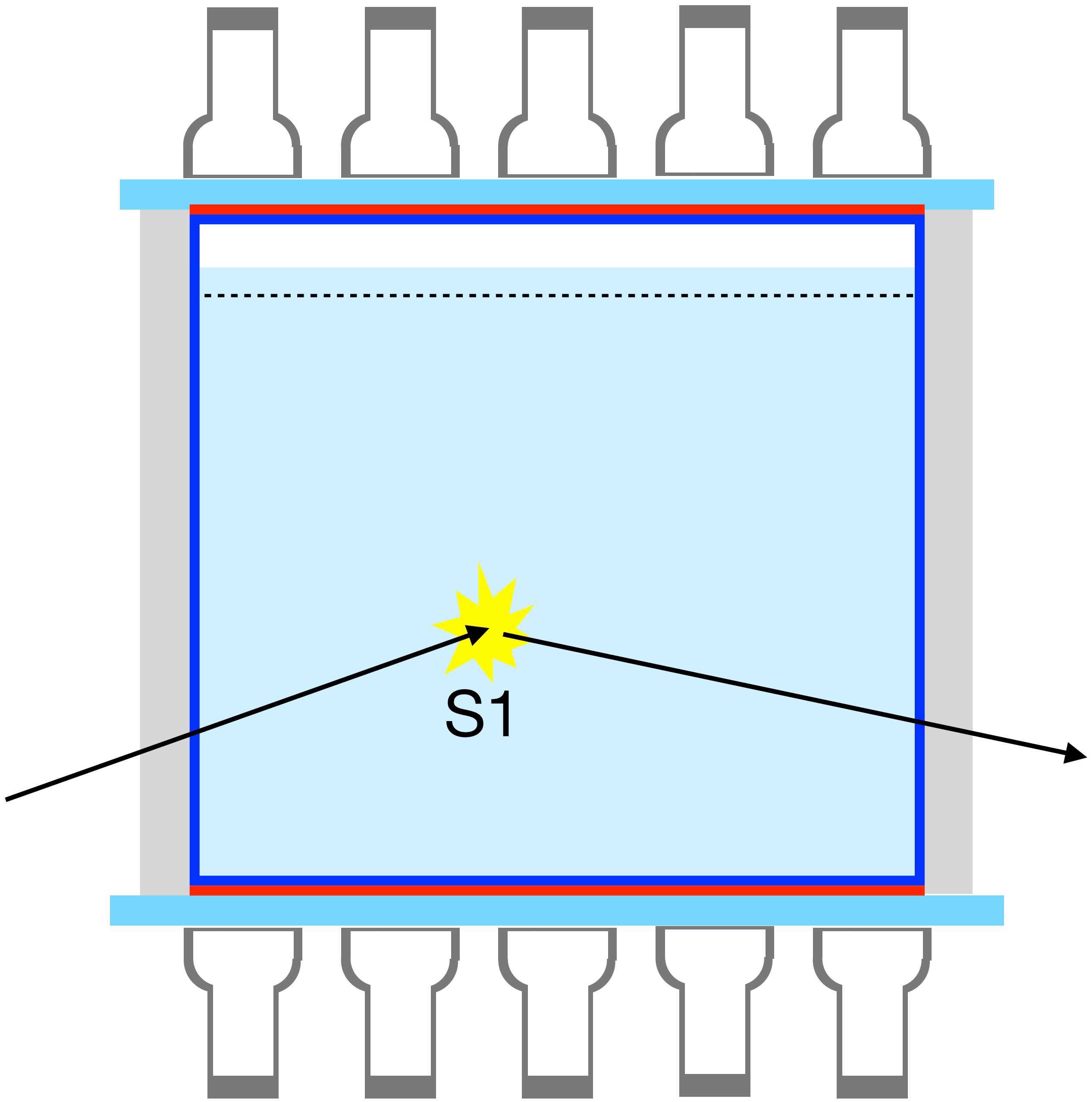
CIPANP 2018 - May, 31st 2018

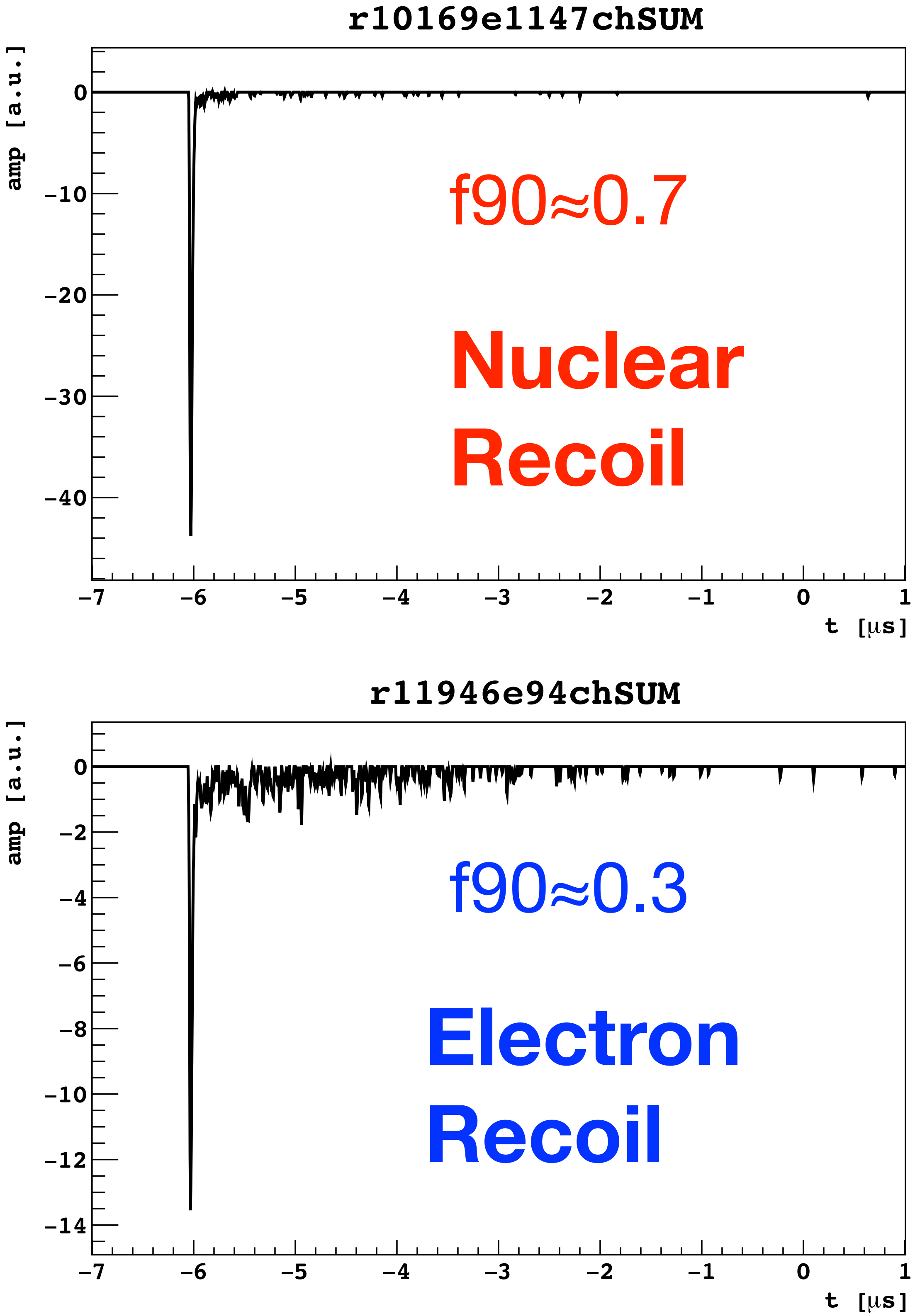
DarkSide-50 detector overview

- **Water Cherenkov** detector (1,000 tons of ultra pure water): active veto for μ and passive shield for external radiation
- **Liquid scintillator** detector (30 tons of PC+PPO+TMB): active γs and neutron detector thanks to ^{10}B loading
- **LAr TPC** detector (current phase ~50 kg of argon in the fiducial volume): inner detector for WIMP



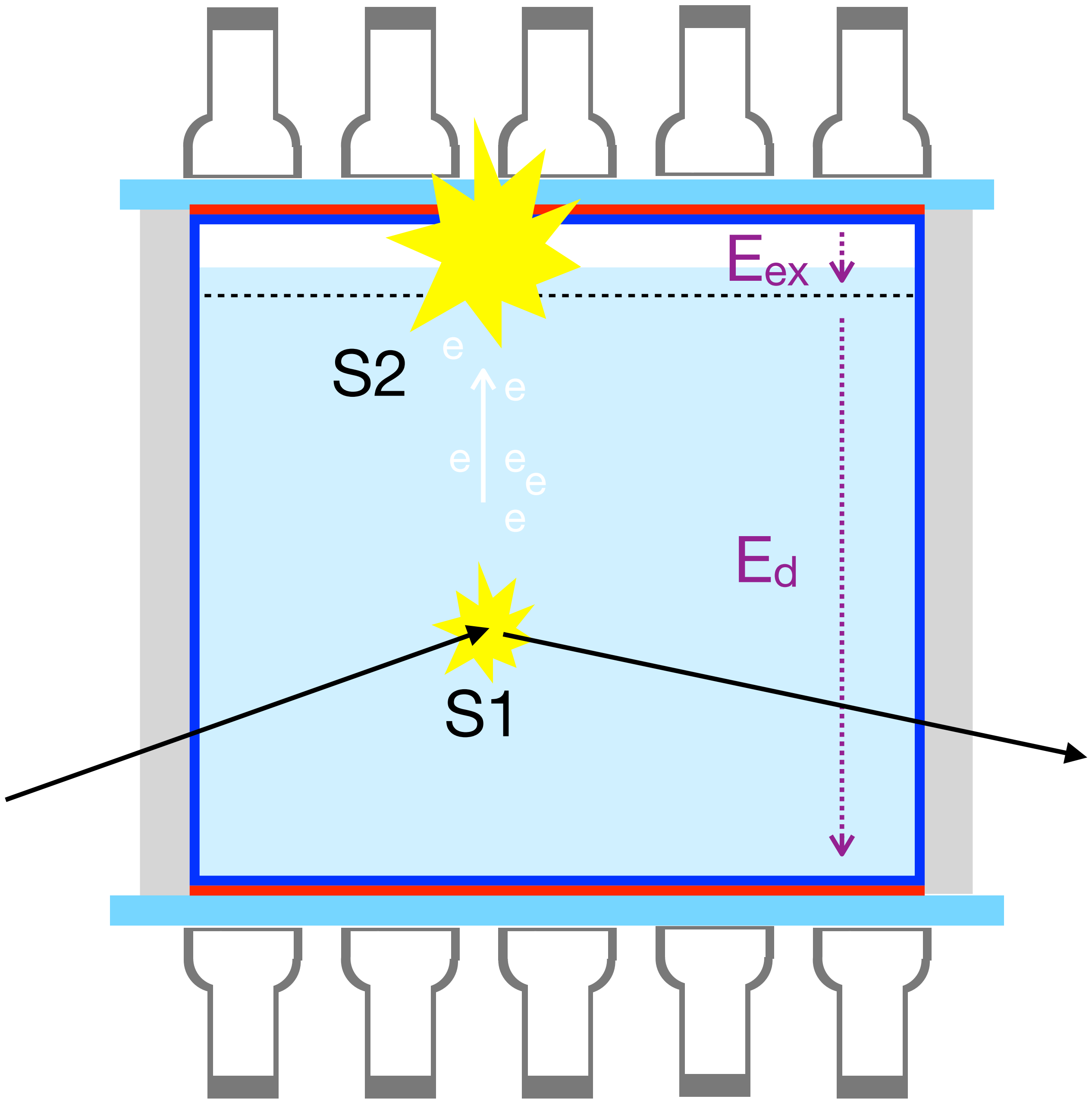
Dual phase TPC technology

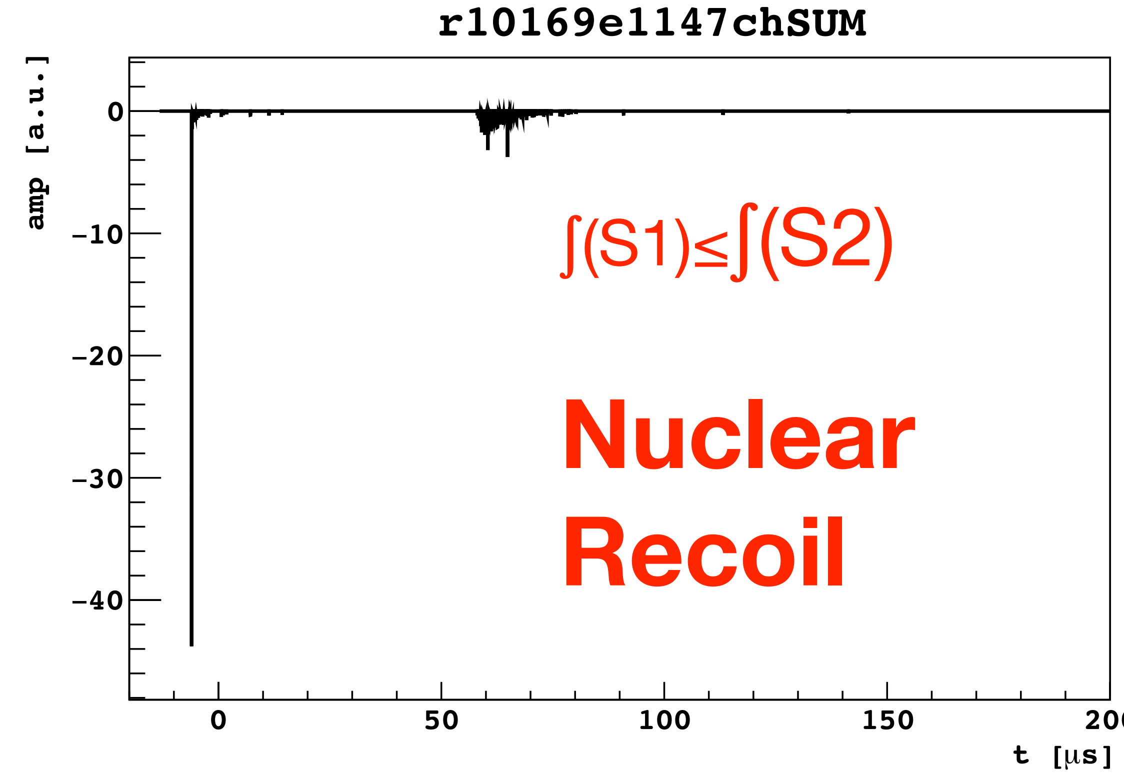


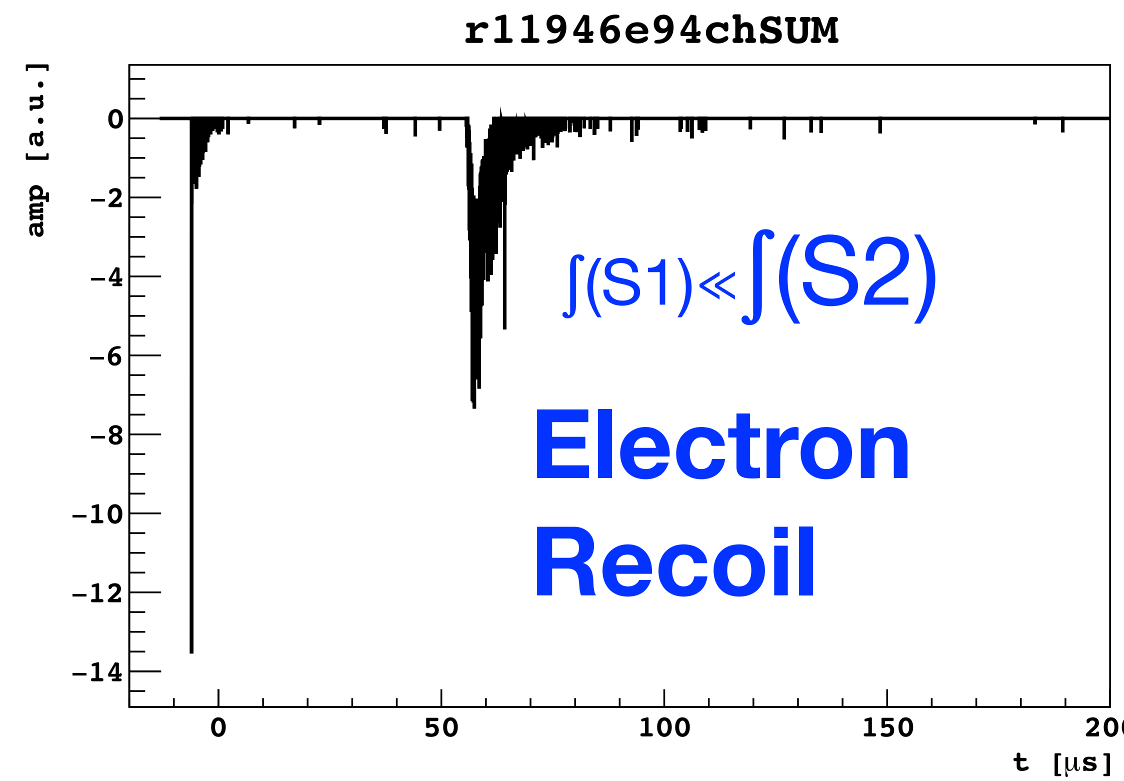


- **Light signal (S1)** time profile allows PSD tanks to f90 parameter (fraction of light in the first 90 ns)

