Model the response: from energy deposit to S1 and S2

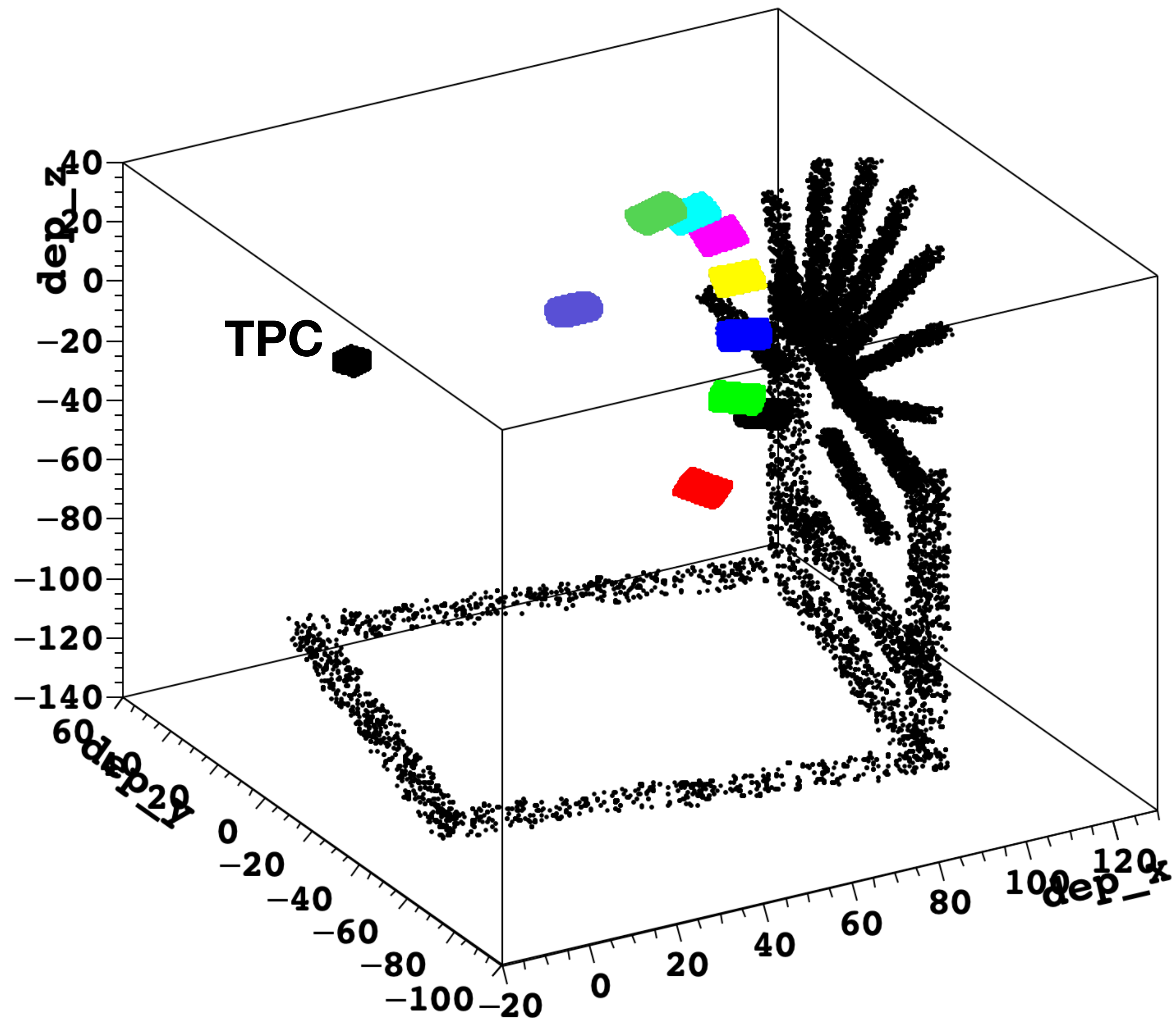
A toyMC is not enough (need to consider effects of beam width, TPC size, multiple scatters, accidental coincidence.

Start from an actual simulation (3E8 neutrons? in a 3 deg cone). CHECK beam-time conversion

Selection based on TOF:
35 ns < TPC time < 41 ns &&
20 ns < ND time - TPC time < 26 ns

Determine energy deposited in the TPC for TPC-ND coincidence events. *Neglect coincidence with Si for the moment*.

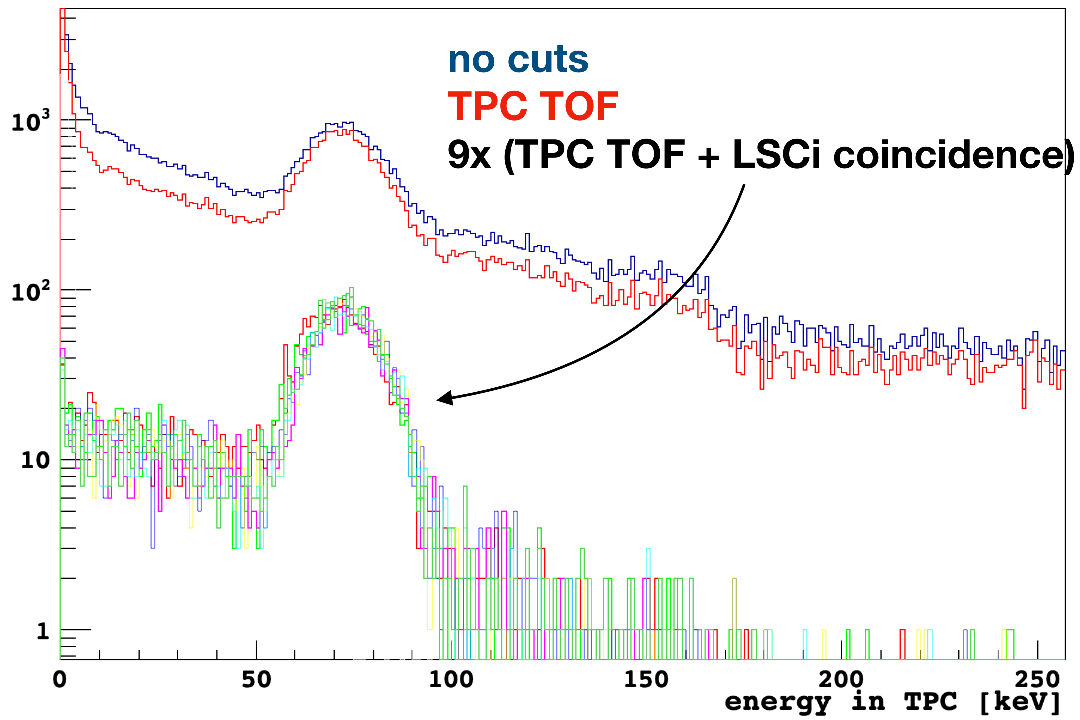
GOAL is to store the distribution of **the azimuthal angle of the recoiling ^{40}Ar** (angle with respect to the drift field) vs **^{40}Ar recoil energy**.



same color scheme maintained when looking at TPC-LSCi coincidence

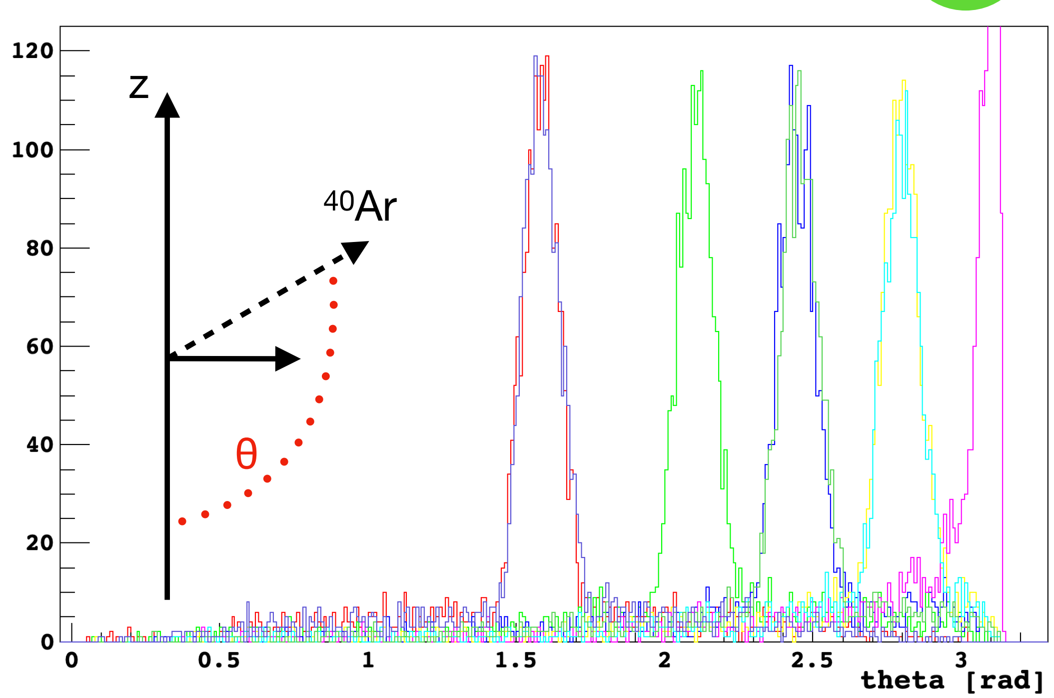
Model the response: from energy deposit to S1 and S2