Dual phase TPC technology



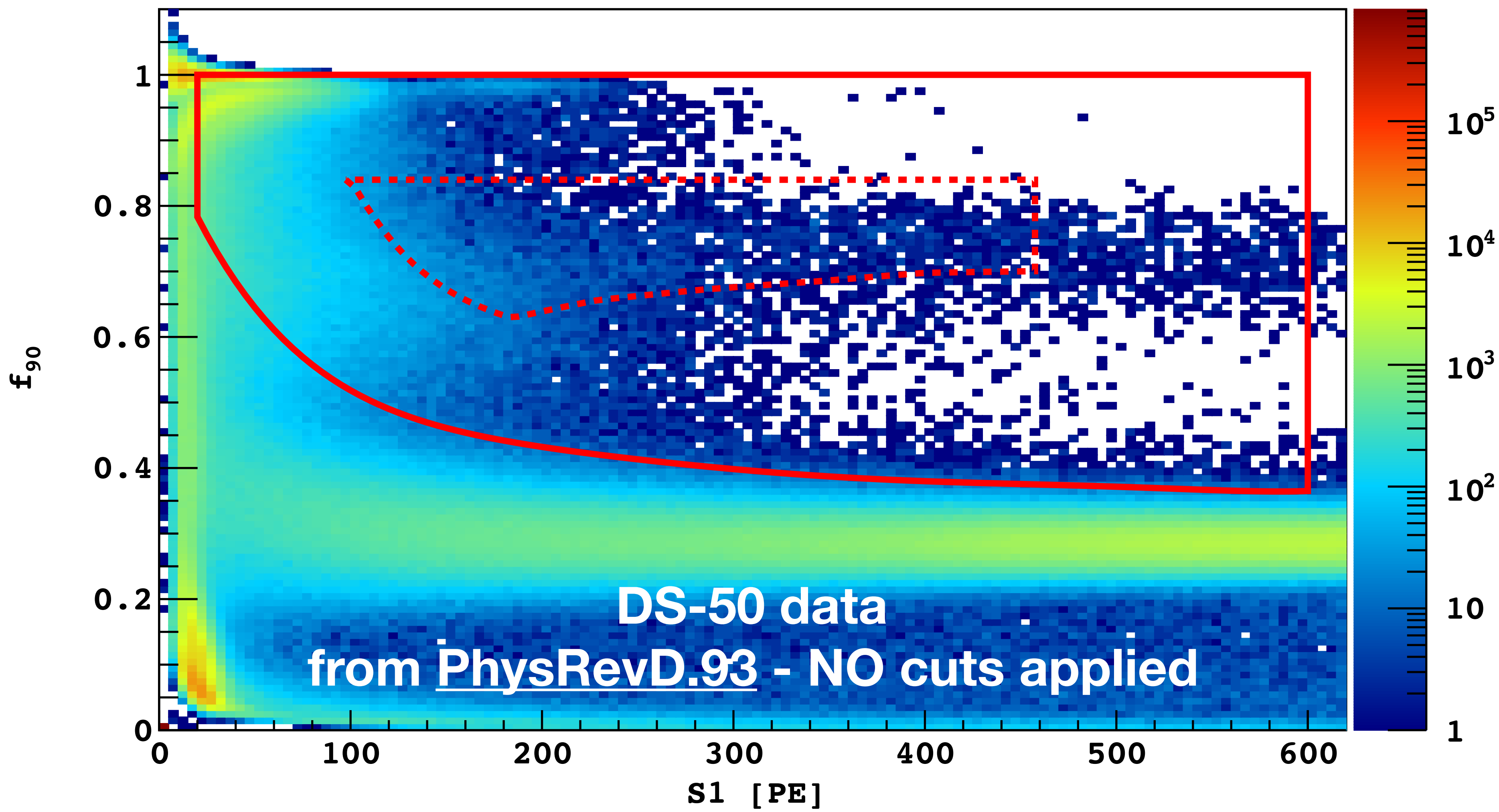




- **Electroluminescence/ionization signal (S2)** due to drifted electrons allows 3d position reconstruction and additional discrimination (S2/S1)

High mass χ search results

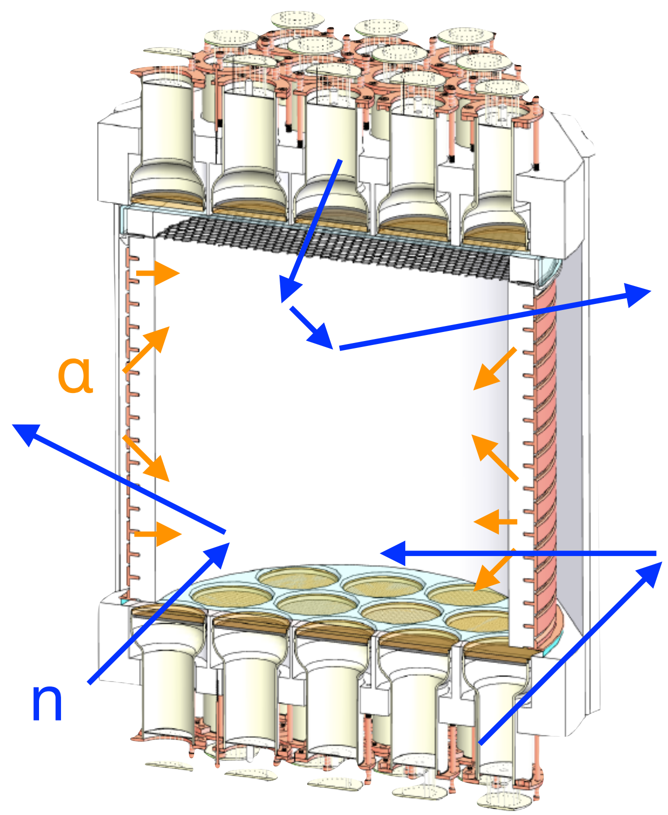
- A 534 live-days blind analysis: blinding box (red outline) shown on the old data sample



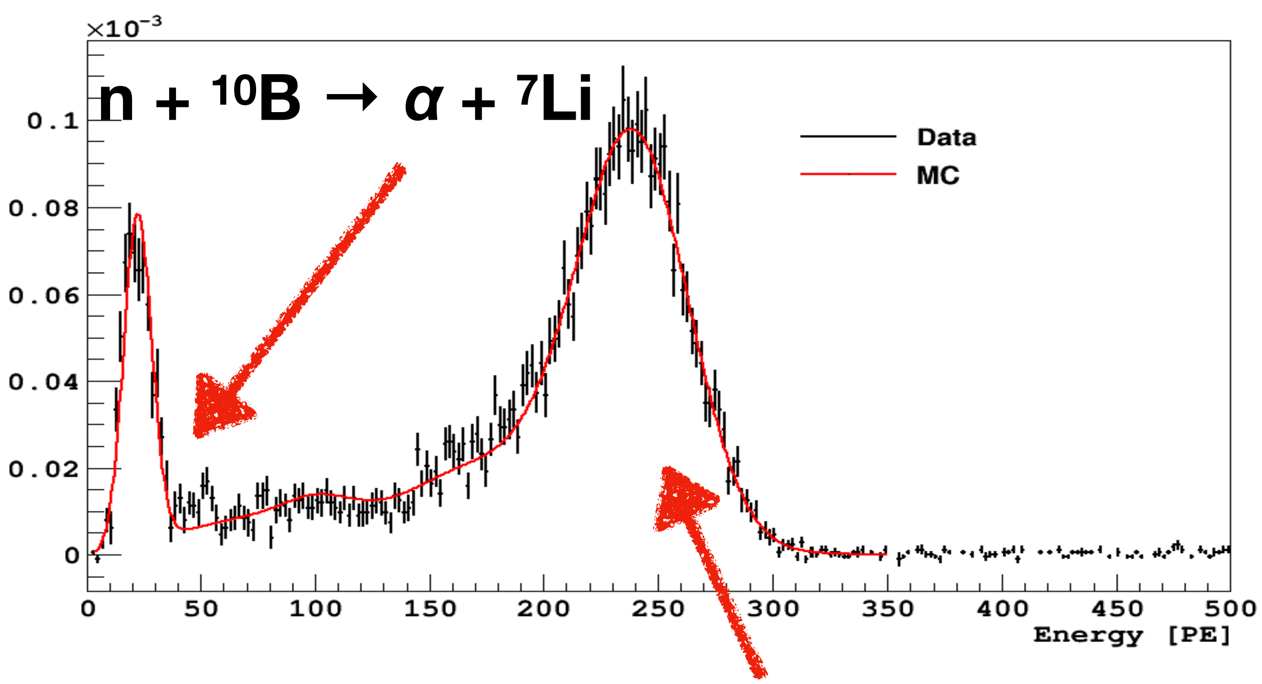
- Goal: design an analysis that will have <0.1 event of background in the to-be-designed search box (Final box chosen: dashed red)

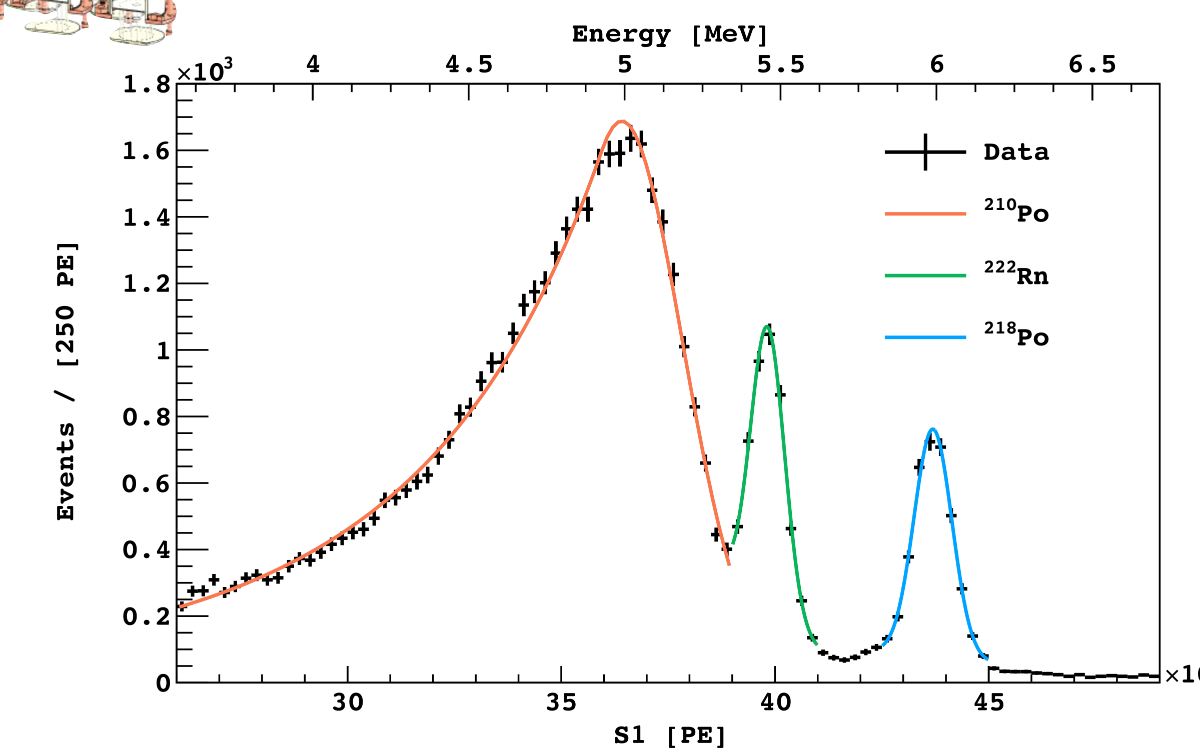
Nuclear recoil background

- **Neutrons:** cosmogenic (produced by muons interaction with surrounding materials) or spontaneous (α,n) reaction. PMTs are the main source
- Rejection:
  - Multiple scatter in TPC
  - Coincidence with LSV - measured efficiency with AmC: 0.9964±0.0004
  - Coincidence with WCD - suppression of cosmogenics



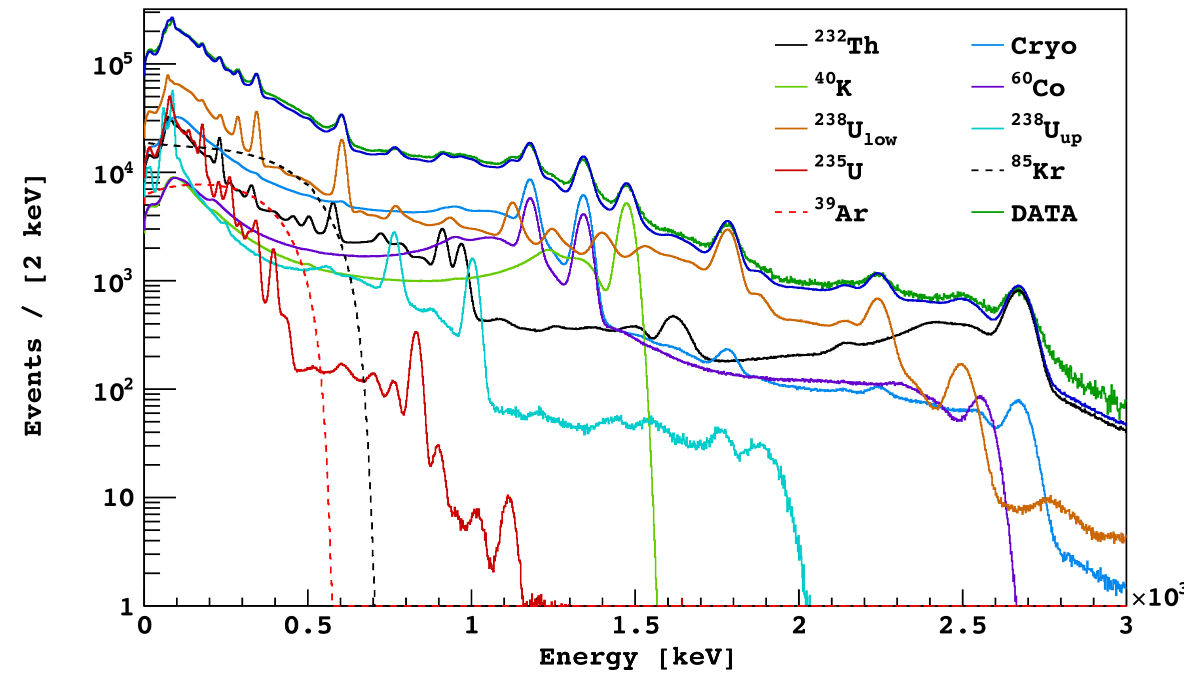
- **Alphas:** high radio-pure material selection constrains alpha-emitters to be Rn daughters either deposited on surfaces during fabrication/assembly or introduced during LAr recirculation
- Rejections:
  - Small background at low energy (S1<460PE) but can be degraded
  - Self-vetoing in DS50:
    - Small or no S2
    - Long S2 tail from TPB scintillation

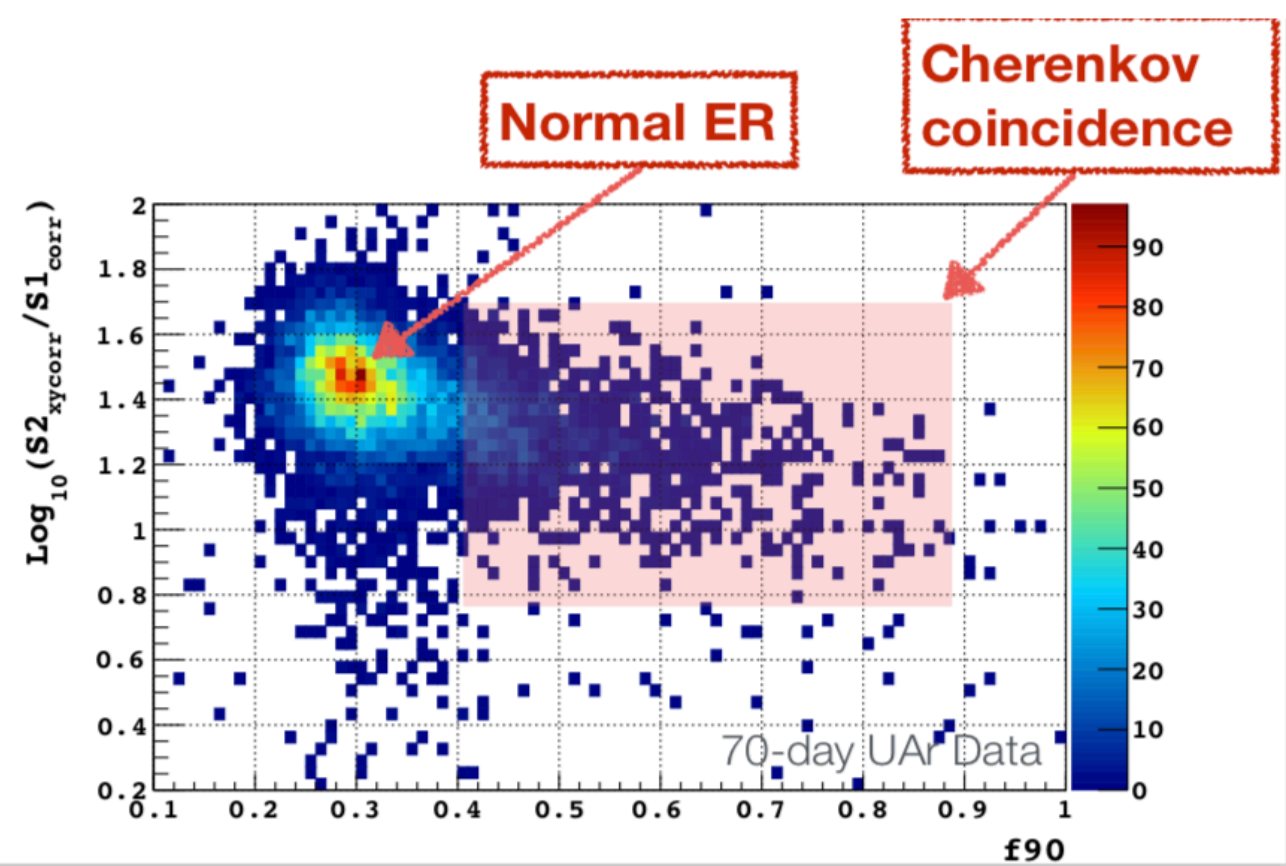




Electron recoil background

- ^{39}Ar, ^{85}Kr and external Ɣ-rays
- Cherenkov+S1: very dangerous - move regular scintillation into NR band
- Rejection:
  - Usage of UAr (low ^{39}Ar content)
  - Cut on S1 fraction in max PMT
  - Pulse Shape Discrimination
- Goal: design cut to reduce ER bkg <0.08