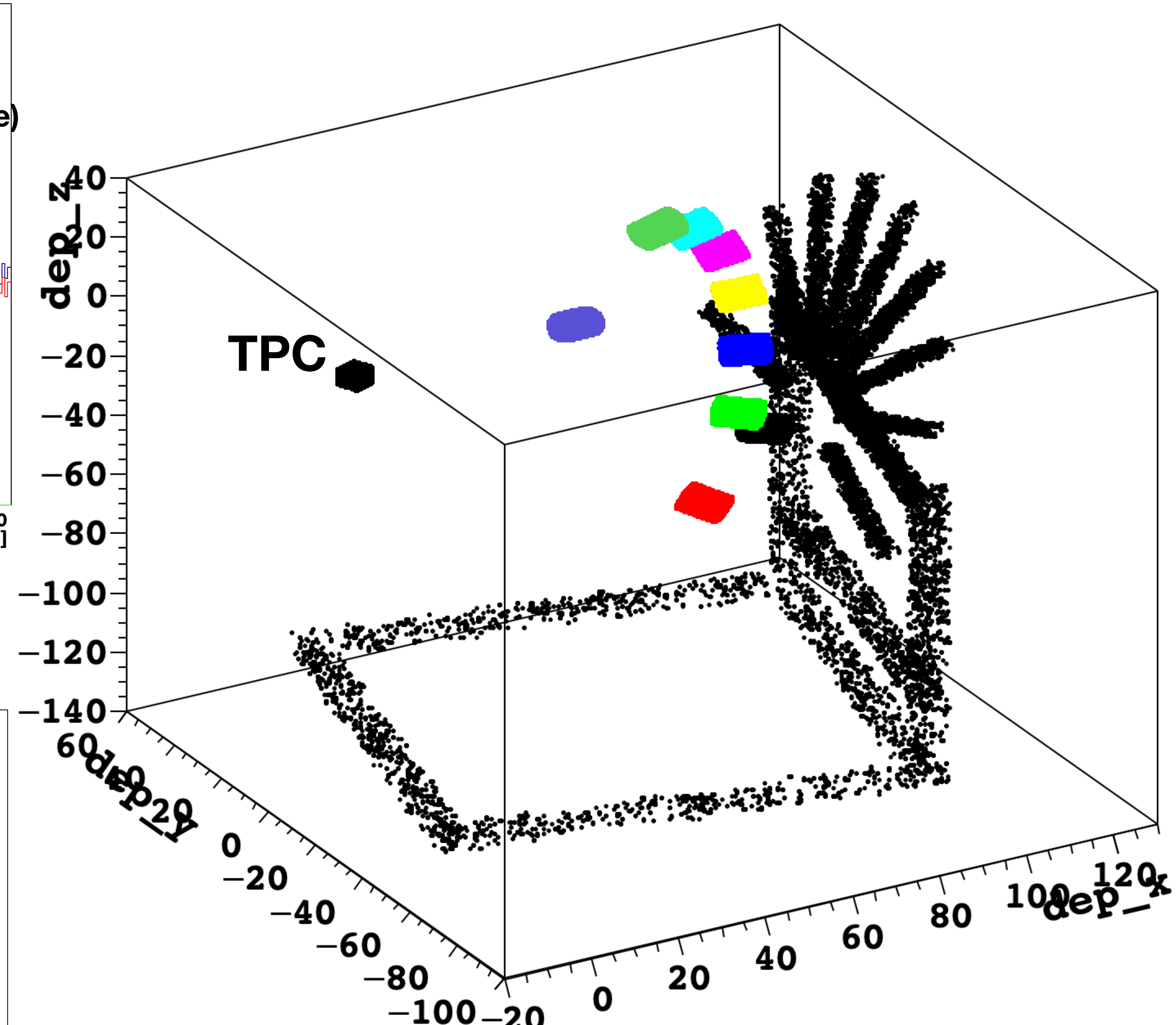
energy in TPC before and after coincidence and TOF selection



^{40}Ar recoil angle wrt to drift field

Each (pair) of LSCi selects one angle





==> use the join energy-angle 2D distributions from MC as PDF for the following

What next

1) Energy in TPC — — — *L_{Eff} from ARIS* — — — > Visible Energy ✓

2) Visible energy — — — *Model from DS50 and ARIS* — — — > ions and excitons (W = 19.5 eV , N_{ex}/N_i = 1) ✓

3) Free ions — — — *Recombination from ARIS* — — — > ions ↓ excitons ↑

- recombination (S1) ✓
- angle with the field ?
- fluctuations ?

Effect of the field: can be INVENTED to reproduce SCENE. Smth like α·cosθ ?

fluctuations:
in DS50 we fluctuate (Gaus) independently Ni and Nex only at this point (S1 driven).
Need update?

Surviving ions — — — > S2

g2 / ionization yield (PE/e-) ?

S2 resolution ?

Excitons — — — > S1

g1 / light yield (PE / ph) ?

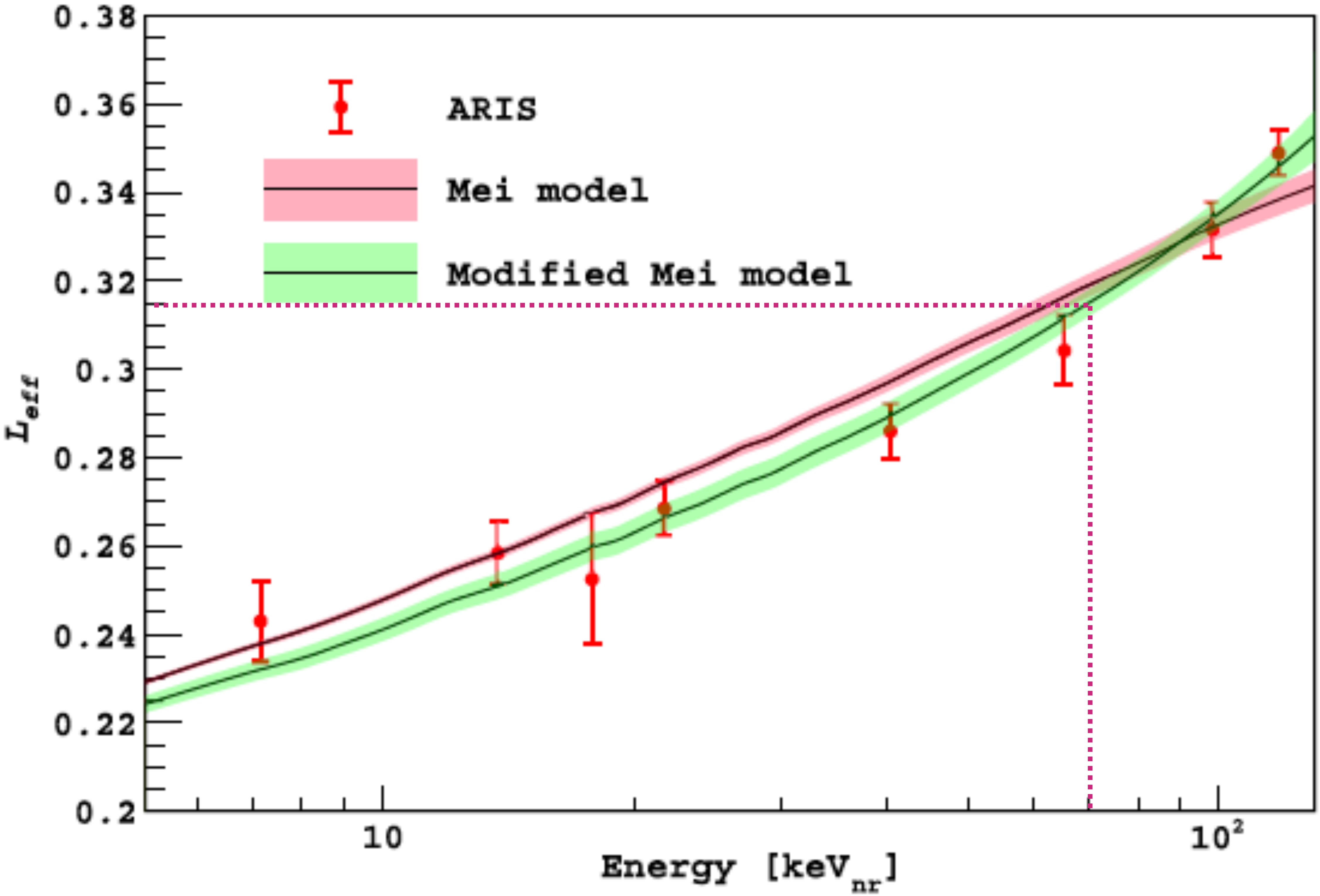
S1 resolution ?

Measure from current ReD

1) True energy to visible energy.

Use L_{Eff} from ARIS measurement

0.315 at 70 keV



2) Model from DS50 and ARIS

The model:

N_Q = Gaus (E_{vis} / 19.5 eV)
$N_i = N_Q / (1 + \alpha) = N_Q / 2$
$N_{ex} = N_Q - N_i$

$N\gamma$ = Nex + Binomial (Ni , R(θ))
Ne- = N_Q - Nγ

meanS1 = Binomial (Nγ, g1)
meanS2 = g2 x Ne-

S1 = Gaus (meanS1 , $\sigma 1 \sqrt{meanS1}$)
S2 = Gaus (meanS2 , $\sigma 2 \sqrt{meanS2}$)

Considerations:

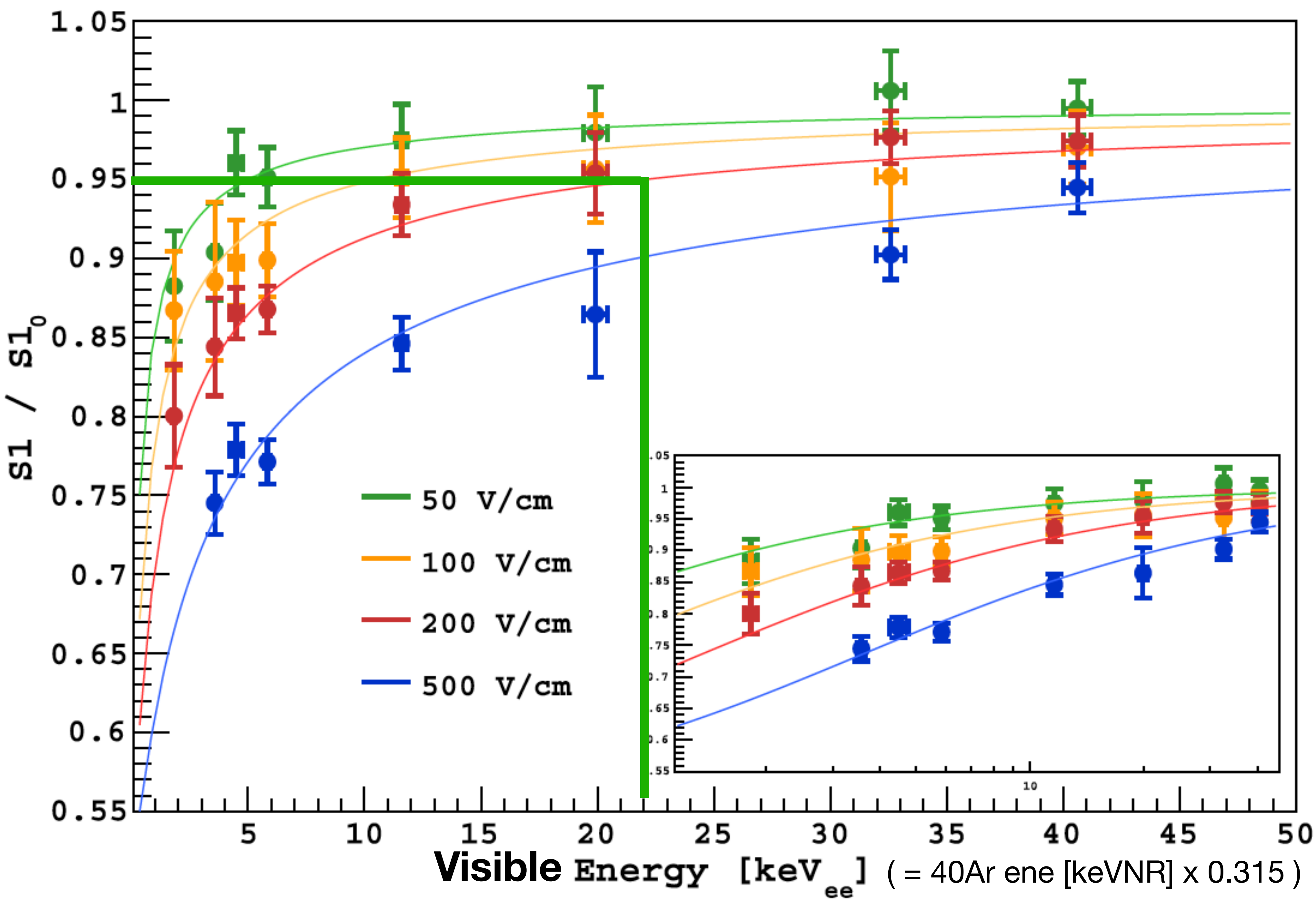
- Recombination R (can be extracted from ARIS) is the parameter with **largest effect** on S2.
- Effect of θ is invented: do we reproduce SCENE?
- Fluctuations and correlations are assumed (can not establish with DS50 or ARIS)
- S2 is not tuned in DS50. The only handle is the ARIS/DS50 cross calibration.

NQ	*number of produced quanta*	*R*	*Recombination*
Ni	*number of e-/ion pairs*	*θ*	*azimuthal angle*
Nex	*number of excitons*	*g1*	*light detection probability*
α	*Nex/Ni (assumed 1 for NR)*	*g2*	*multiplication in gas*
Nγ	*Number of scintillation photons*	*σ1*	*S1 resolution other than binomial (SPE, geometry…)*
Ne-	*Number of free electrons*	*σ2*	*S2 resolution (multiplication, SPE, e- lifetime?…)*

3A) Recombination from ARIS

- Recombination R (can be extracted from ARIS)

$S1/S1_0 = (1 + R) / (1 + Nex/Ni) = 0.95$ ==> $R(T_{\perp}E) \sim 0.9$



(= 40Ar ene [keVNR] x 0.315)

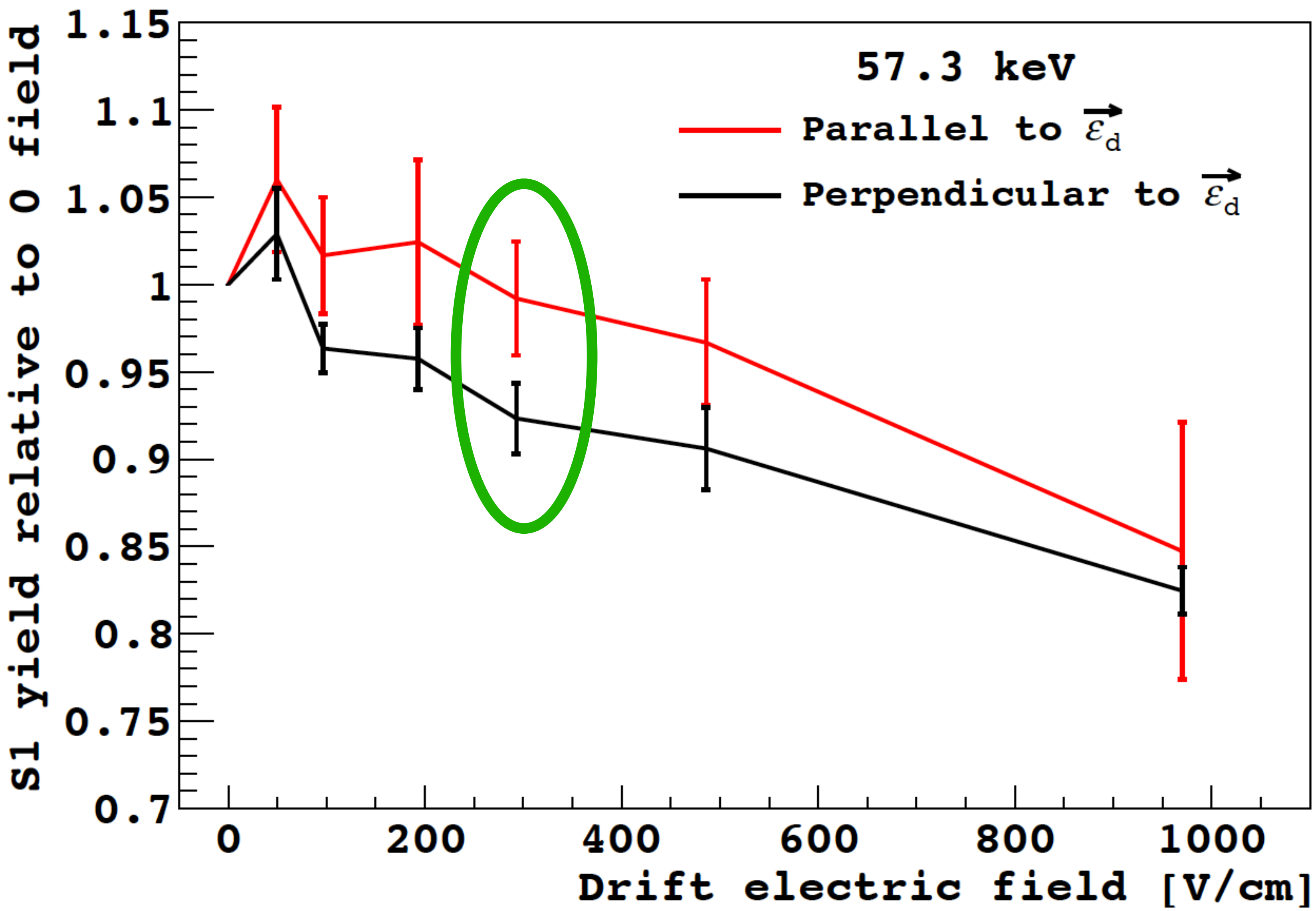
3A) Effect of θ - invented to reproduce SCENE

- Effect of θ is invented: do we reproduce SCENE.

Recombination becomes **R = 0.9 * (1. + A * abs(cos(θ)))** ;

For A = 0.08 the $T_{||}E$ vs $T_{\perp}E$ effect is ~ as observed in SCENE

For T//E, recombination is 98% of e-/ion pair. A 10% increase in the A parameter (0.08 to 0.09) implies a factor of ~2 less S2 signal!



4) Detector resolutions.

This input is easy to adjust, based on the measured detector performance.
Do we have reference values?

Excitons —––> S1

g1 / light yield (PE / ph) ?

S1 resolution ?

Surviving free e- —––> S2

g2 / ionization yield (PE/e-) ?

S2 resolution ?