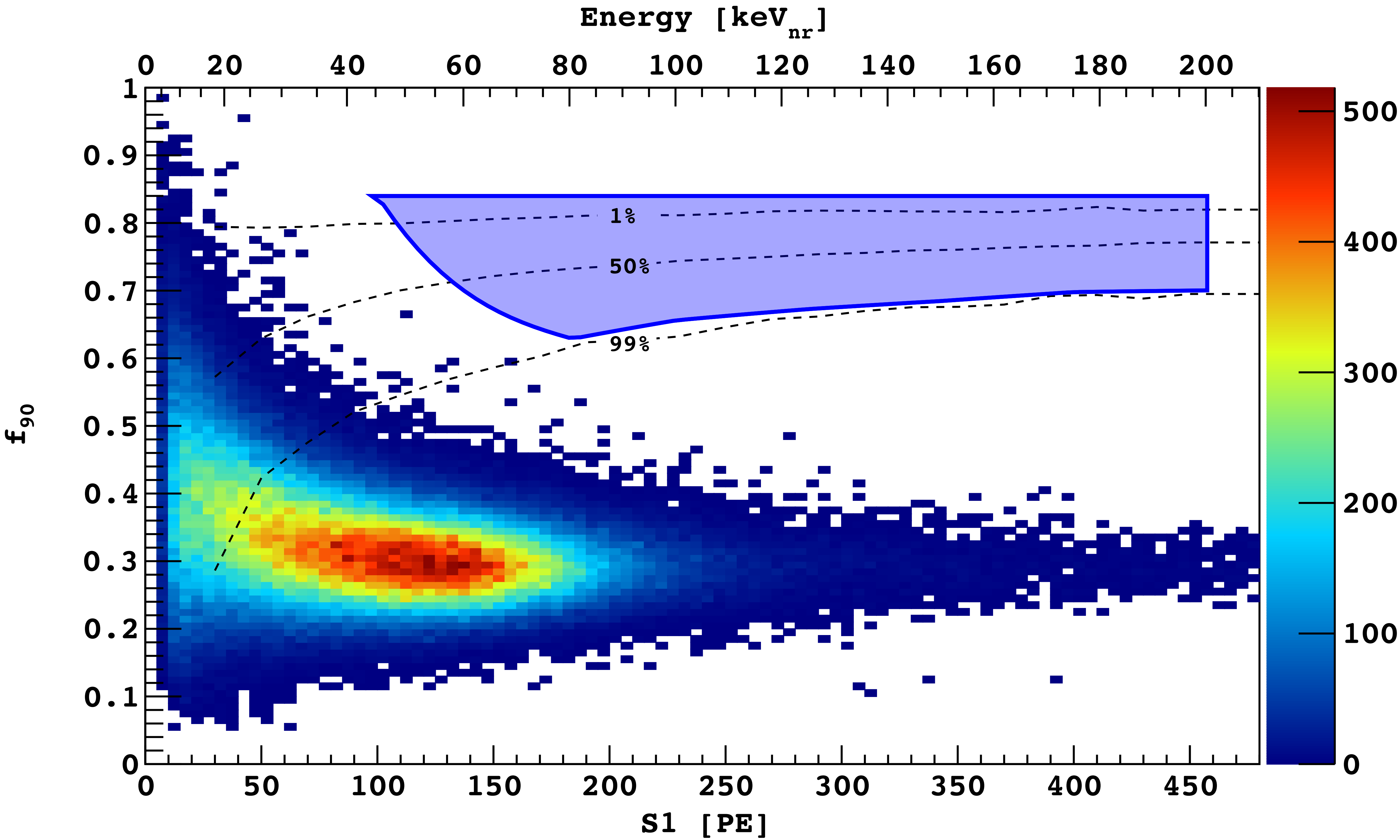


Summary: overall background budget

Background	Estimated survivors
Surface α	0.001
Cosmogenic n	<0.0003
Radiogenic	<0.005
ER	0.08
Total:	**0.09±0.04**

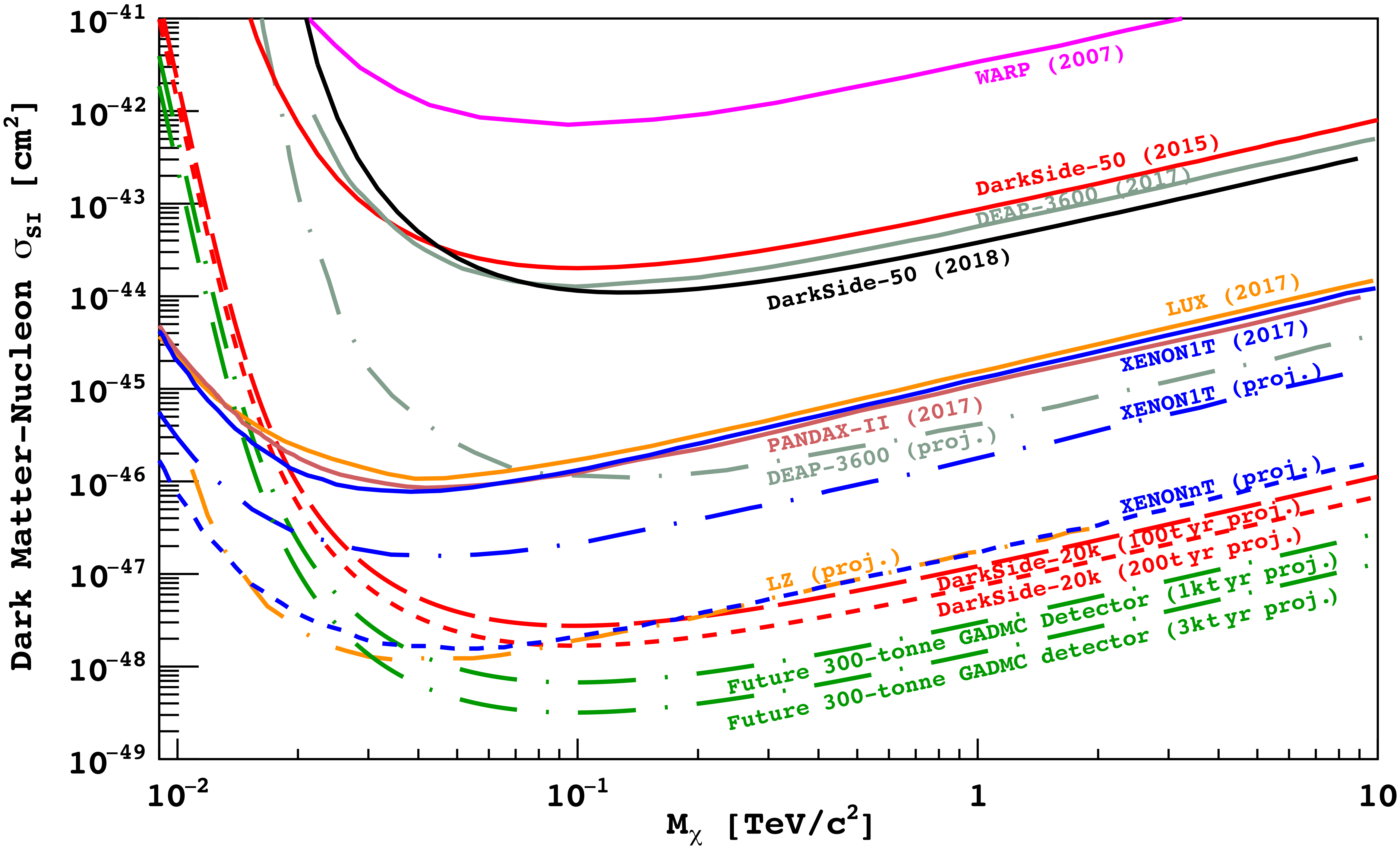
- Intensive background modeling of S1+Cherenkov and data selection criteria
- Goal of <0.1 event of background in the to-be-designed search box: achieved!
- Let's open the box …

Final data set and box



arXiv:1802.07198

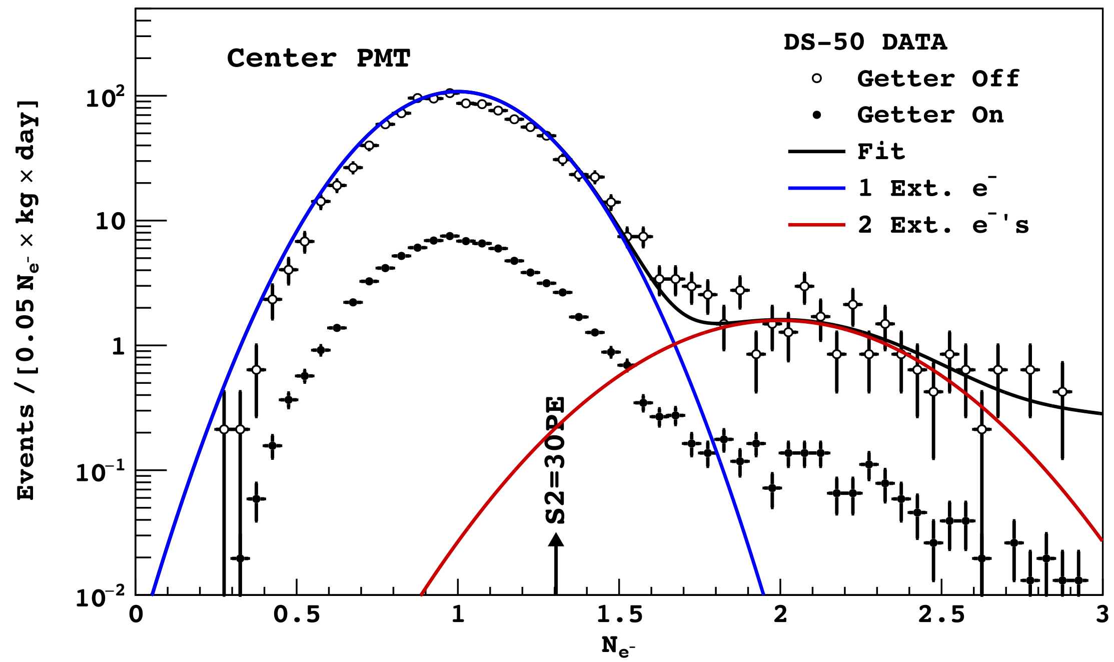
90% C.L. Exclusion limit



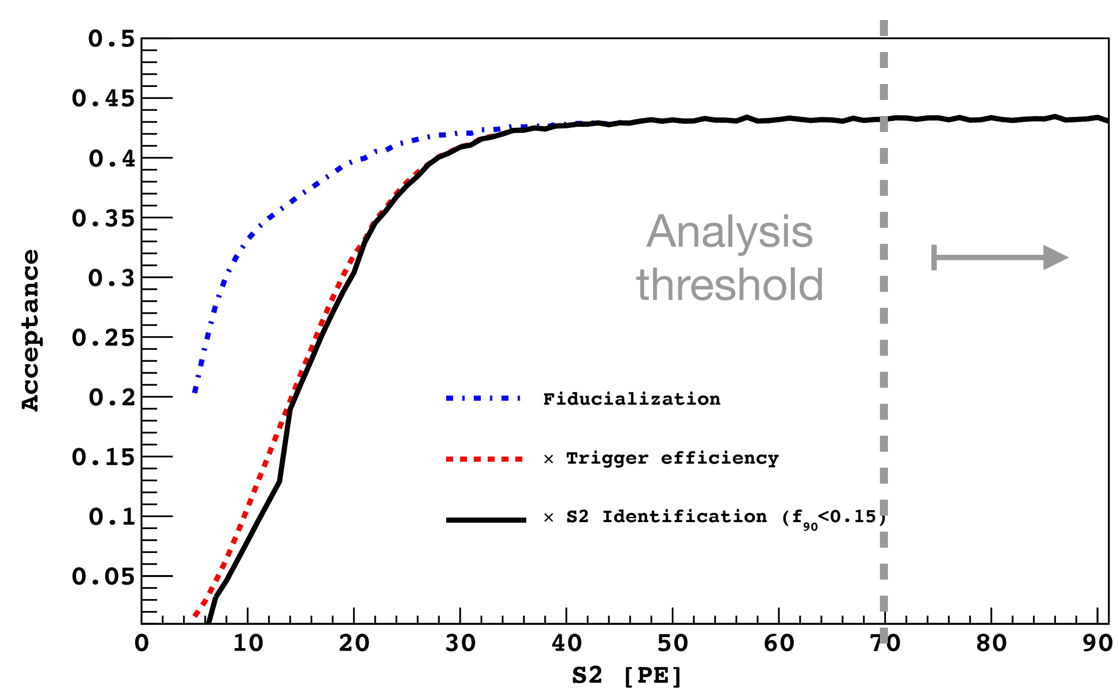
arXiv:1802.07198

Low mass χ search results

- Scintillation signal (S1): E_{th}~ 13keV_{nr} weak sensitive to low mass WIMP
- Ionization signal (S2): E_{th}<0.6keV_{nr} is sensible to low mass WIMP
- S2-only signal:
  - Sensitive to single extracted electron
  - No need of PSD
- Acceptance: estimated by data+MC (MC reproduces both spatial and temporal distribution of S2 as measured in electron diffusion - see arXiv:1802.01427)
- Fiducialization: no xy available, but use volume under inner 7 PMTs (position assigned using PMT receiving largest light)

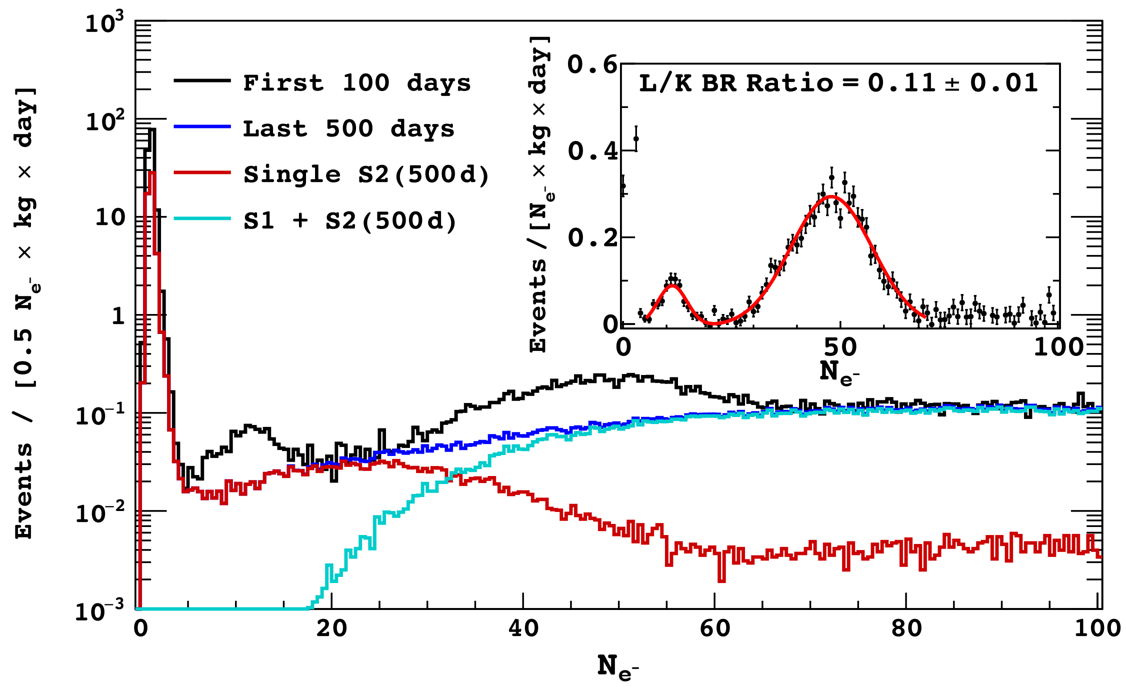


N_e=S2/**η** where **η**=(23±1)PE/e

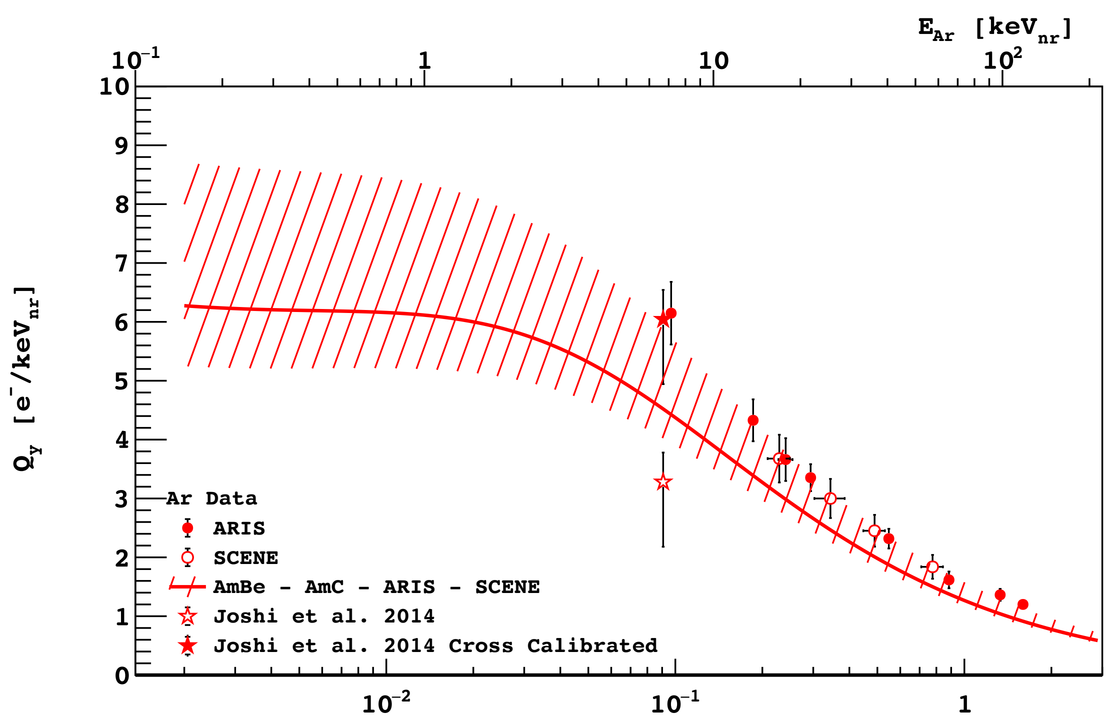


Energy scale for ER and NR

- ER energy scale: ^{37}Ar
  - Provides 2 X-rays at 0.27 and 2.82 keV
  - Decayed with $t_{½}$ =35d and no remain in the last 500d data set (compare **black** and **blue** spectra)

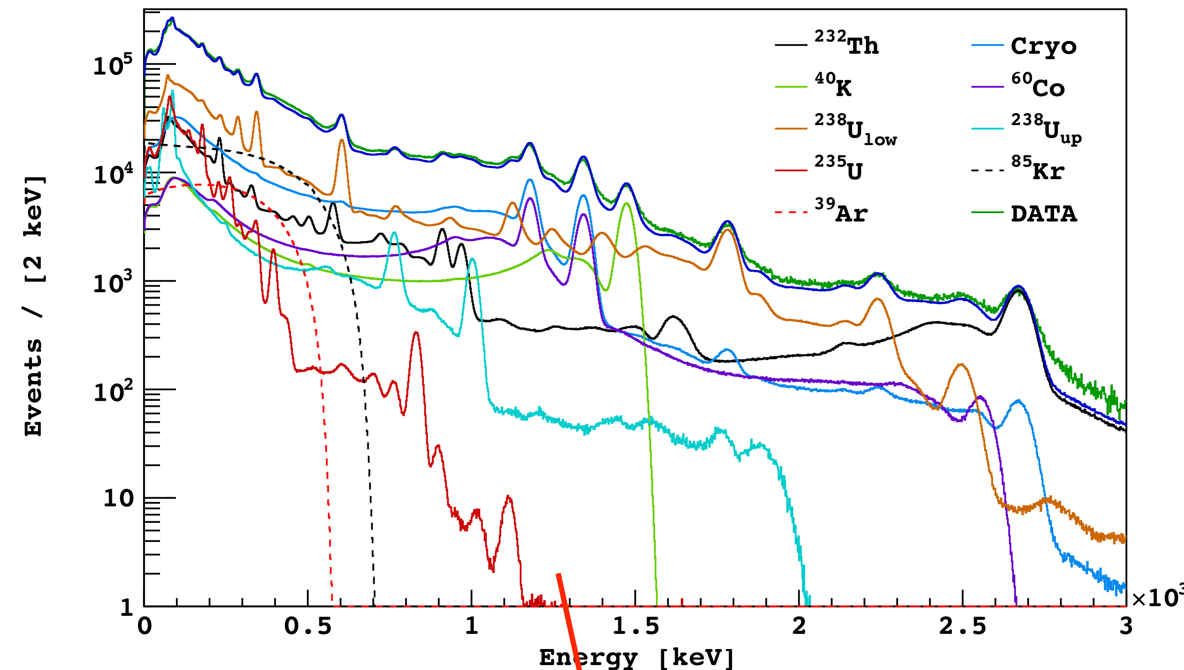


- NR energy scale: AmBe and AmC
  - Fit to get NR ionization yield at ROI
  - Difference with other measured points taken as systematic
  - Conservative assumption - measured points are higher than fit: less ionization → less e⁻ → less sensitivity

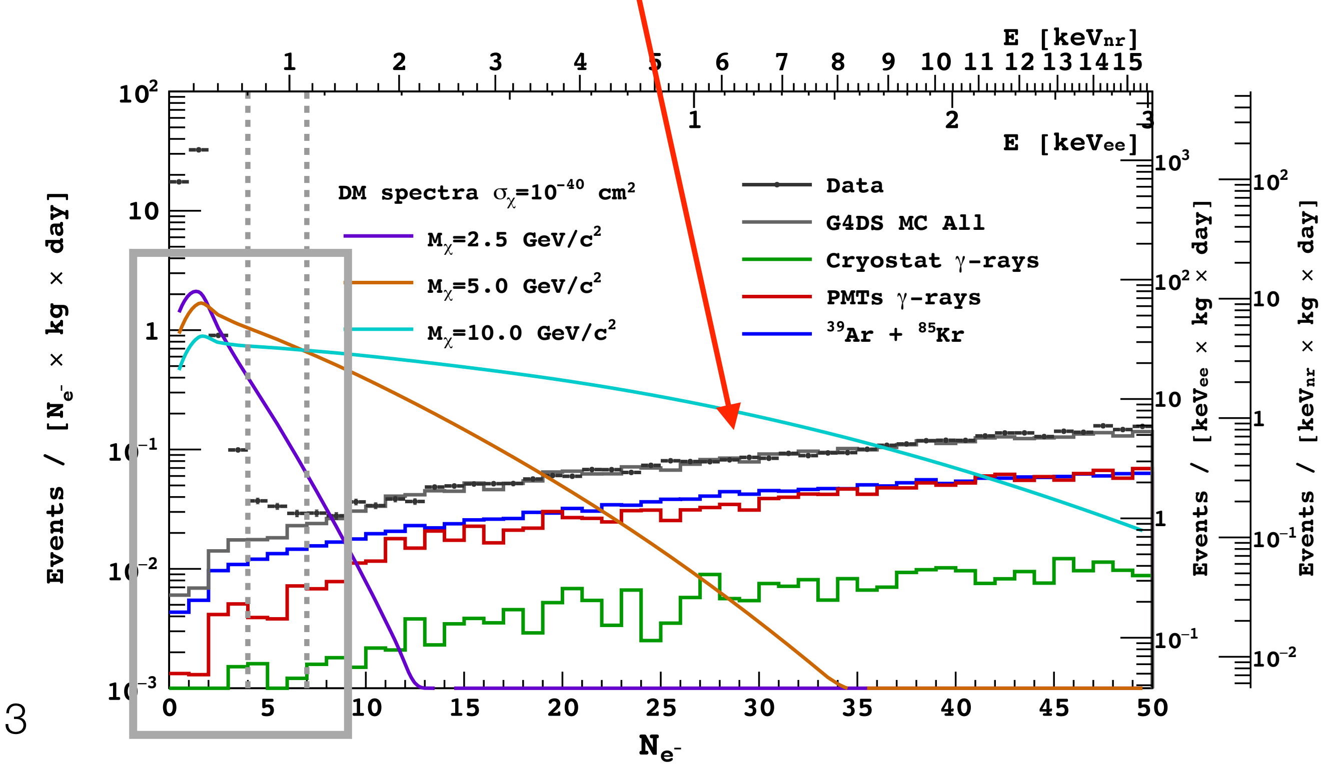


Background and χ signal

- Background: constrained in ROI fitting high energy part of the spectrum
  - At low energy, excess of events it is not understood: we are gonna measure it!
- WIMP recoil energy spectra modeled using
  - Ionization, energy quenching and detector response



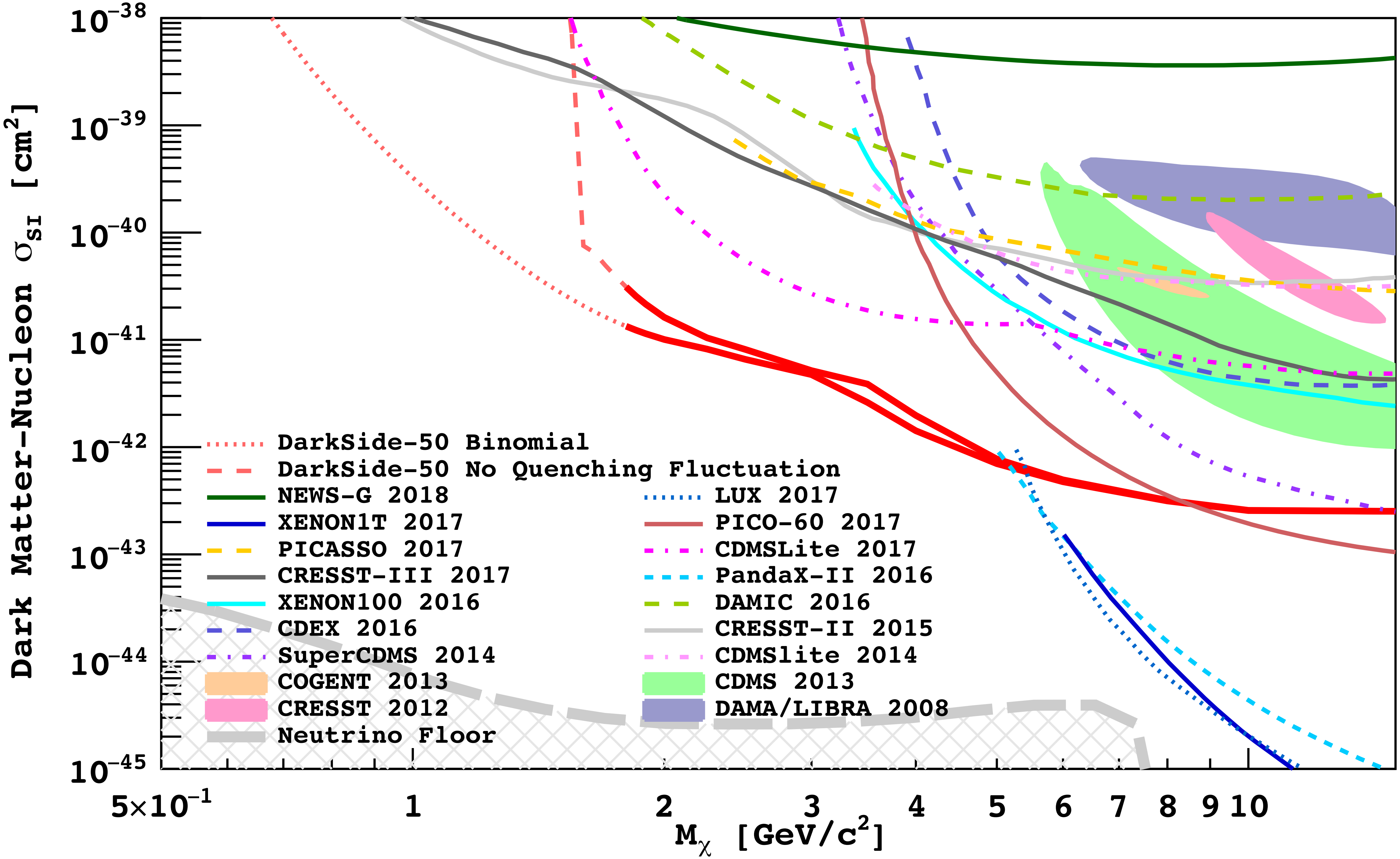
Extrapolation at low energy is ok within few %



Profile likelihood method

- Upper limit σ_{SI} extracted observed N_e spectrum using binned profile likelihood (PL) method
- Two signal regions (N_e^{th} of 4 and 7e^-) which covers M_χ in the range [1.8,10] GeV/c^2
- PL includes uncertainties both on WIMP signals (NR ionization, single electron yield) and background spectrum (rates, ER ionization yield)
- Average ionization yield dominates uncertainties. Use two fluctuation models due to lack of knowledge about fluctuation at low recoil energy: no fluctuation and binomial

90% C.L. Exclusion limit

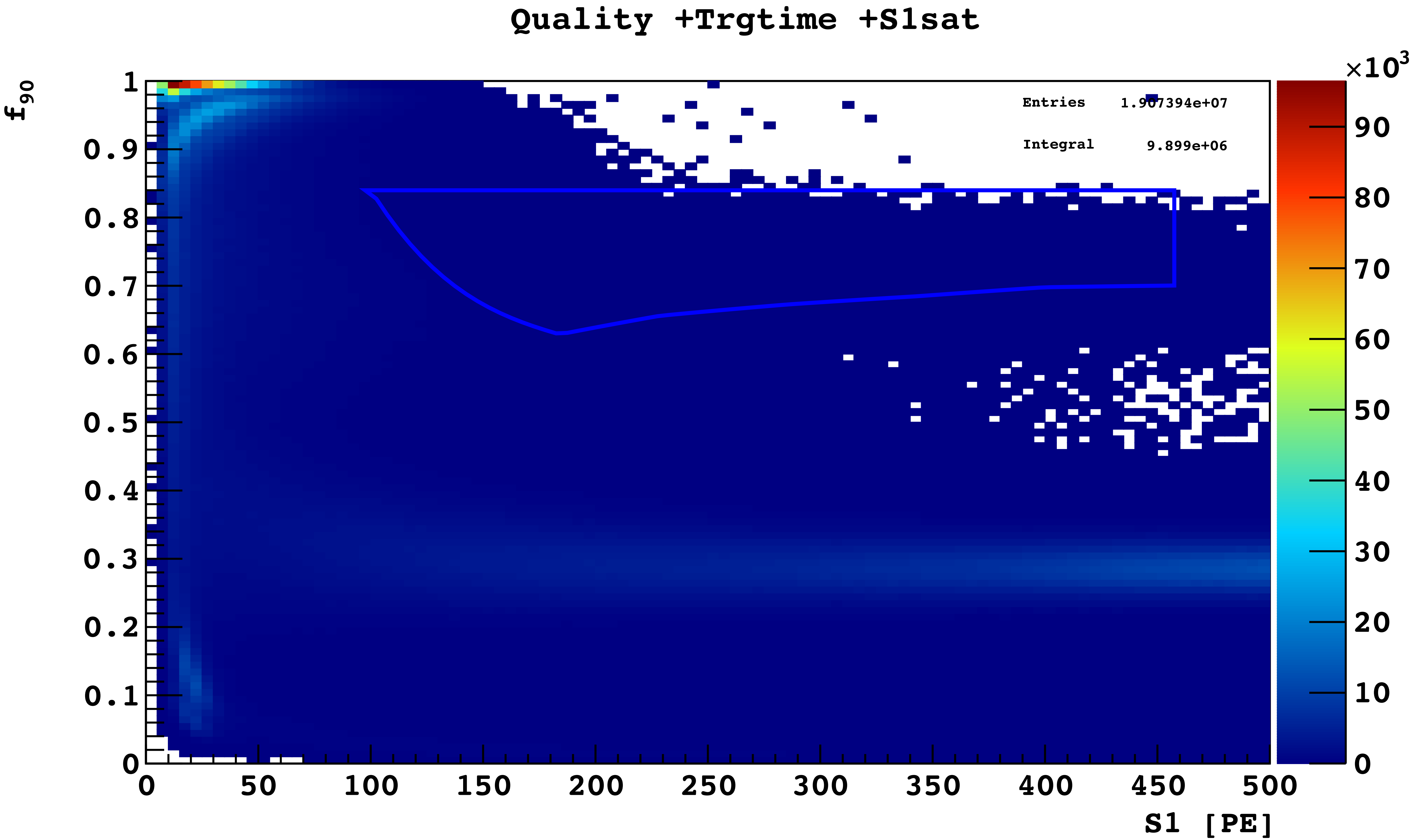


arXiv:1802.06994

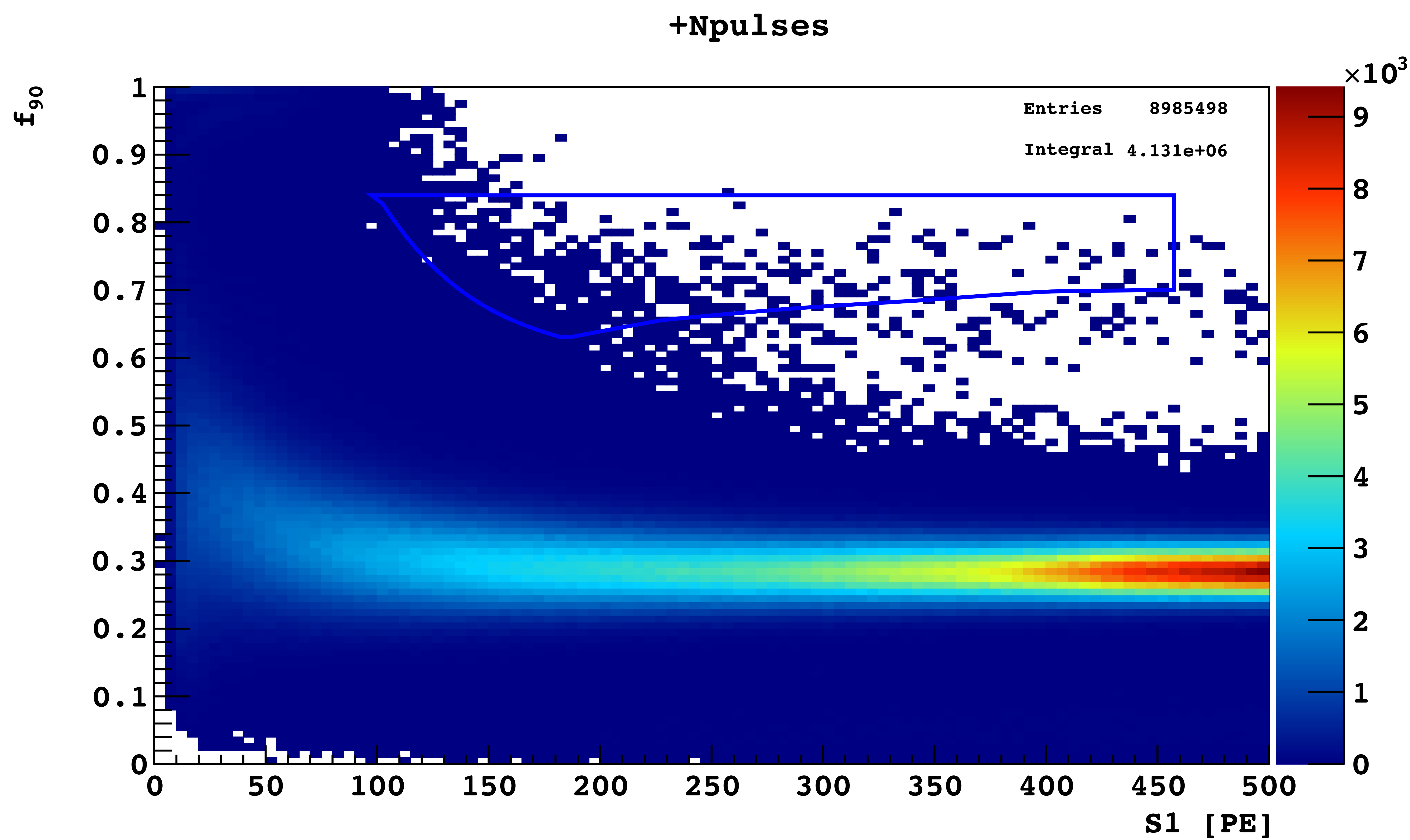
Summary and conclusions

- Successfully carried out blind analysis of 534 live-days improving our sensibility for WIMP at high mass
- Liquid argon is a sensitive media also for low mass WIMP too
- Solid foundations for next generation experiment DarkSide-20k: stay tuned!