S1 LY is ~ 8 PE / keV?
==> g1 ~ 0.2

S1 = Gaus (Nγ x 0.2, sigma)
sigma is sqrt(g1*(1-g1)*Nγ + $\sigma1^2$*Nγ*g1)

σ1 ~ 2 to match ReD data
(peak RMS ~ 10%@ 60 keV)

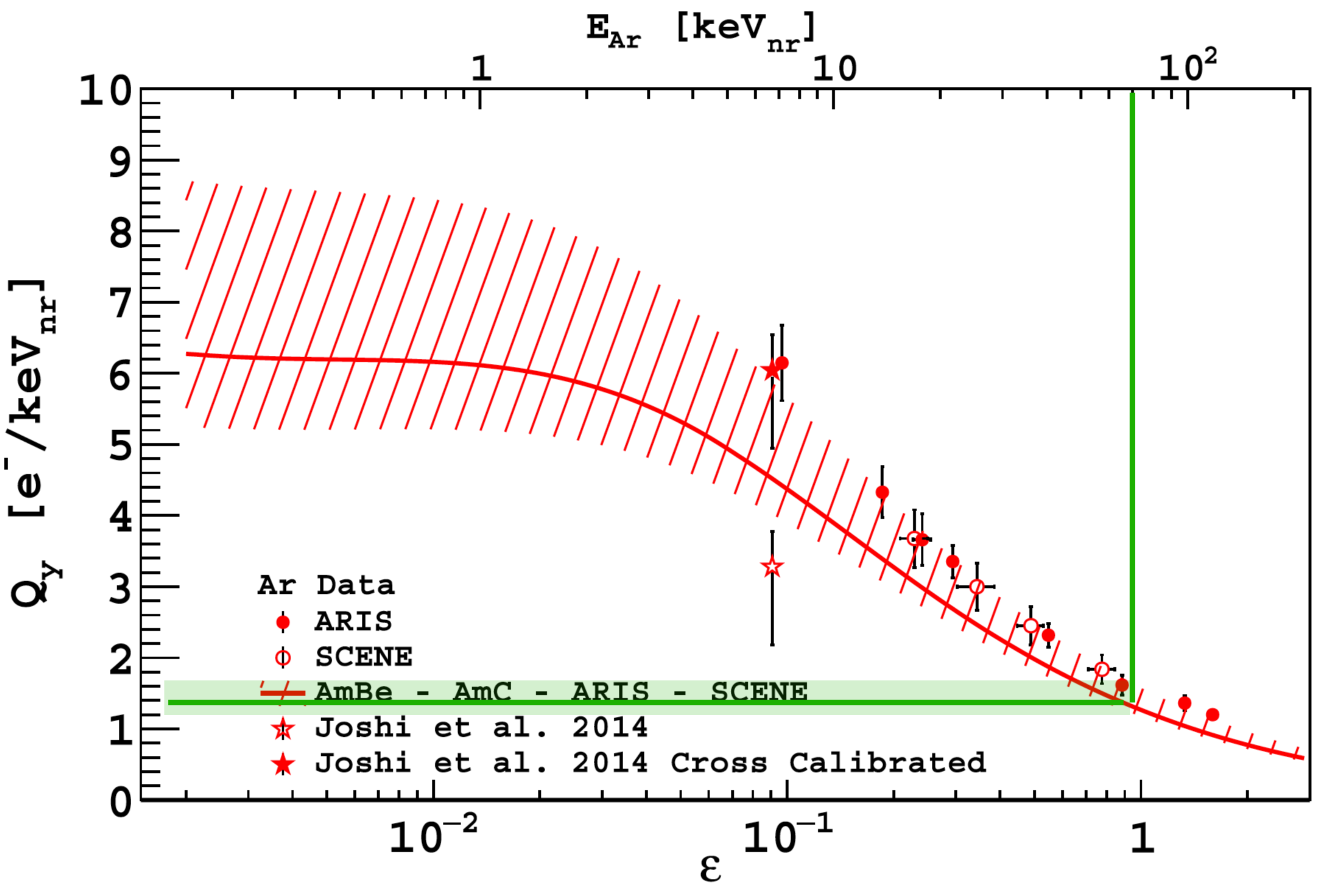
S2 multiplication ?
Use g2 = 10 PE / e-

S2 resolution ?
Use σ2 ~ 2
Use Gaus (g2 x Ne, σ2 x √(g2*Ne))

g1	*light detection probability*
g2	*multiplication in gas*
σ1	*S1 resolution other than binomial (SPE, geometry…)*
σ2	*S2 resolution (multiplication, SPE, geometry, e- lifetime?…)*

Validation of the Model ?

Ionization yield from ARIS/DS50.
Expect 1.2 to 1.6 e- / keV_{NR} at 70 keV_{NR}



Consistent

According to this model:

Test

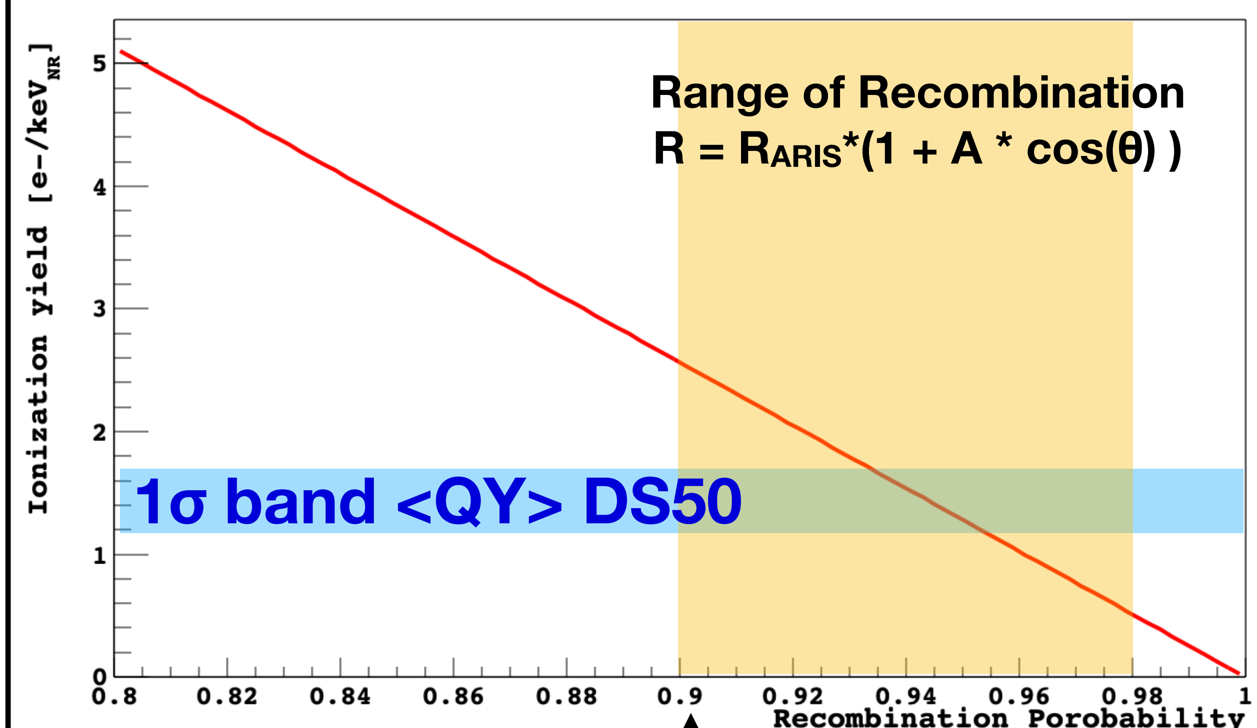
$< N_Q > = (E_{vis} / 19.5\ eV)$

$N_i = N_Q / (1 + \alpha) = N_Q / 2$

$N_{ex} = N_Q - N_i$

$Ne- = Ni \times (1 - R) = NQ /2 \times (1 - R)$

$Ne-/E_{vis} = NQ /2 \times (1 - R) / E_{vis}$

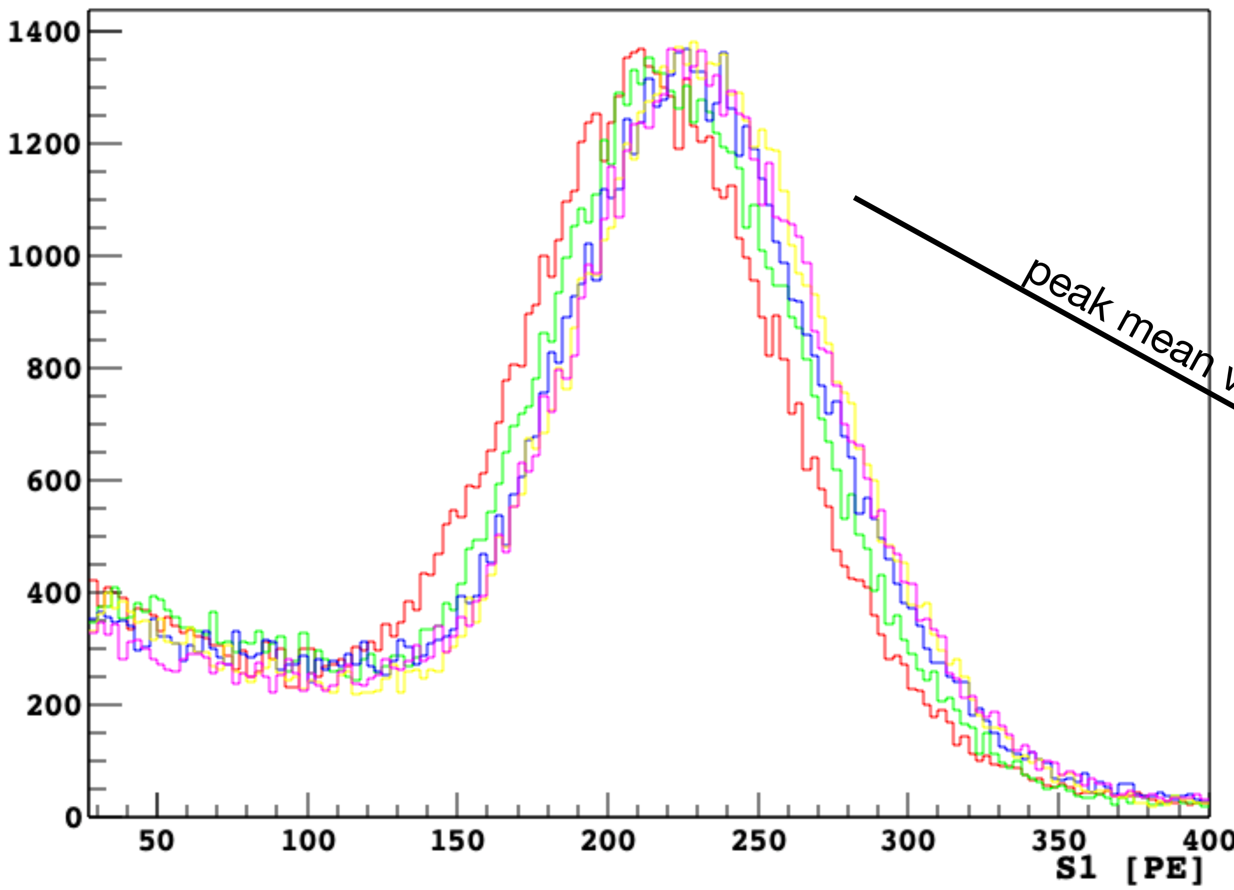


Recombination in ARIS is 0.9
(geometry selects T⊥E....)

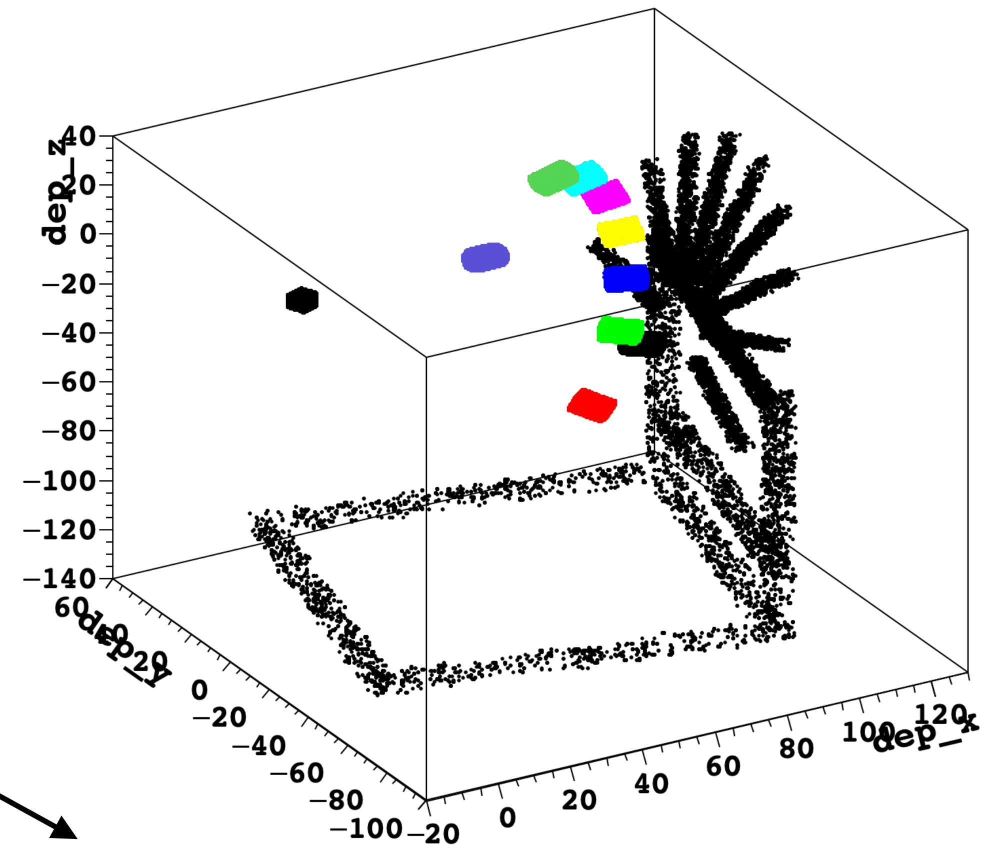
Some examples

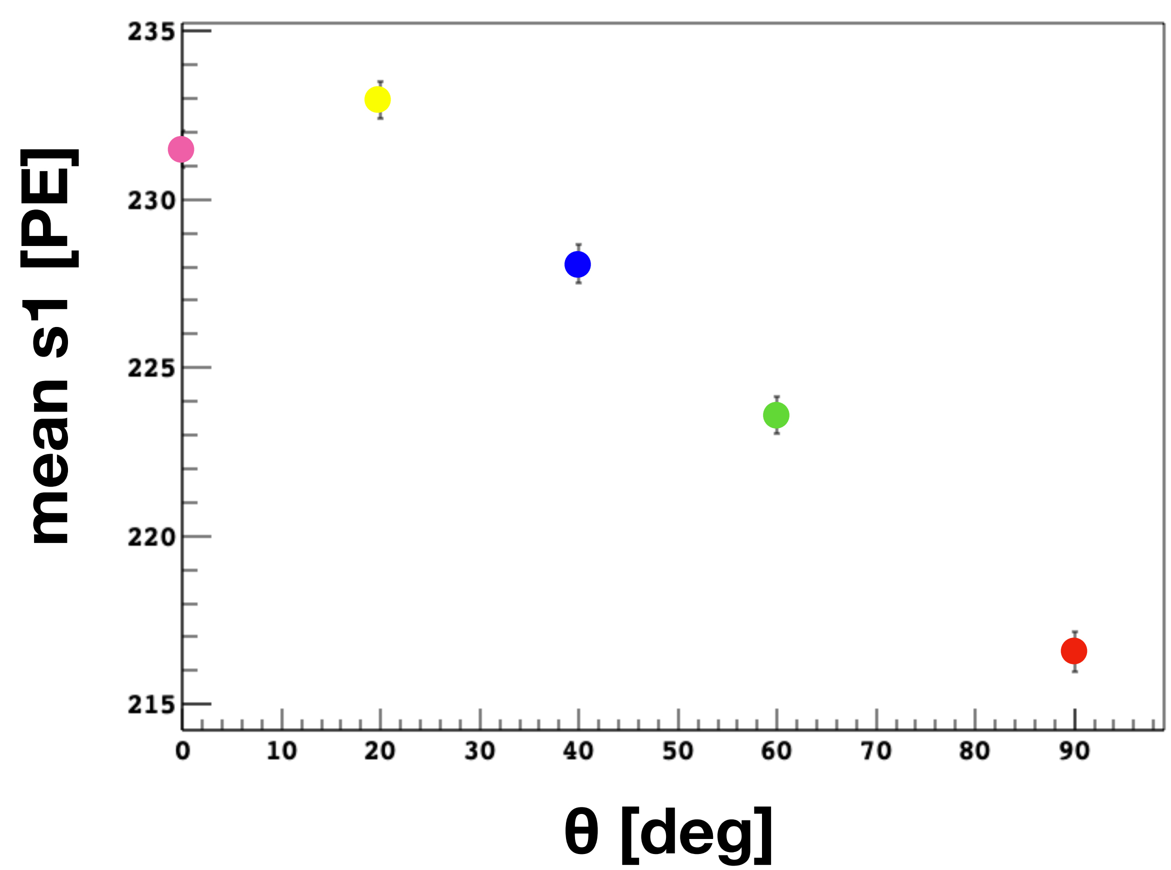
S1 spectra for 5 LSci

With arbitrary large statistics



peak mean values

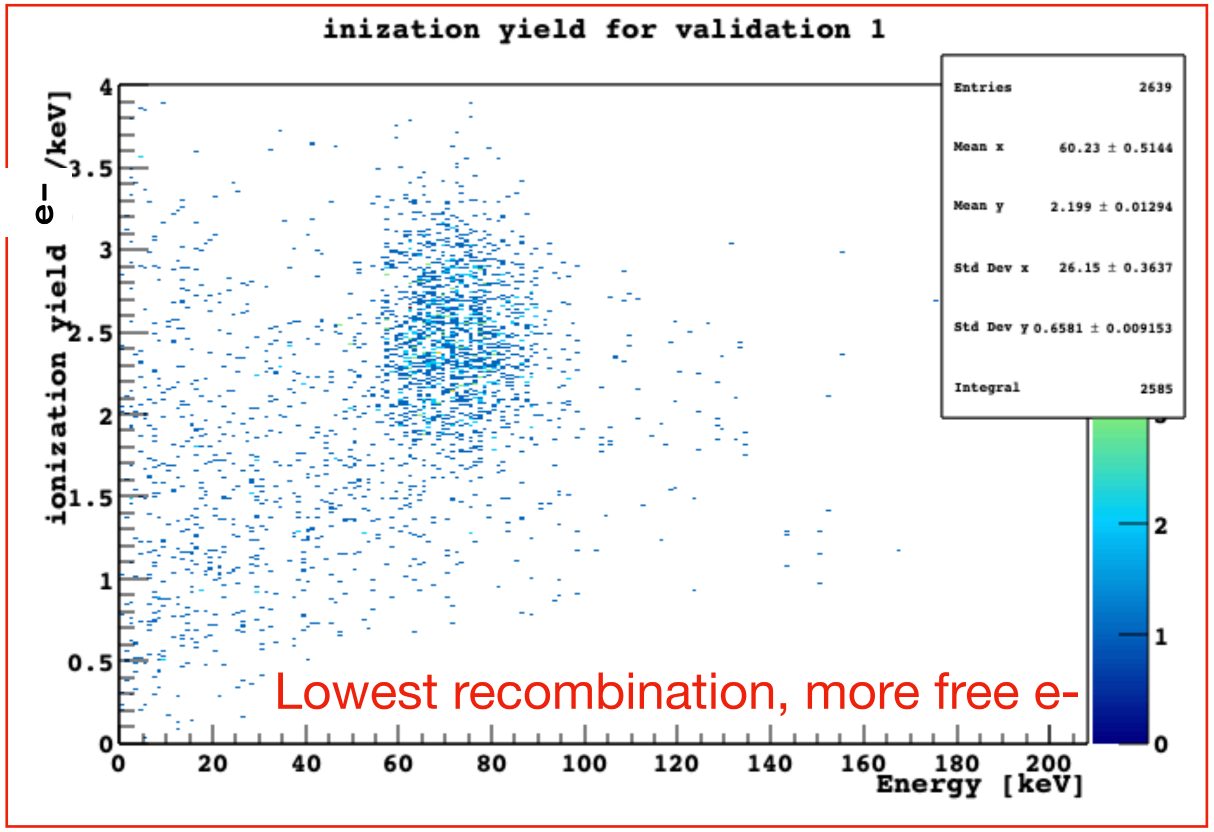


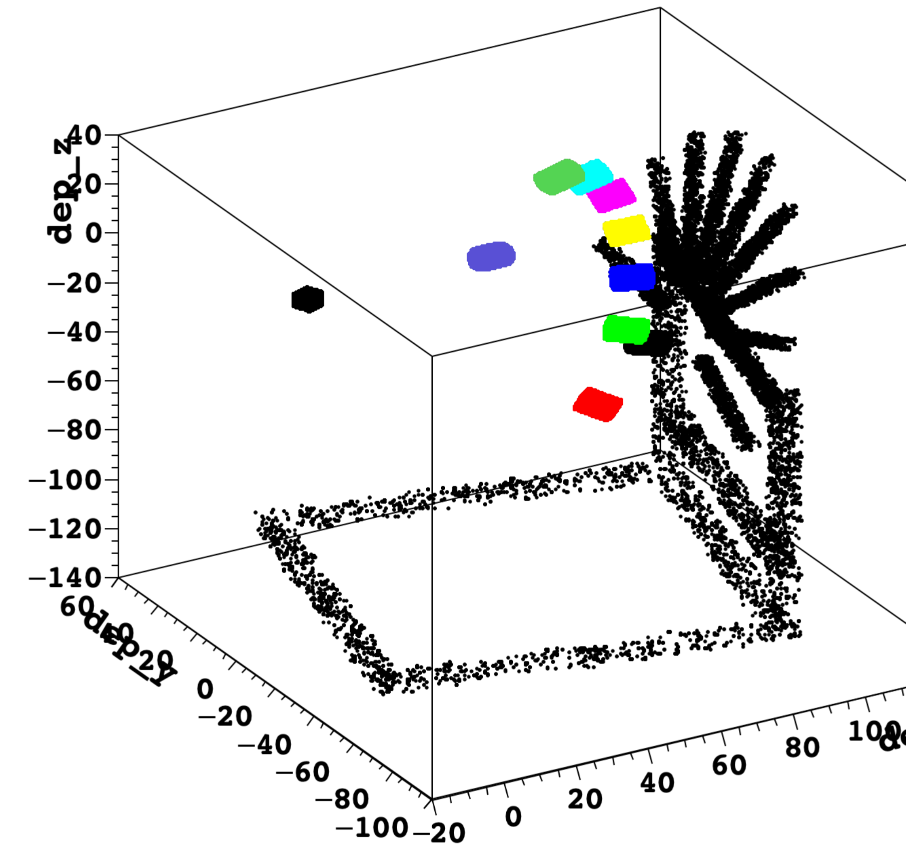


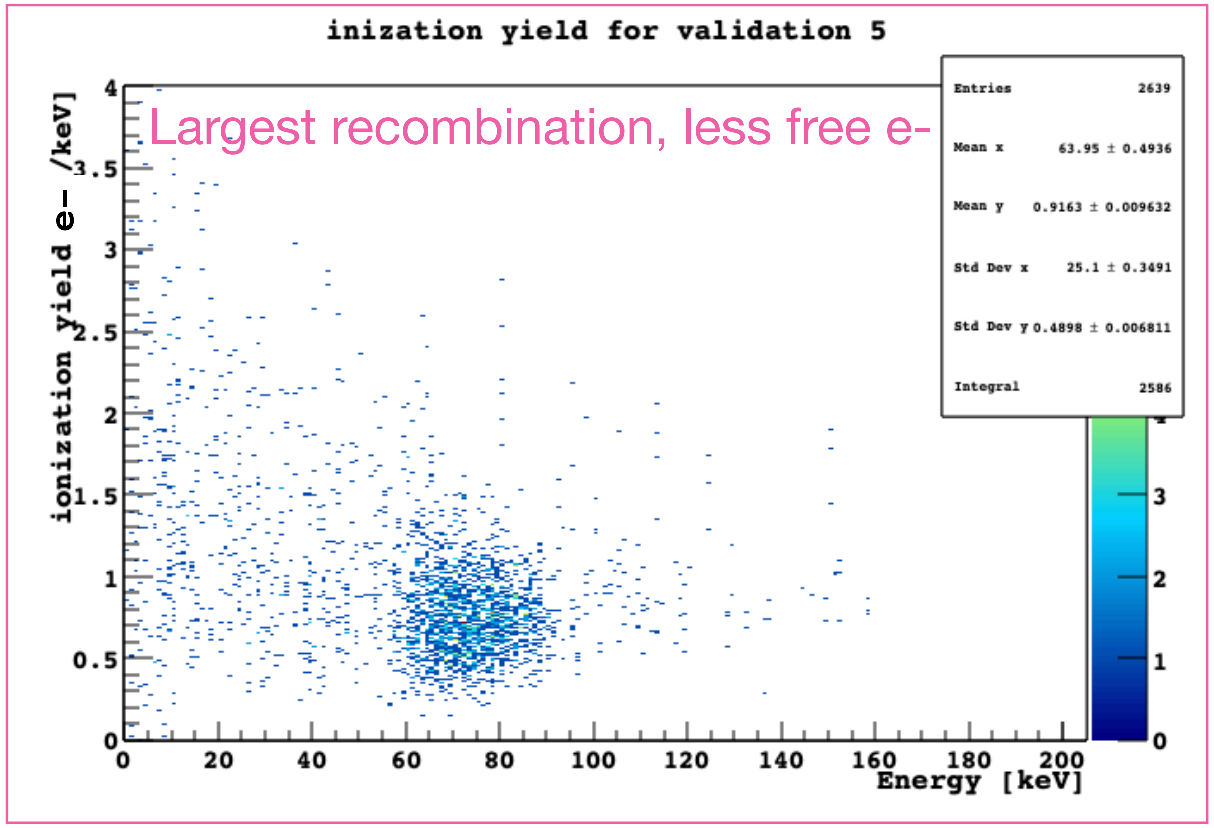
From a gaussian + bg fit of the peaks:

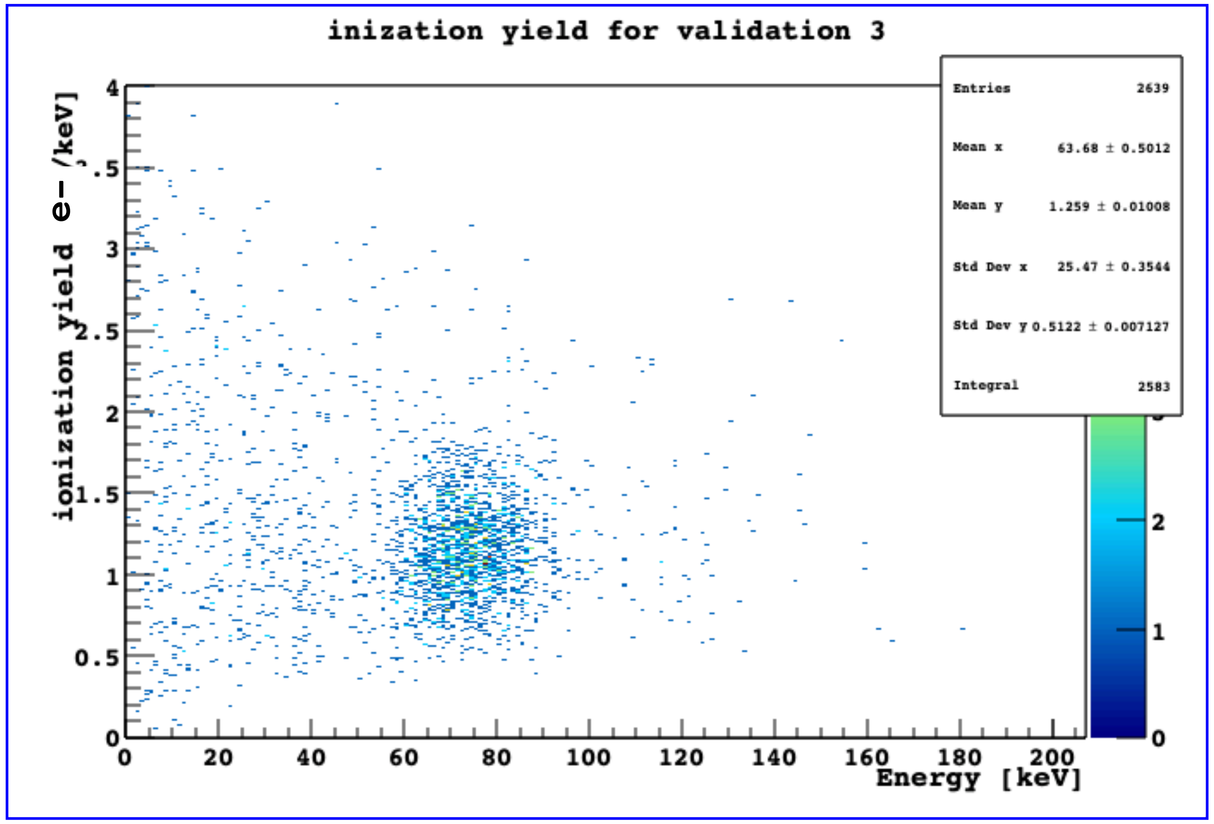
Compatible with SCENE

Ionization yield for 3 LSCi





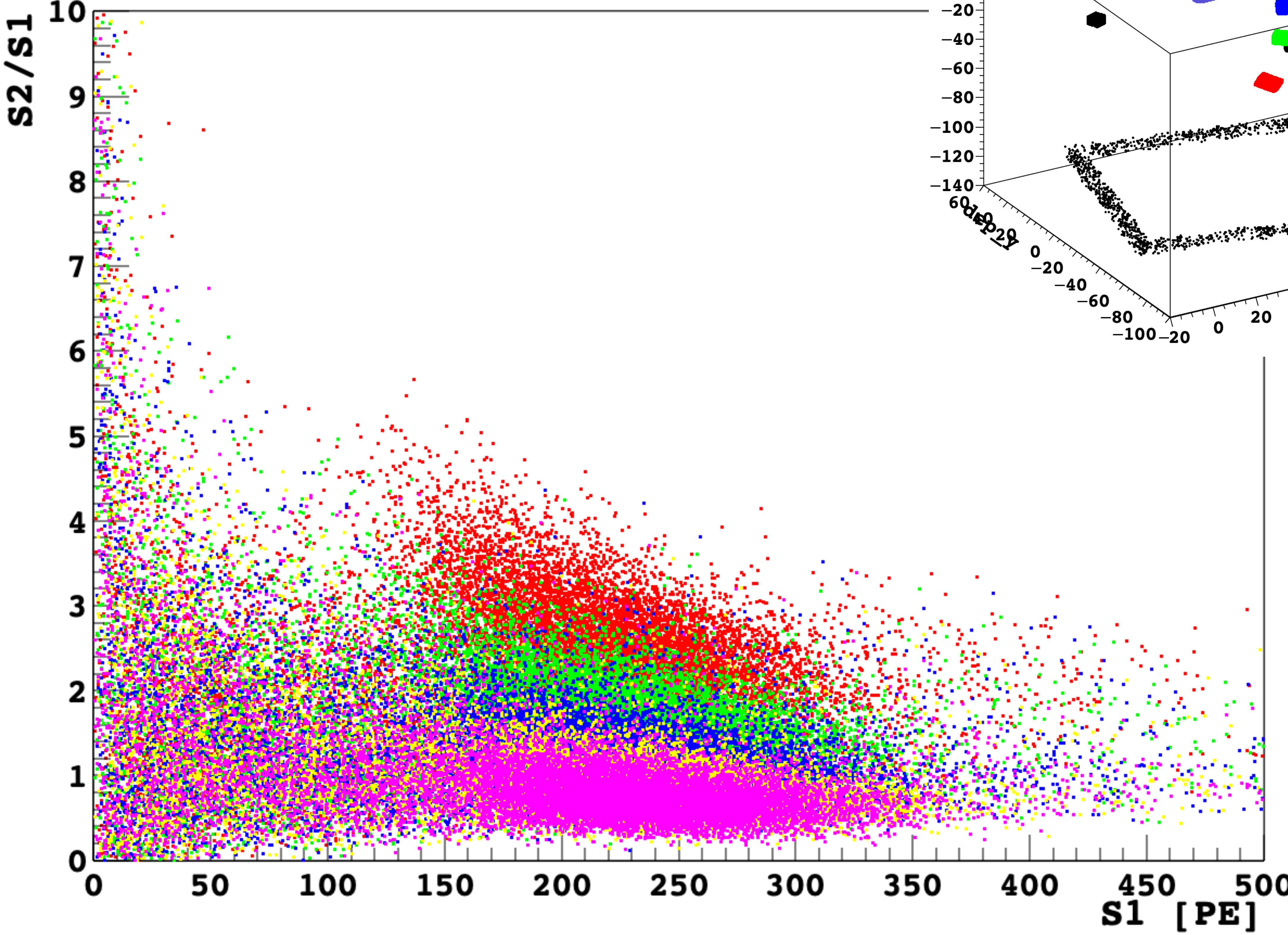


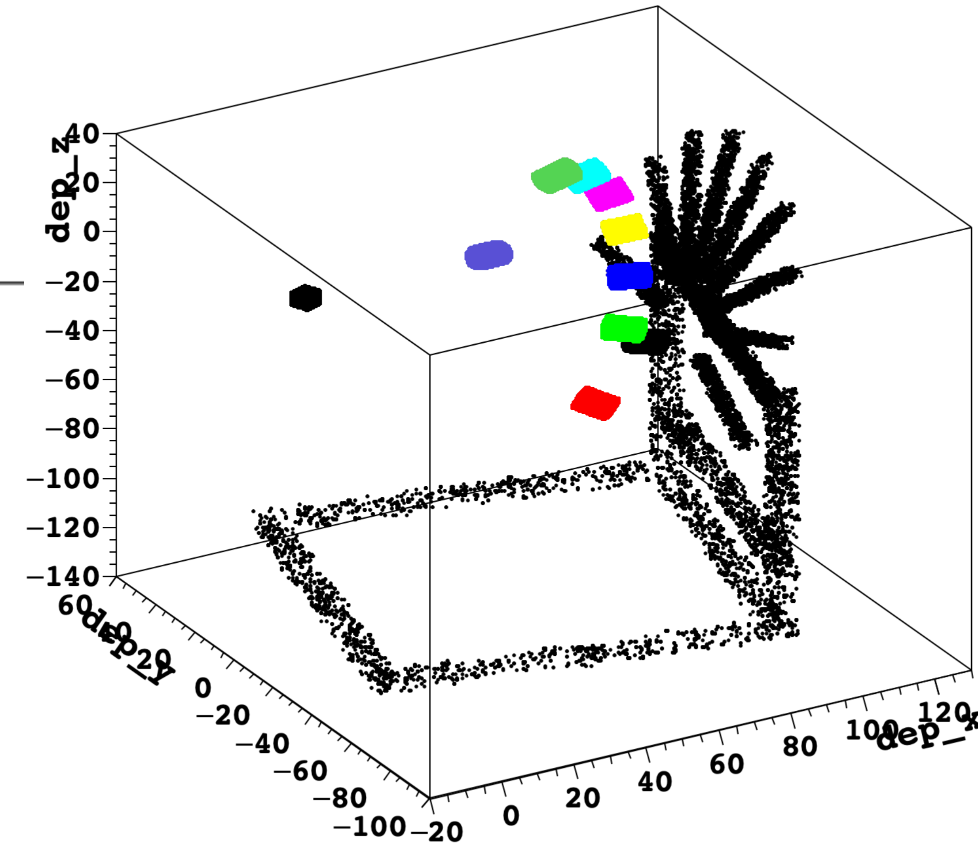


According to DS50, the avg value is 1.4±0.2 e-/keV_{NR}

S2/S1 vs S1

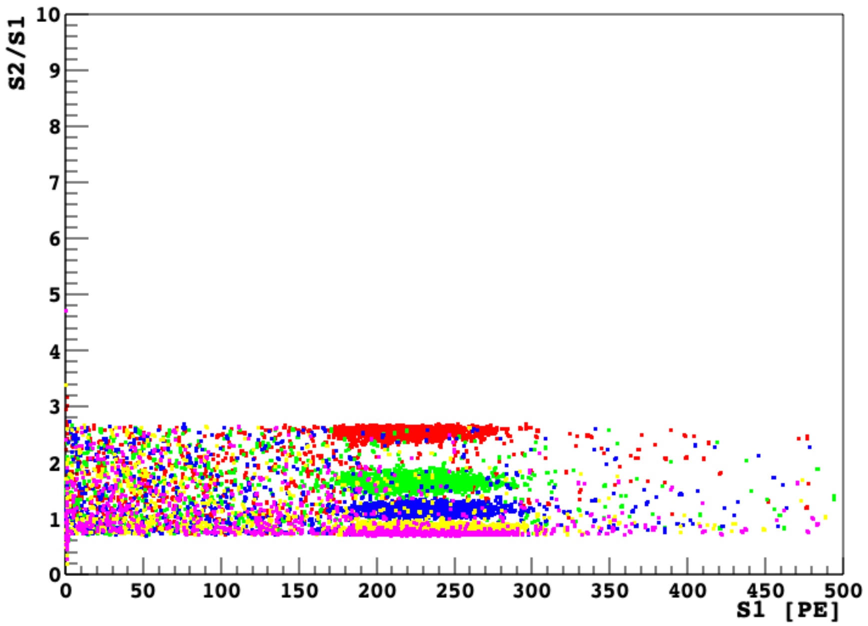
with arbitrary large statistics



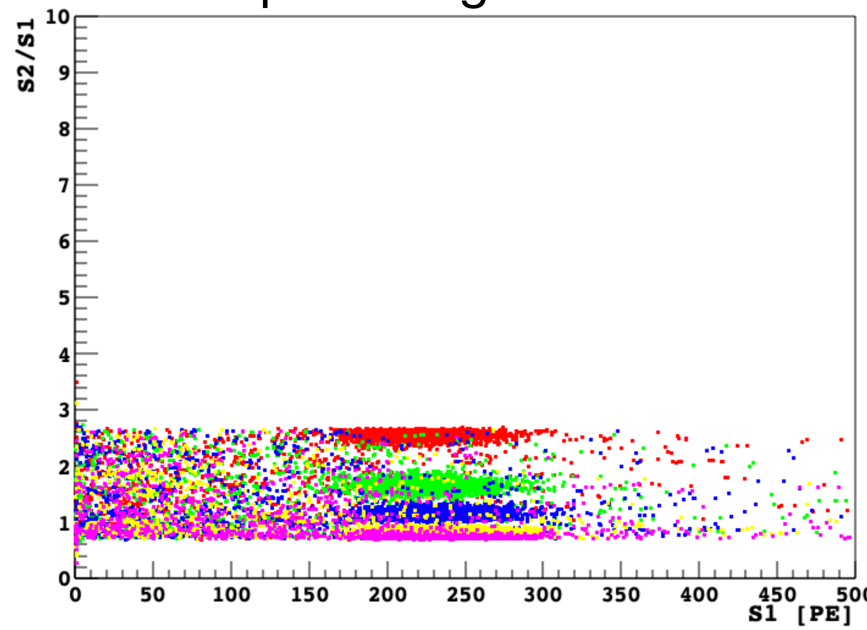