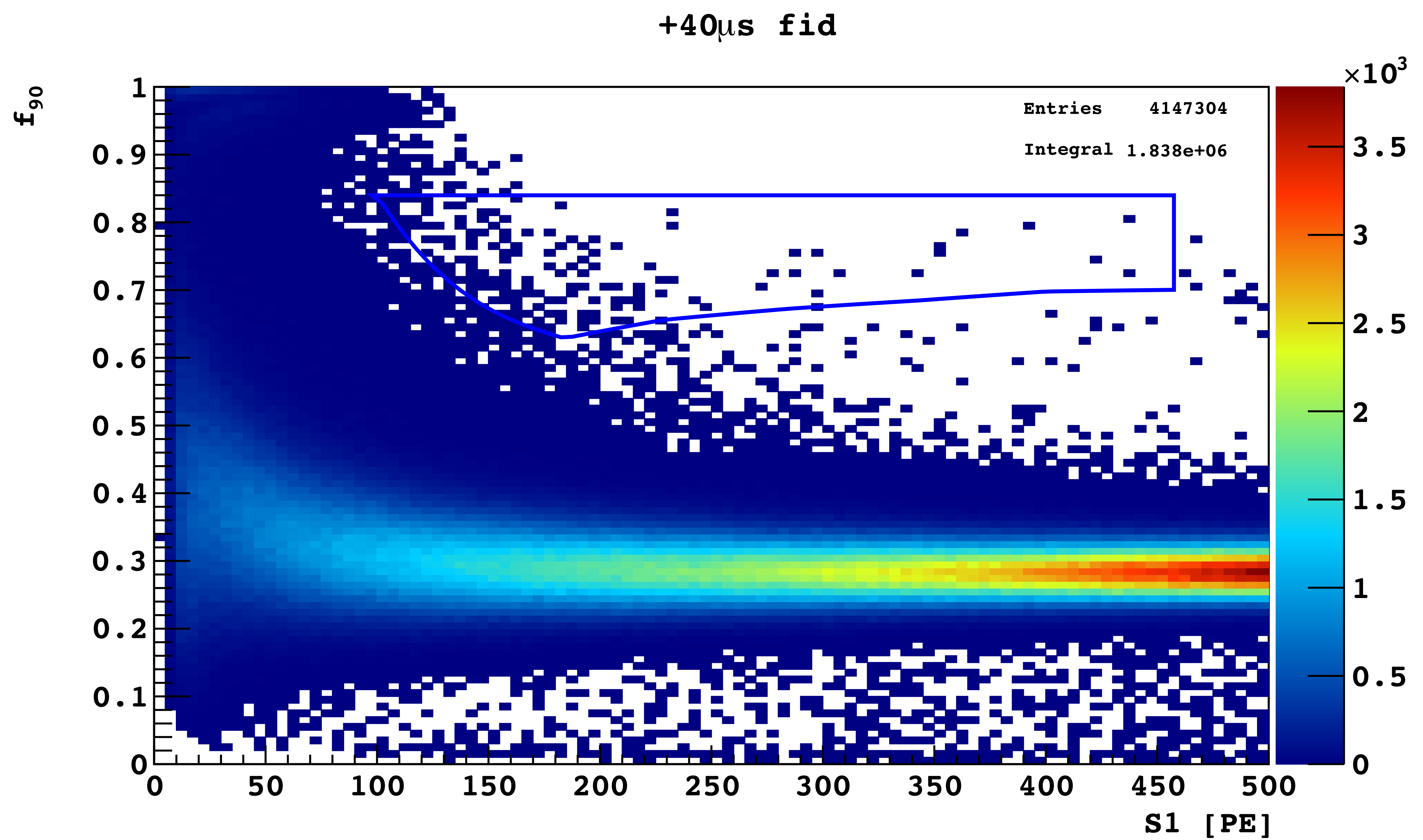
Backups



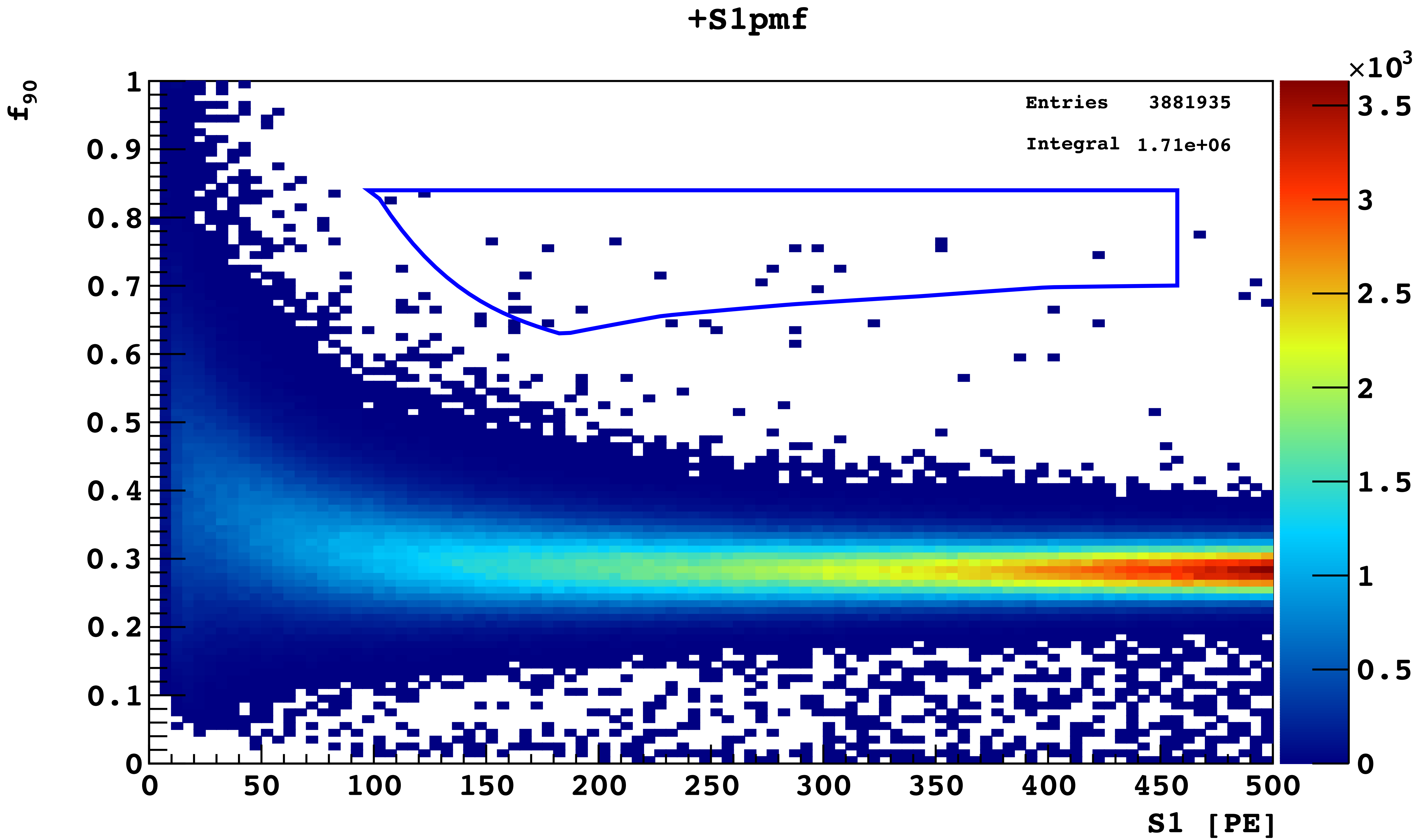
- Trigtime: the first pulse is within expected trigger time window
- S1sat: S1 pulse is not saturated



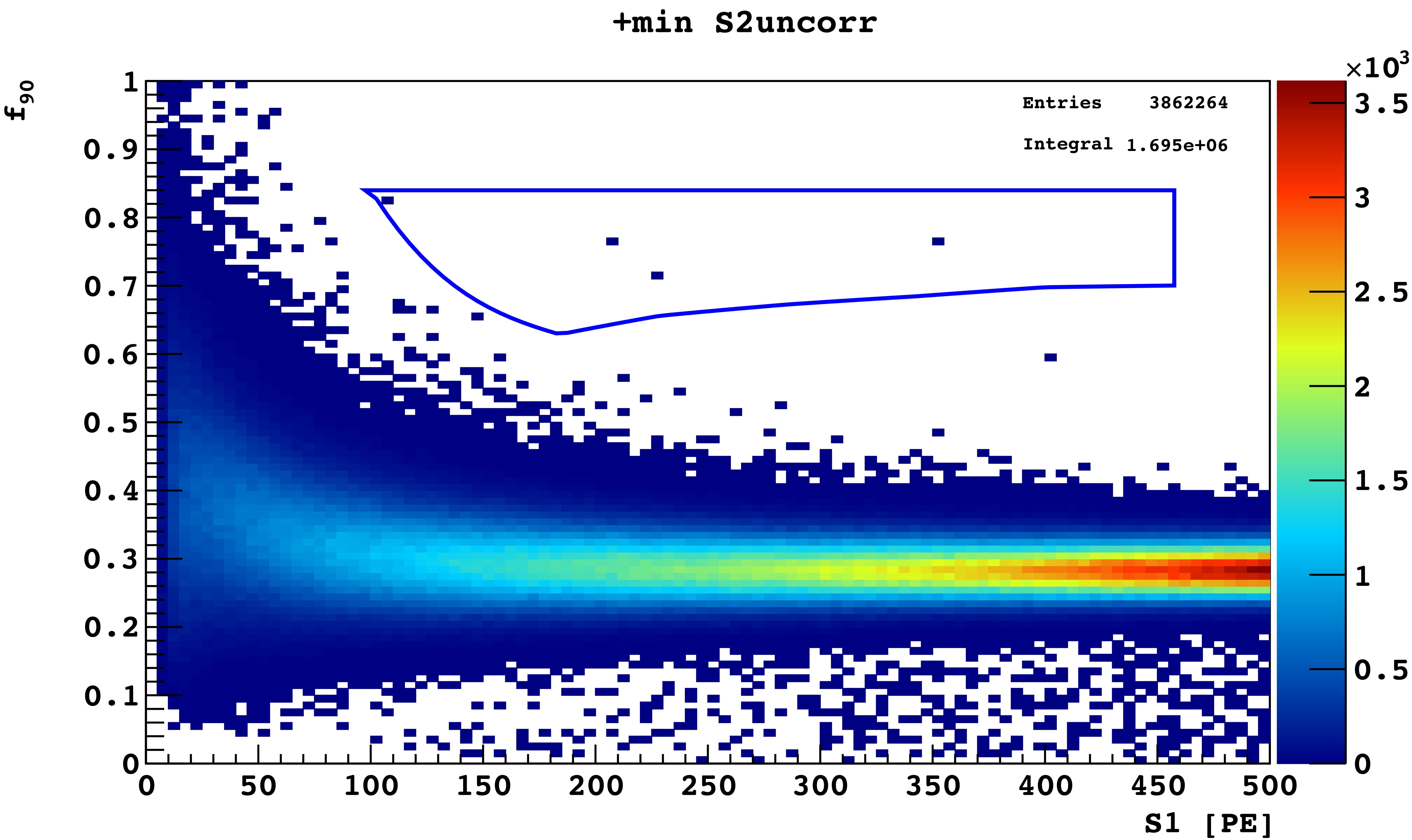
- Npulses: number of pulse is 2 or 3 if there is S3 (echo of S2)
- Most of surface events are gone



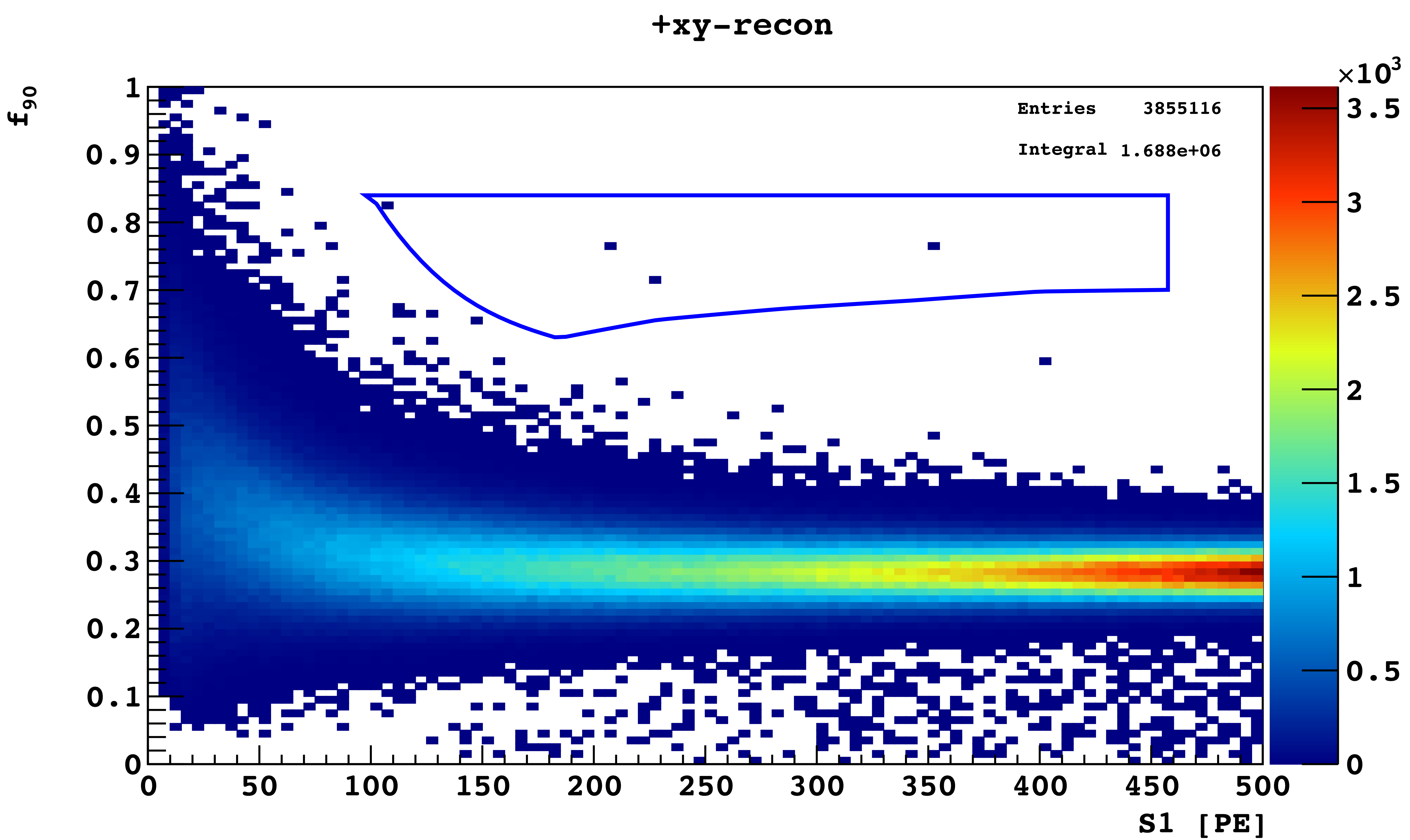
- 40μs fid: remove 40μs from top and bottom in t_drift
- Lots of ɣs from PMTs, unresolved S1+S2 events, and surface close to top are removed



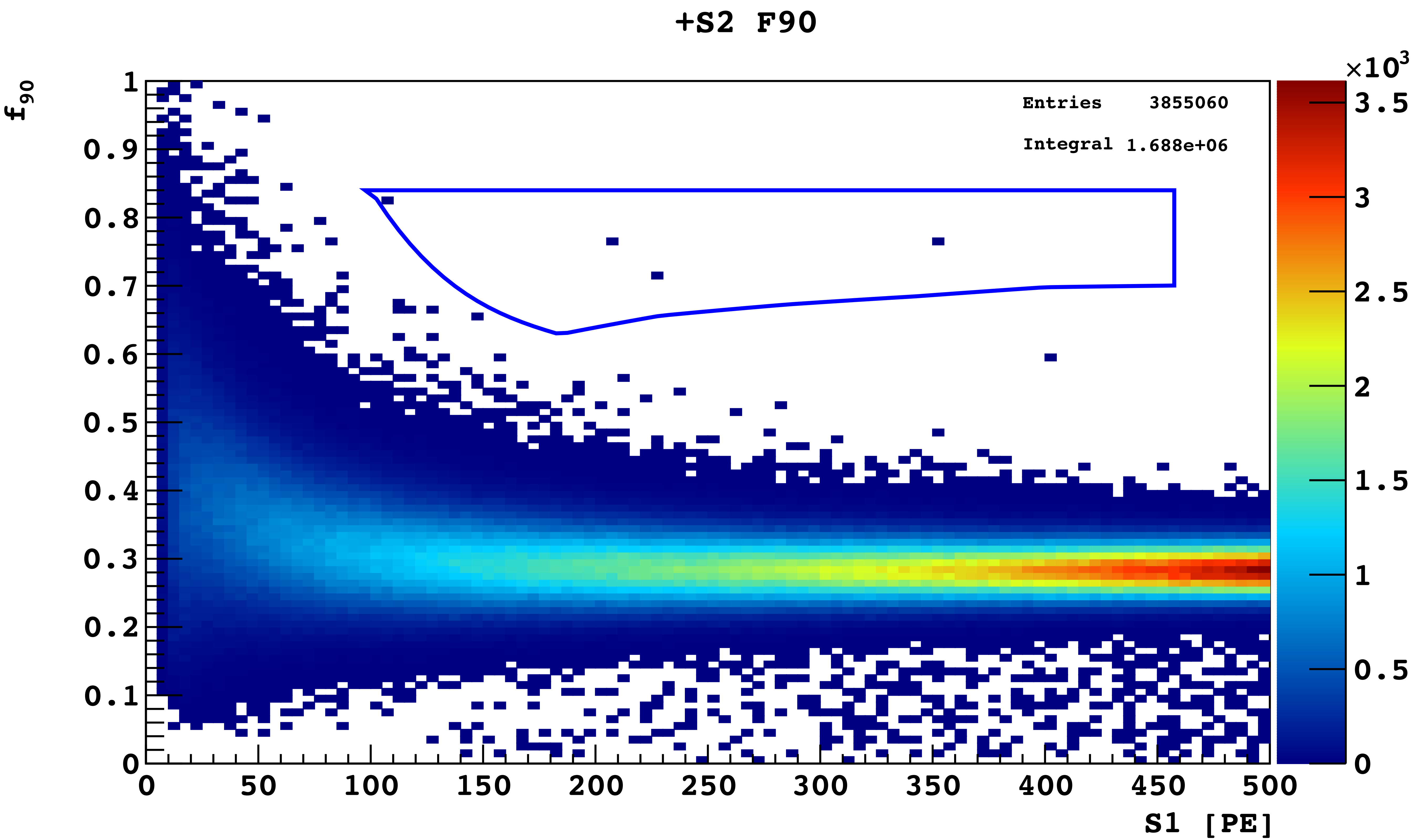
- S1pmf: fraction of prompt light in the maximum PMT is less than a threshold, which is a function of t_drift and S1
- Remove S1+Cherenkov events from fused silica windows



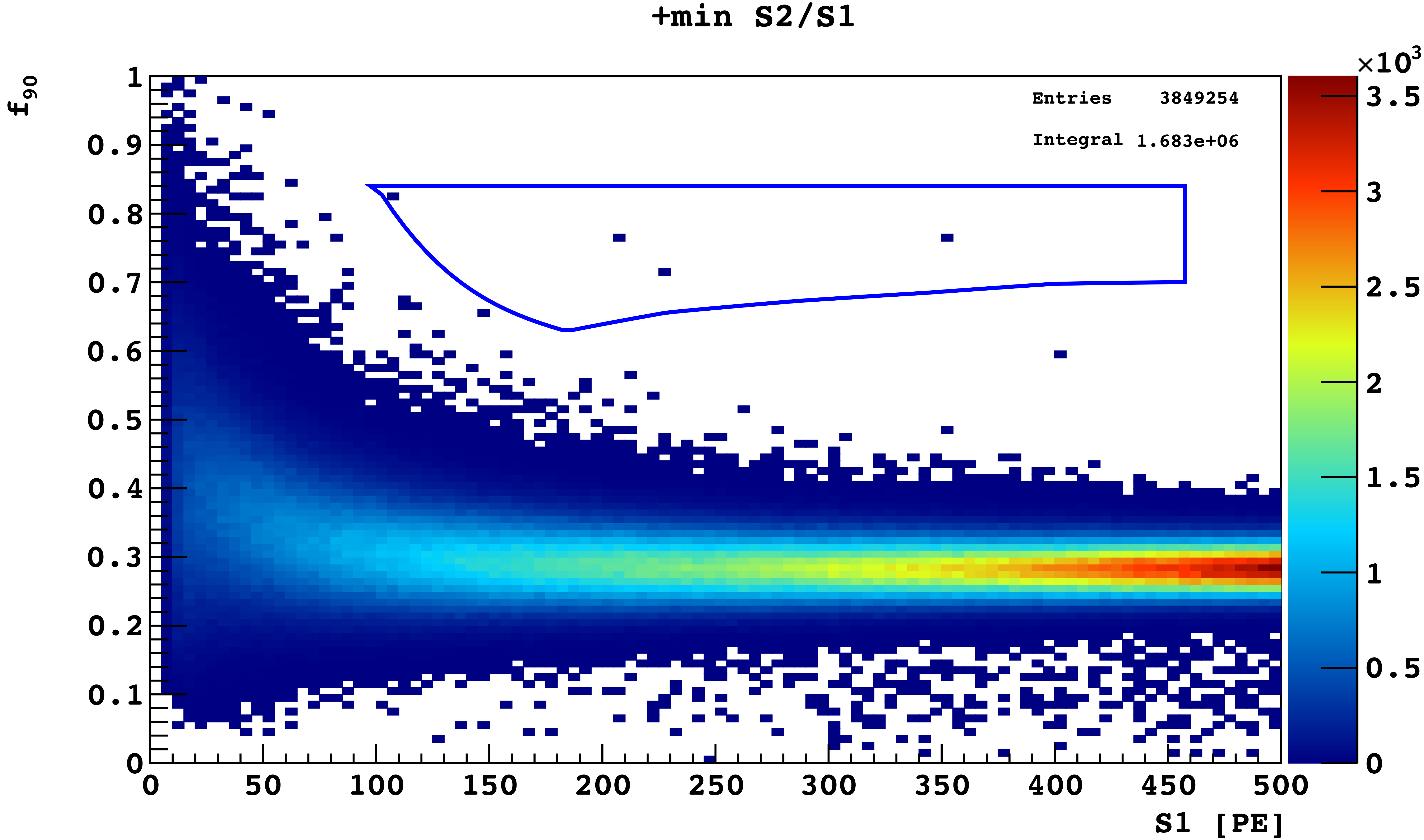
- min S2uncorr: S2≥200 PE
- This is more like quality cut, but remove surface events, which number of electrons are reduced by the surface effect



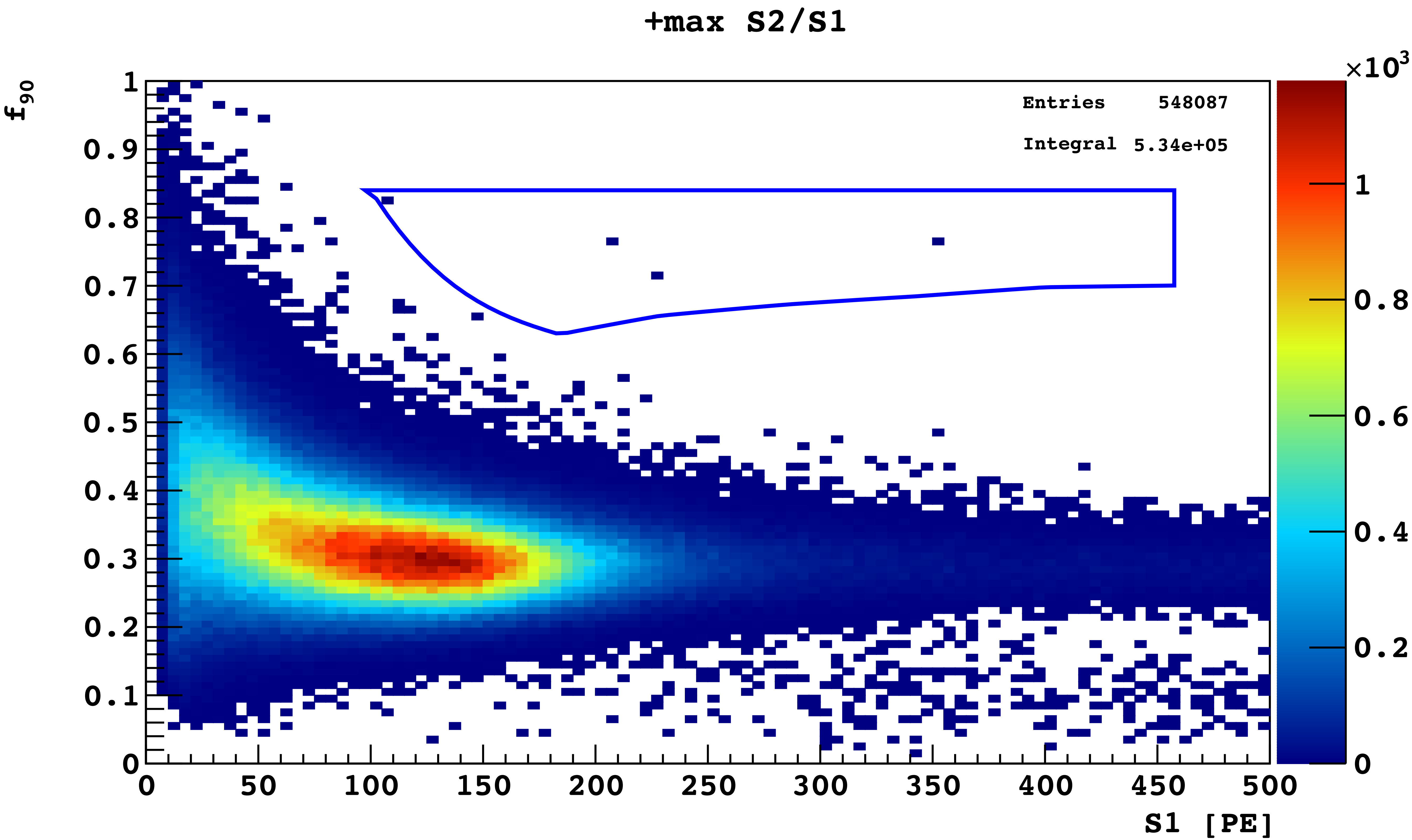
- xy-recon: reasonable x-y reconstructed values



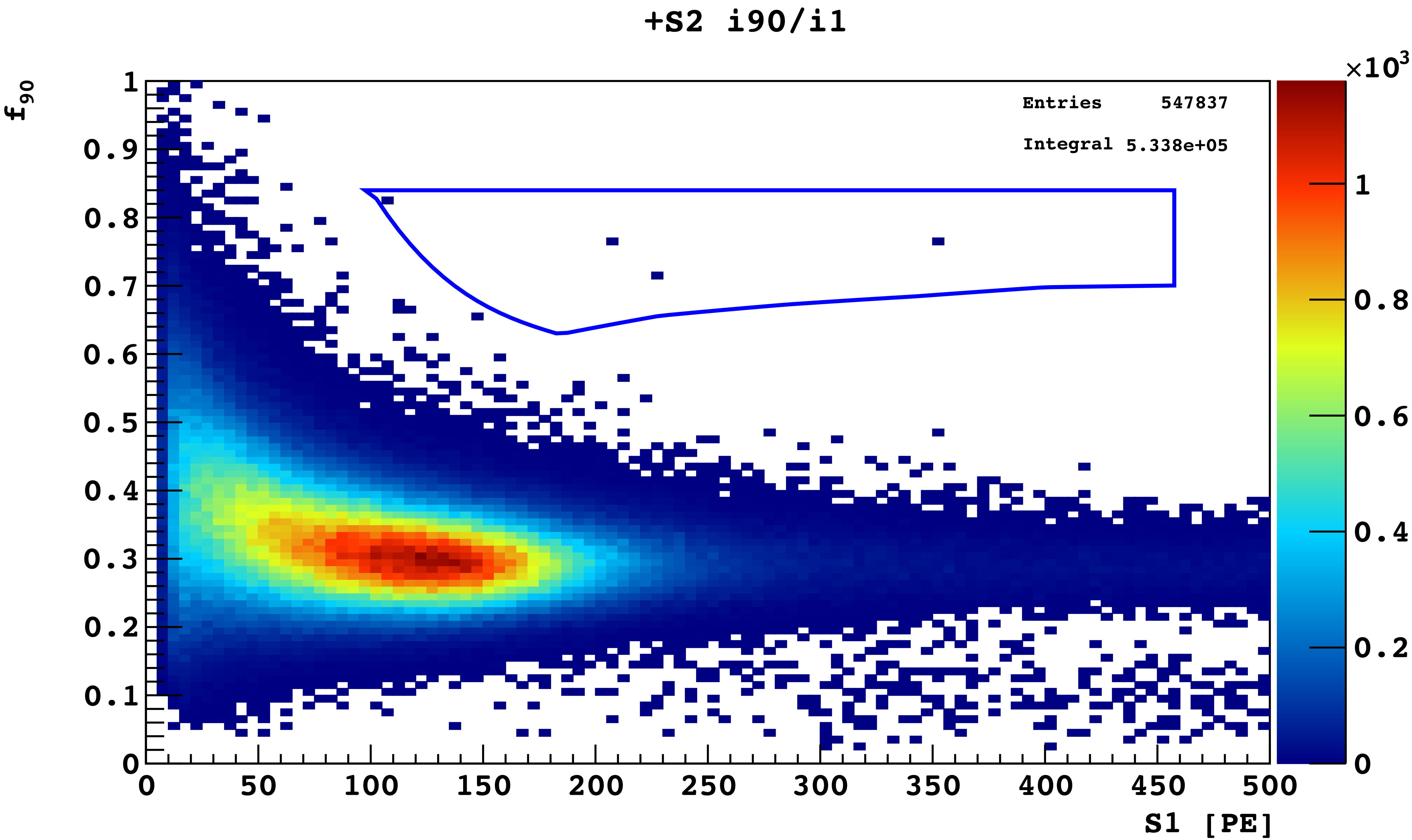
- S2 f90: f90 of S2 pulse <0.20
- Remove S1+S1 pileup events



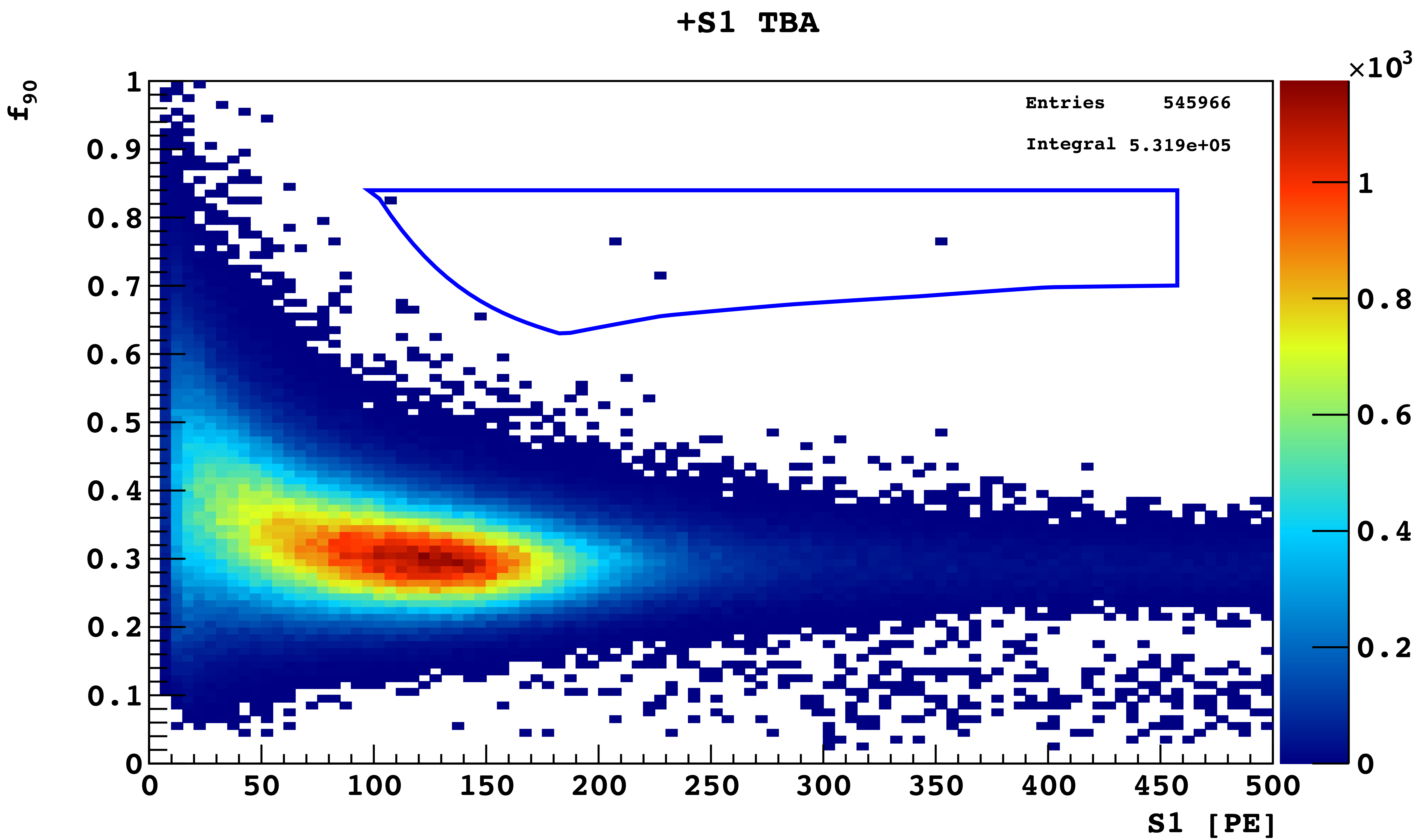
- min S2/S1: S2/S1 need to be above threshold, which is a function of S1
- Remove strangely small S2 events, like surface events



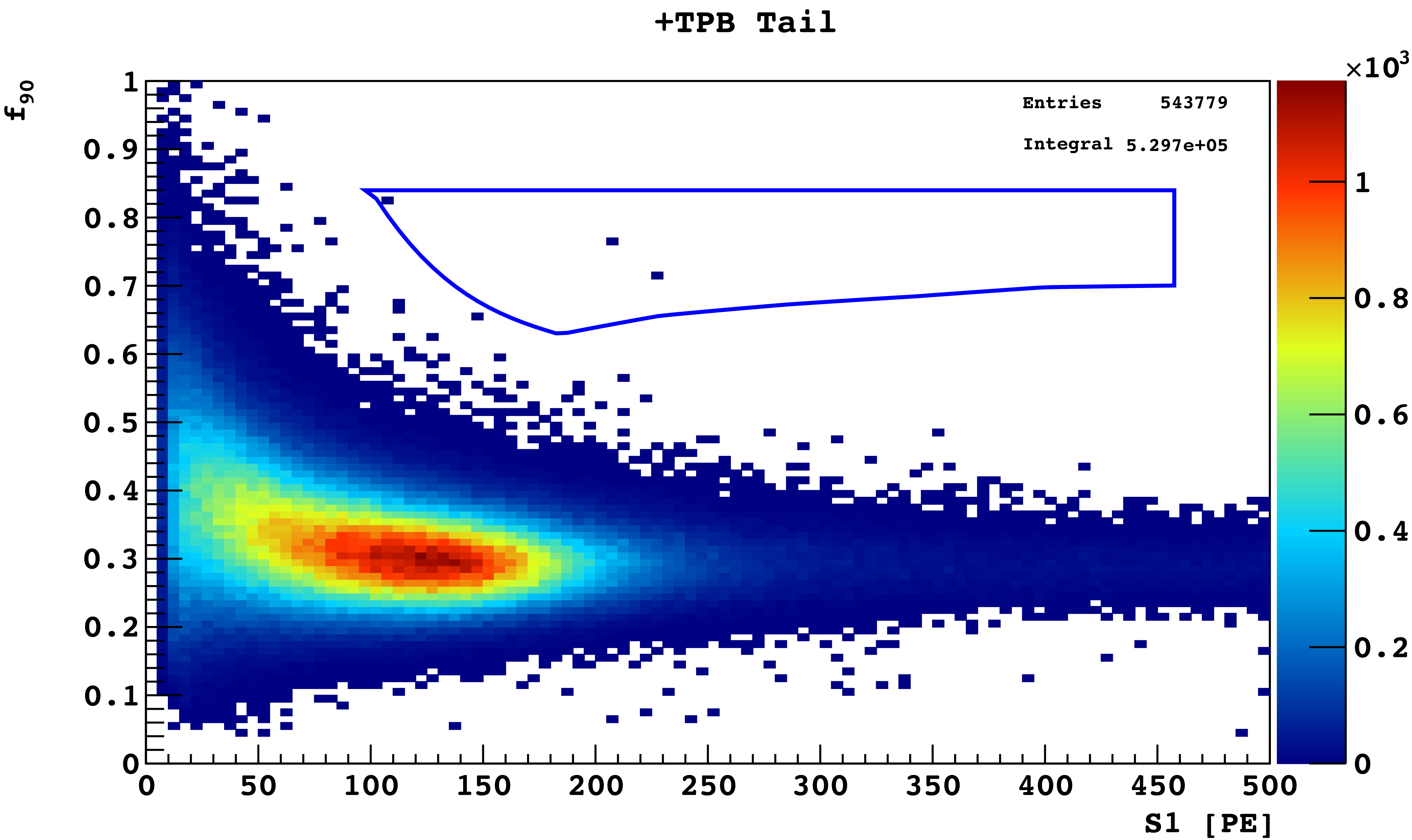
- max S2/S1: S2/S1 need to be below threshold, which is a function of S1
- Remove strangely large S2 events, which we don't expect, but applied as a safety net



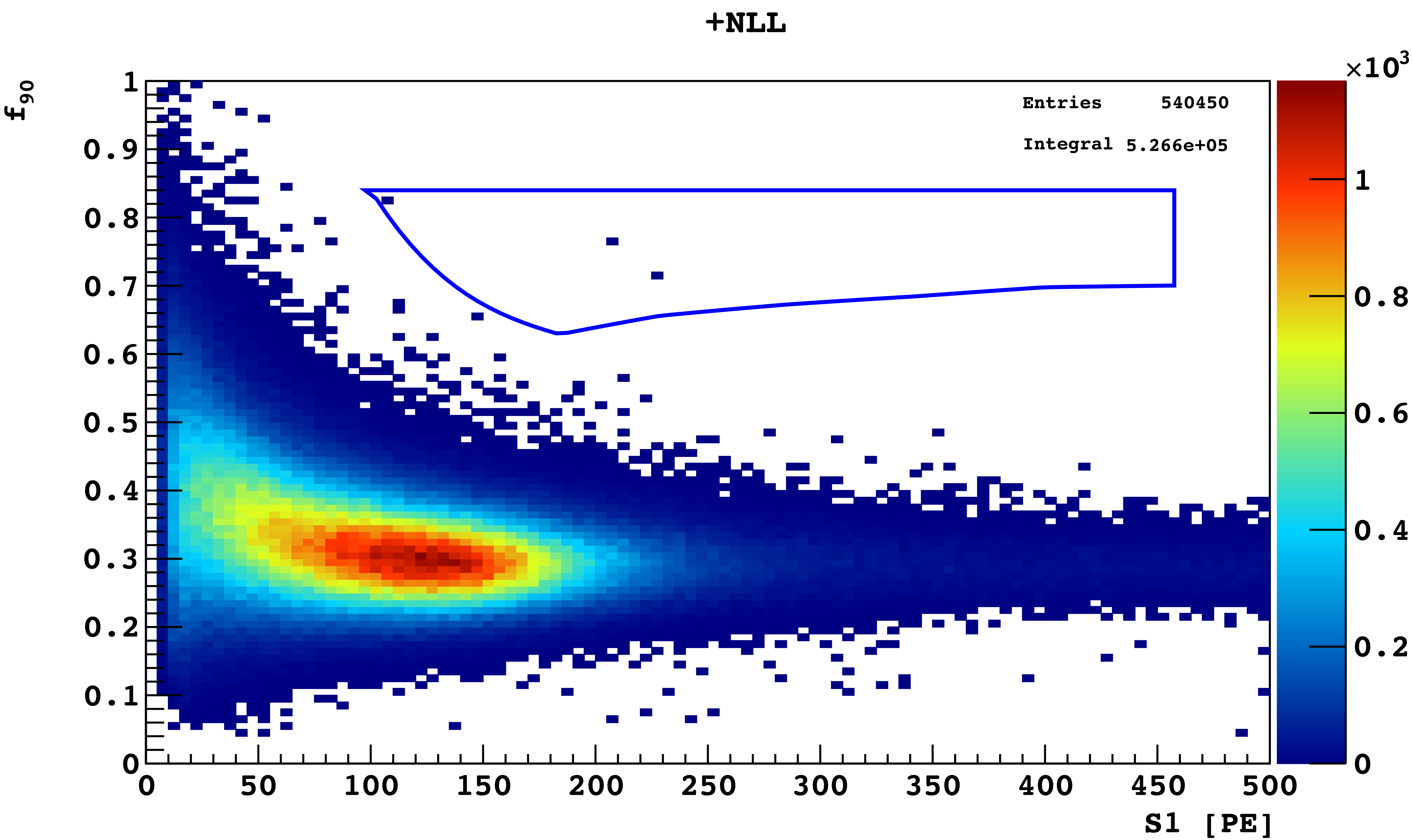
- S2 i90/i1: S2 have reasonable rise time
- Remove events in which S2 is actually S1+S2 pulses



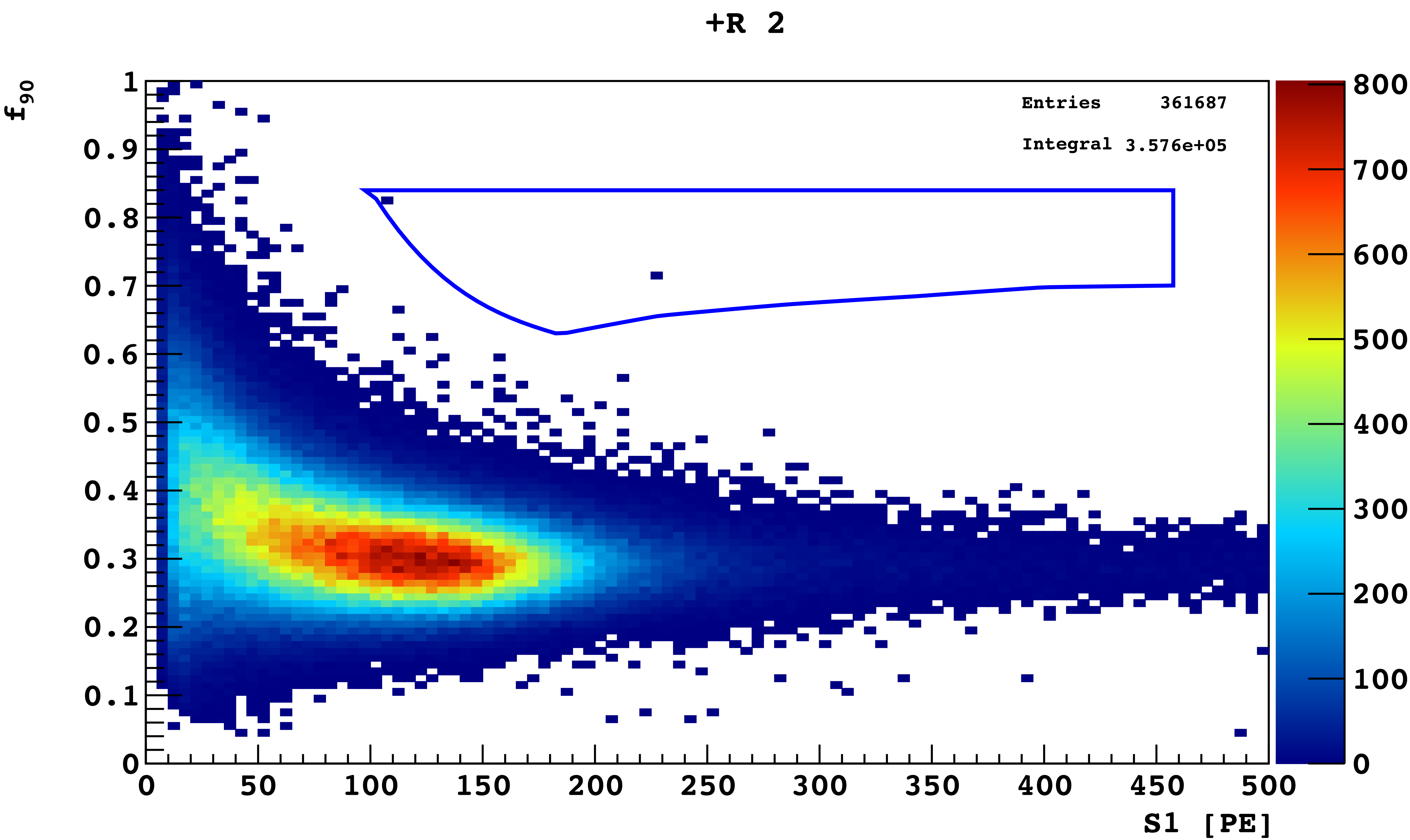
- S1 TBA: z-position from S1 Top-Bottom Asymmetry agrees with t_drift
- Remove random pileup S1 and S2



- TPB Tail: remove events, which have long tail of scintillation caused by TPB scintillation
- Remove surface events, in which α goes through TPB layer

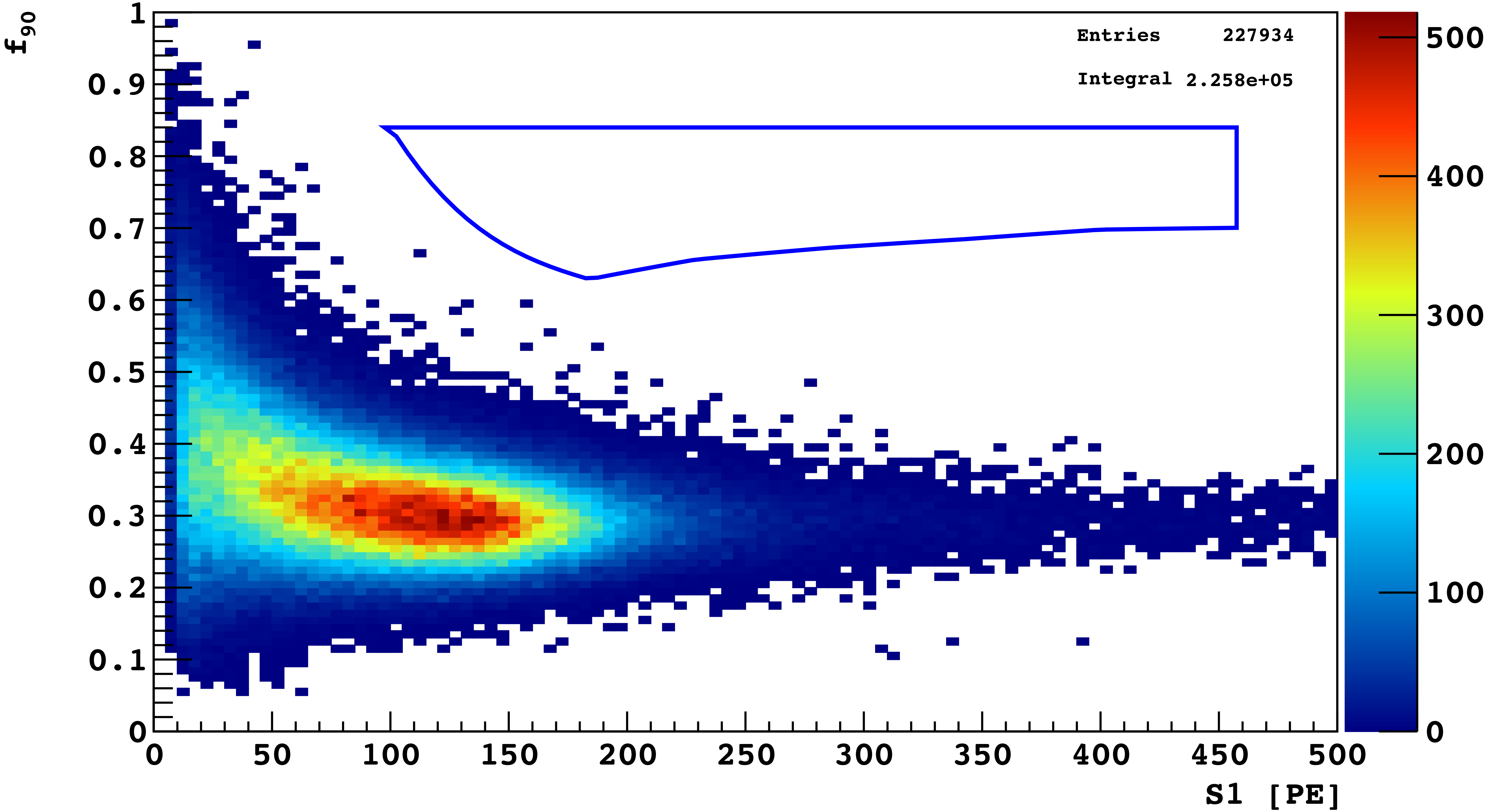


- NLL: Negative Log Likelihood cut, which compare event position from S1 light distribution among PMTs and event position from t_drift and S2 x-y
- Remove S1 + Cherenkov events which deposit energy in separate locations



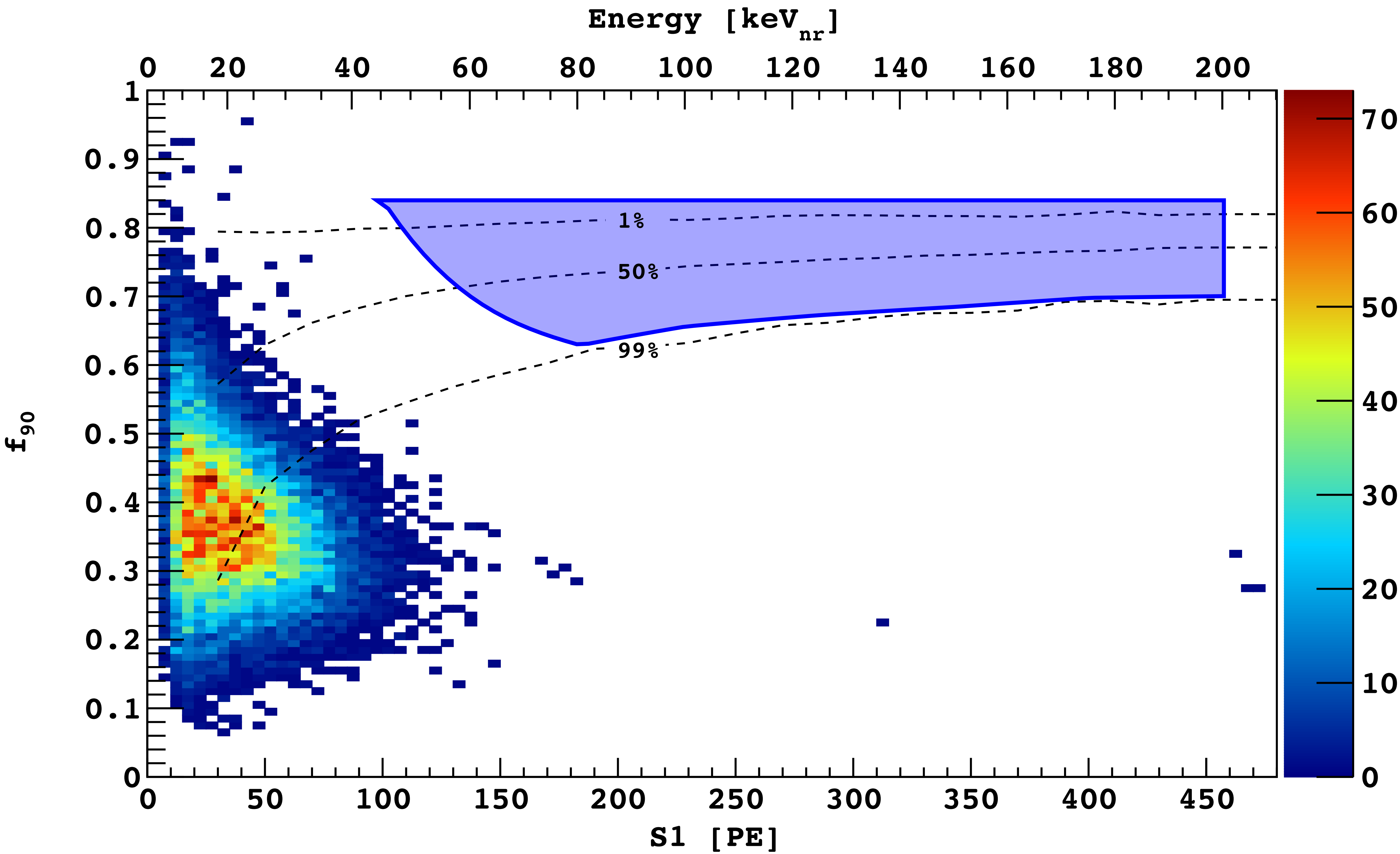
- R 2: Radial cut as a function of t_drift

+Veto

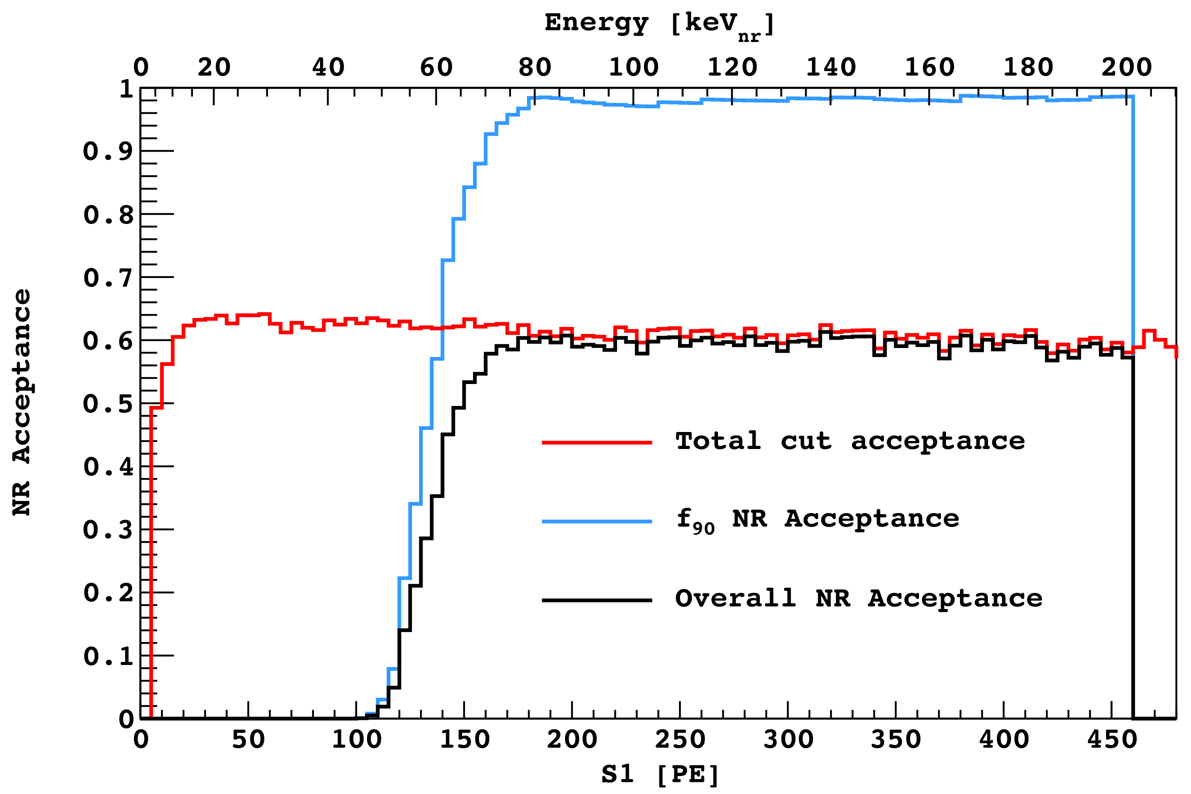


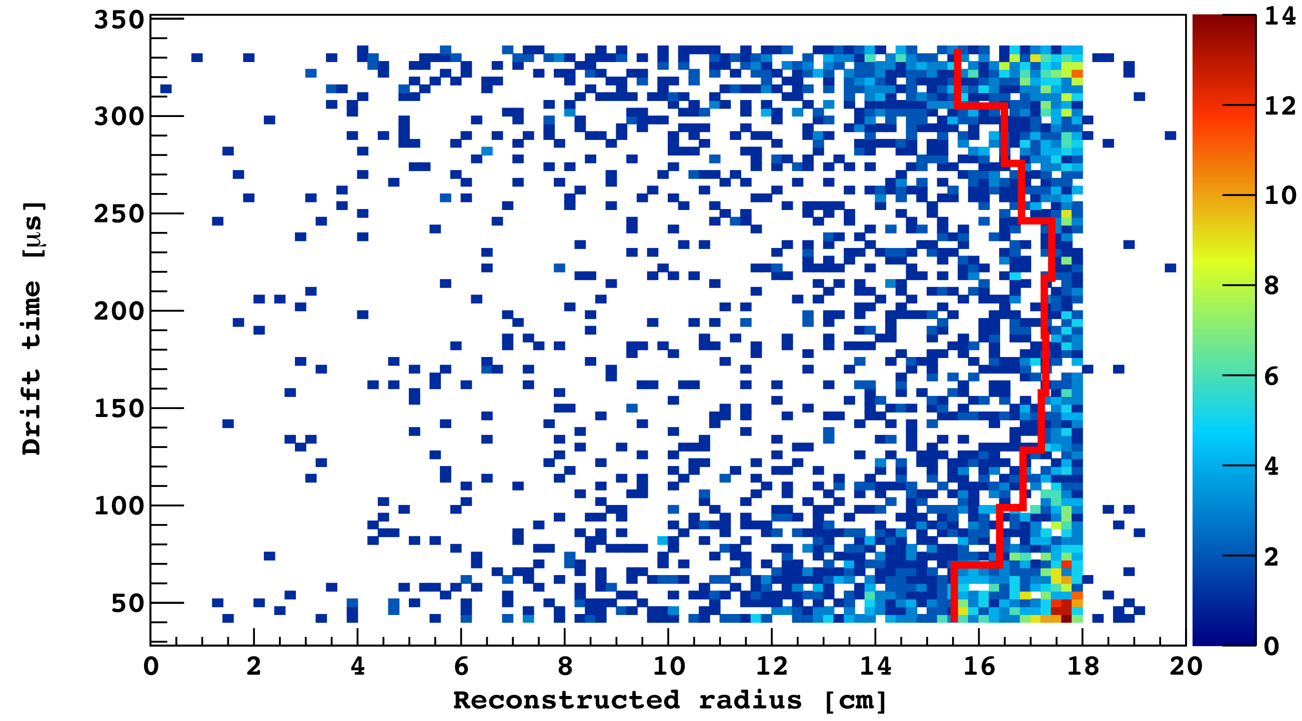
- Veto: all veto cuts
- Remove neutrons

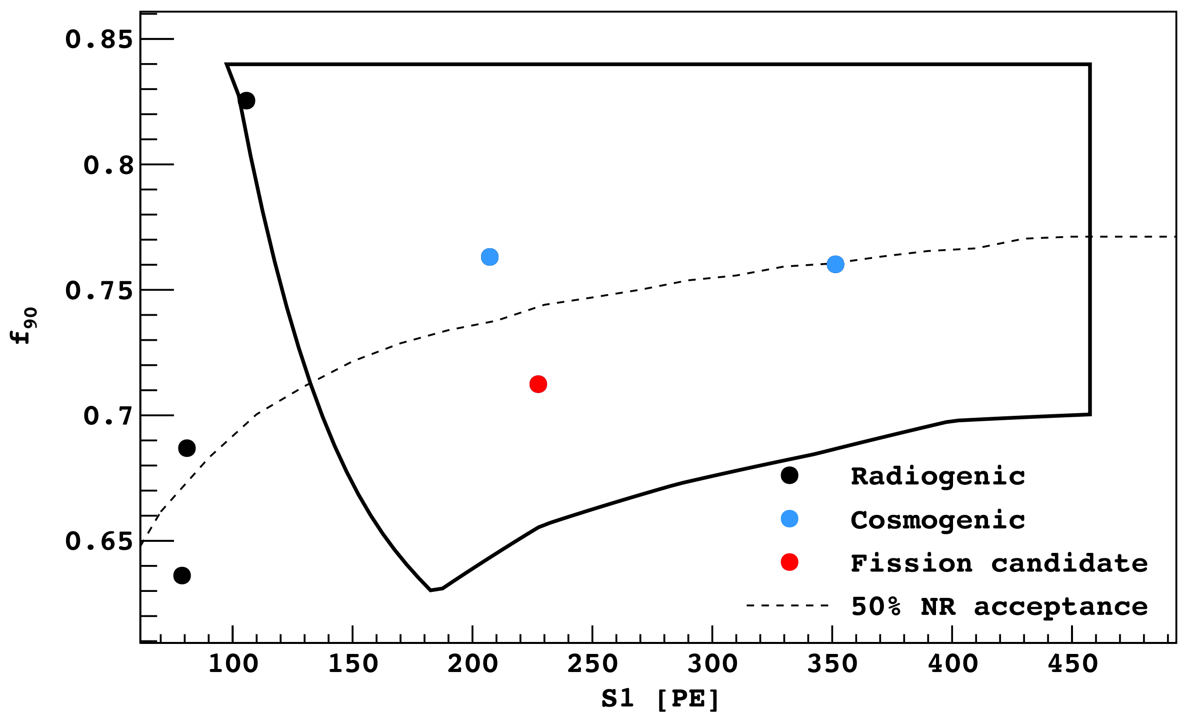
Additional rejection S2/S1

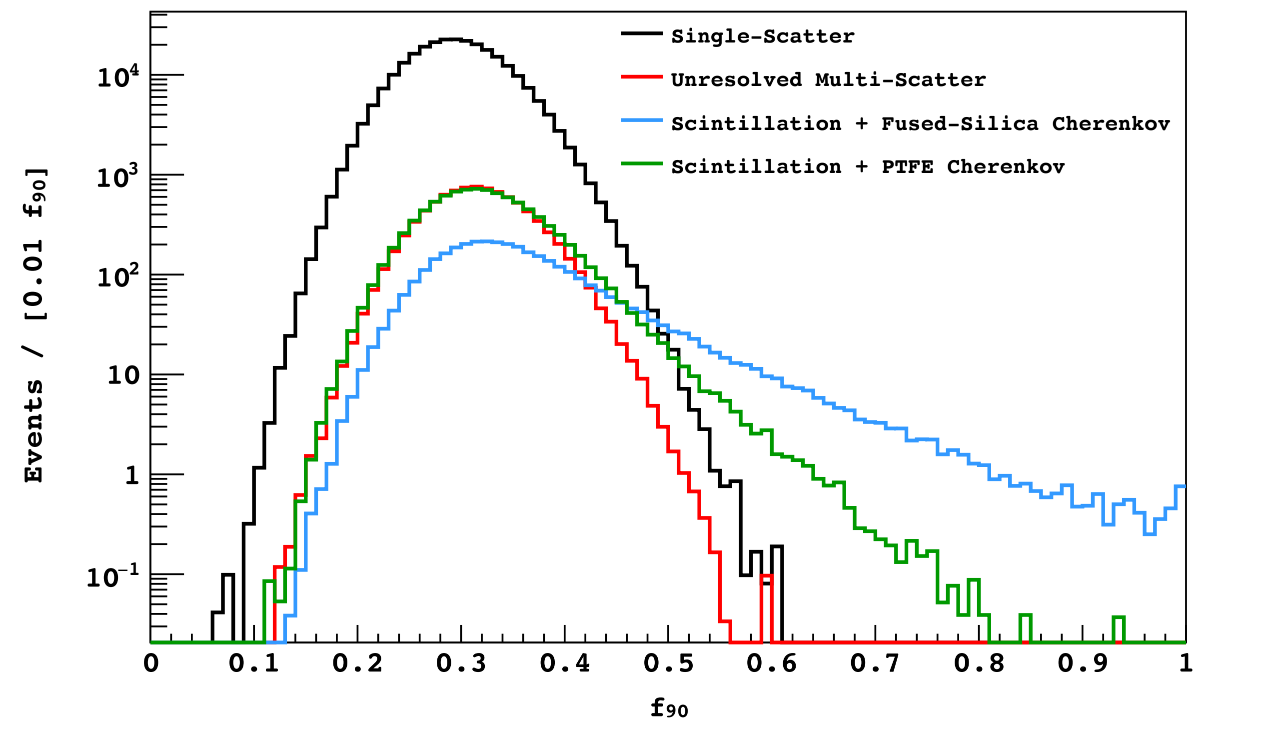


arXiv:1802.07198









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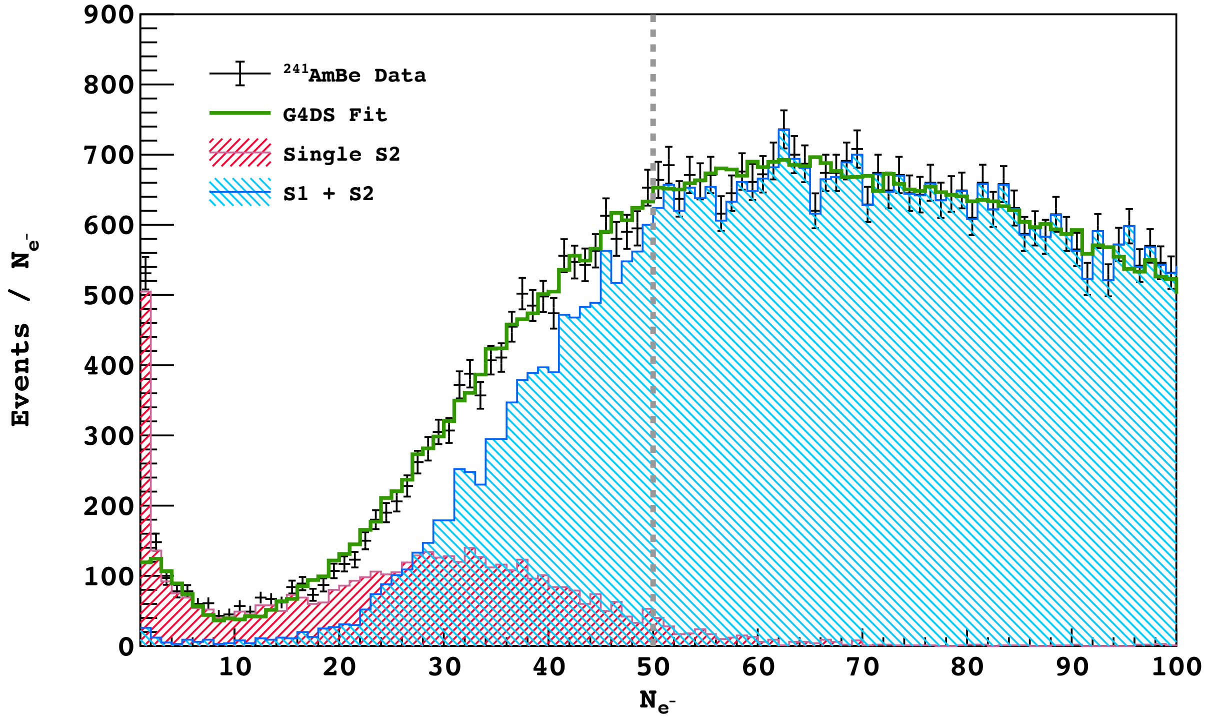
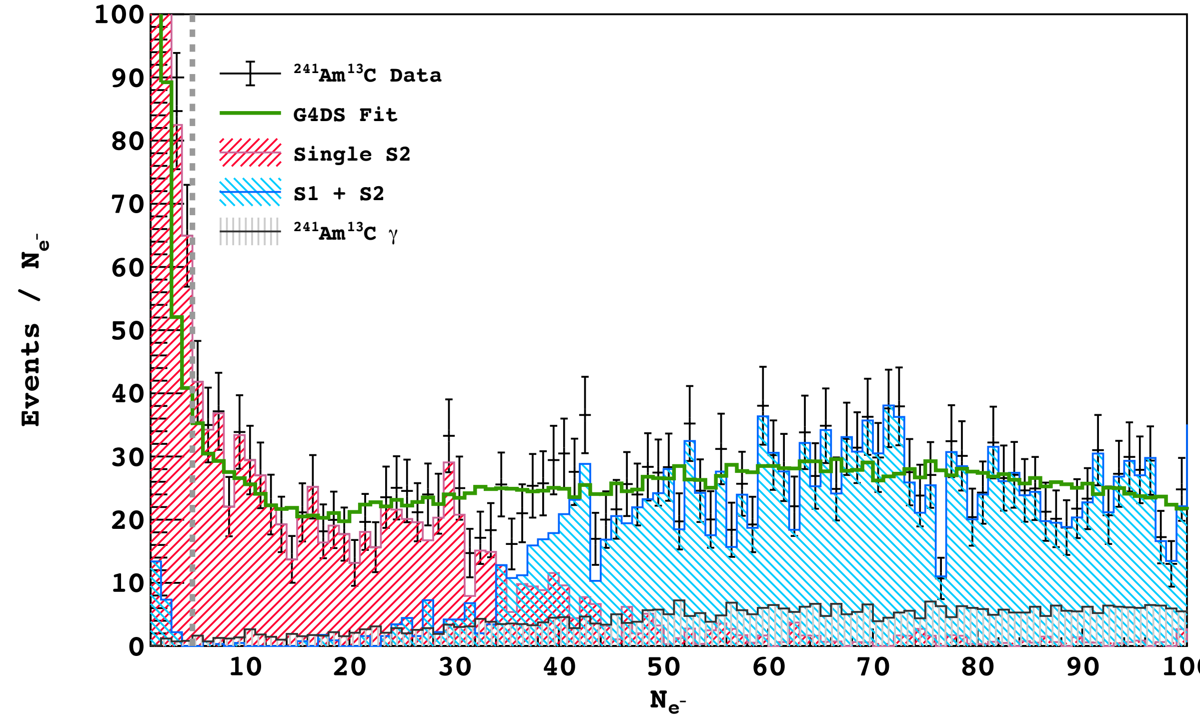
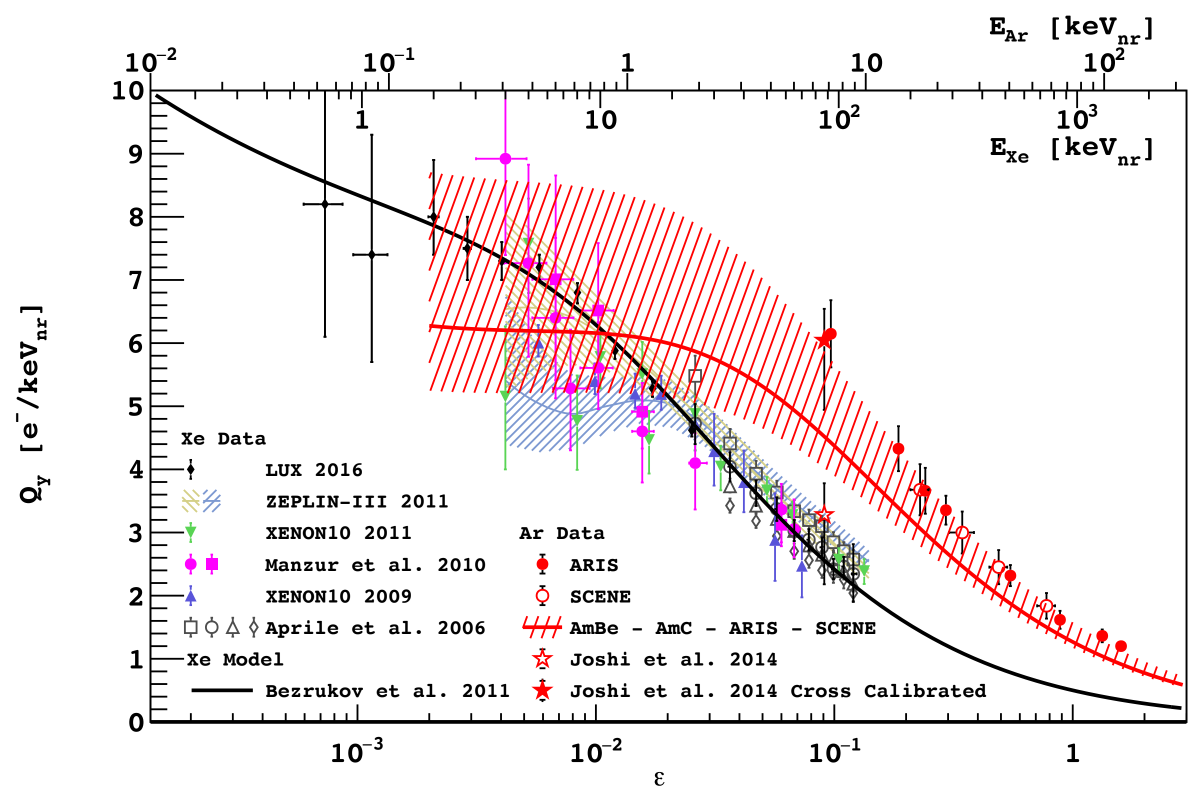




- MC+Ionization model (Ref. [Astropart.Phys.35]) fit to NR data from AmBe and AmC.
- The systematic discrepancy between the extracted and measured ionization yields is taken as systematic uncertainty
- Measured points are higher than MC+Ionization model: conservativa assumption
  - Less ionization → less e → less sensitivity



[arXiv:1802.06994]