S2/S1 vs S1 changing fluctuations and resolutions

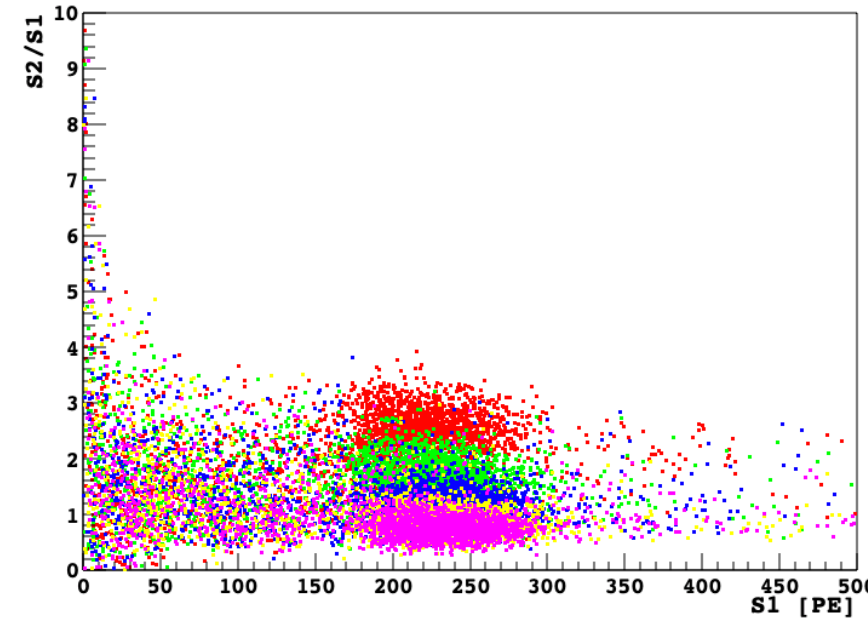
With no fluctuations



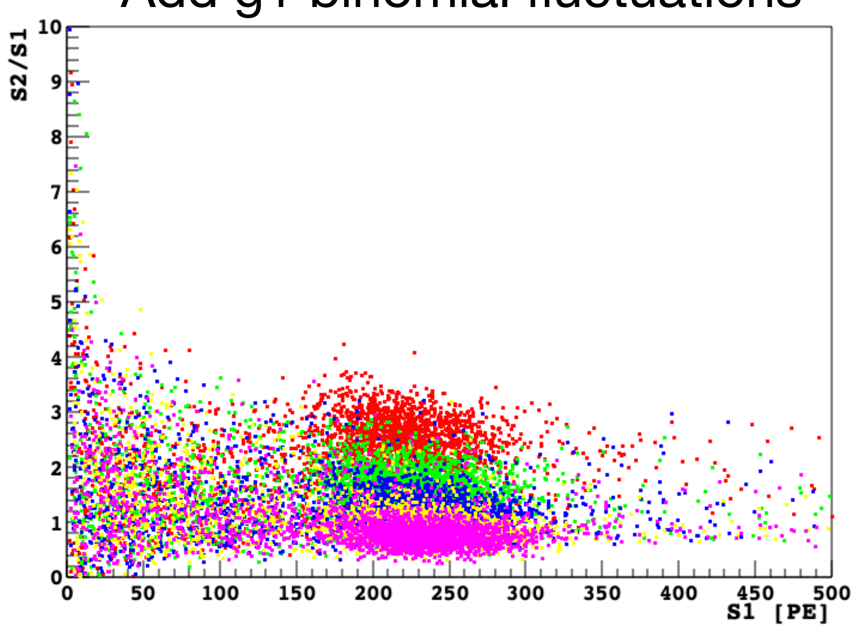
Add quenching fluctuations



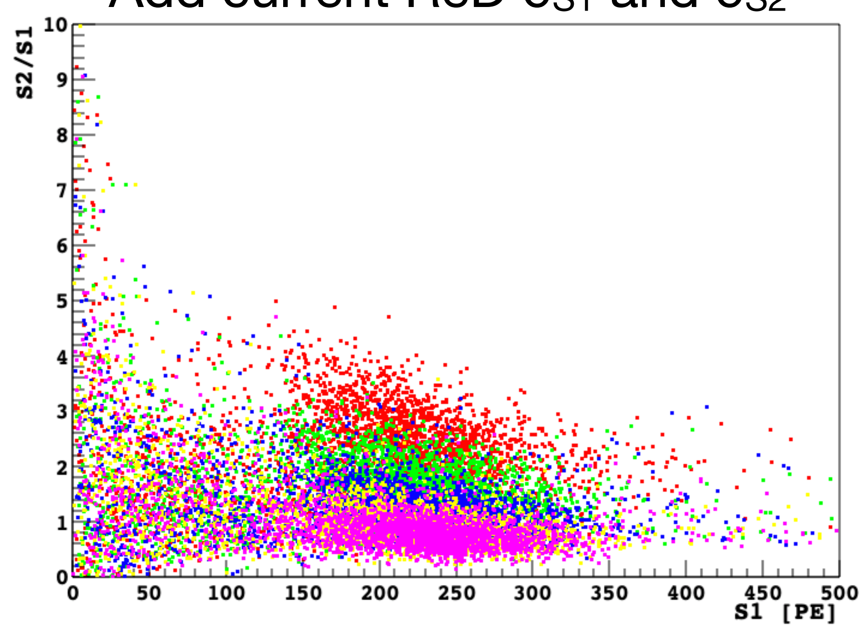
Add recombination fluctuations



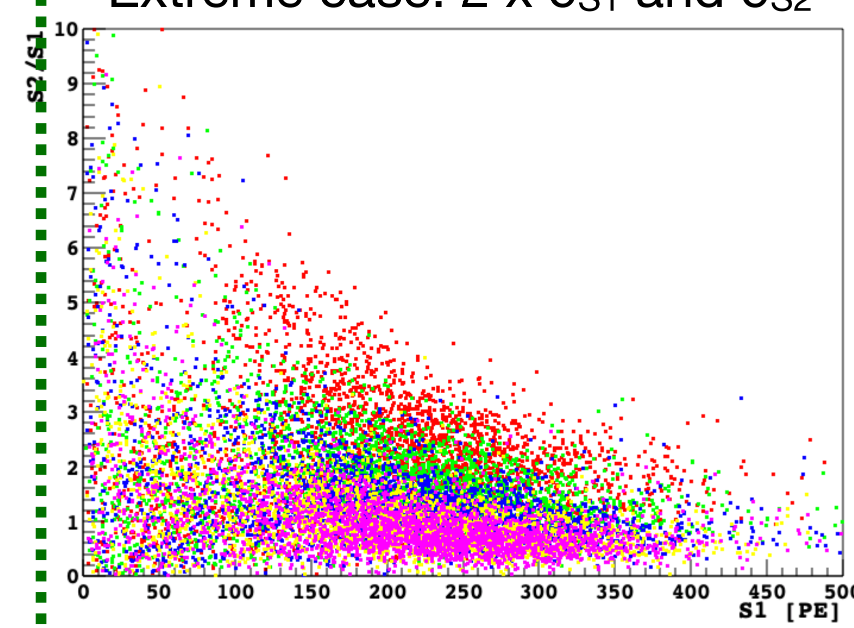
Add g1 binomial fluctuations



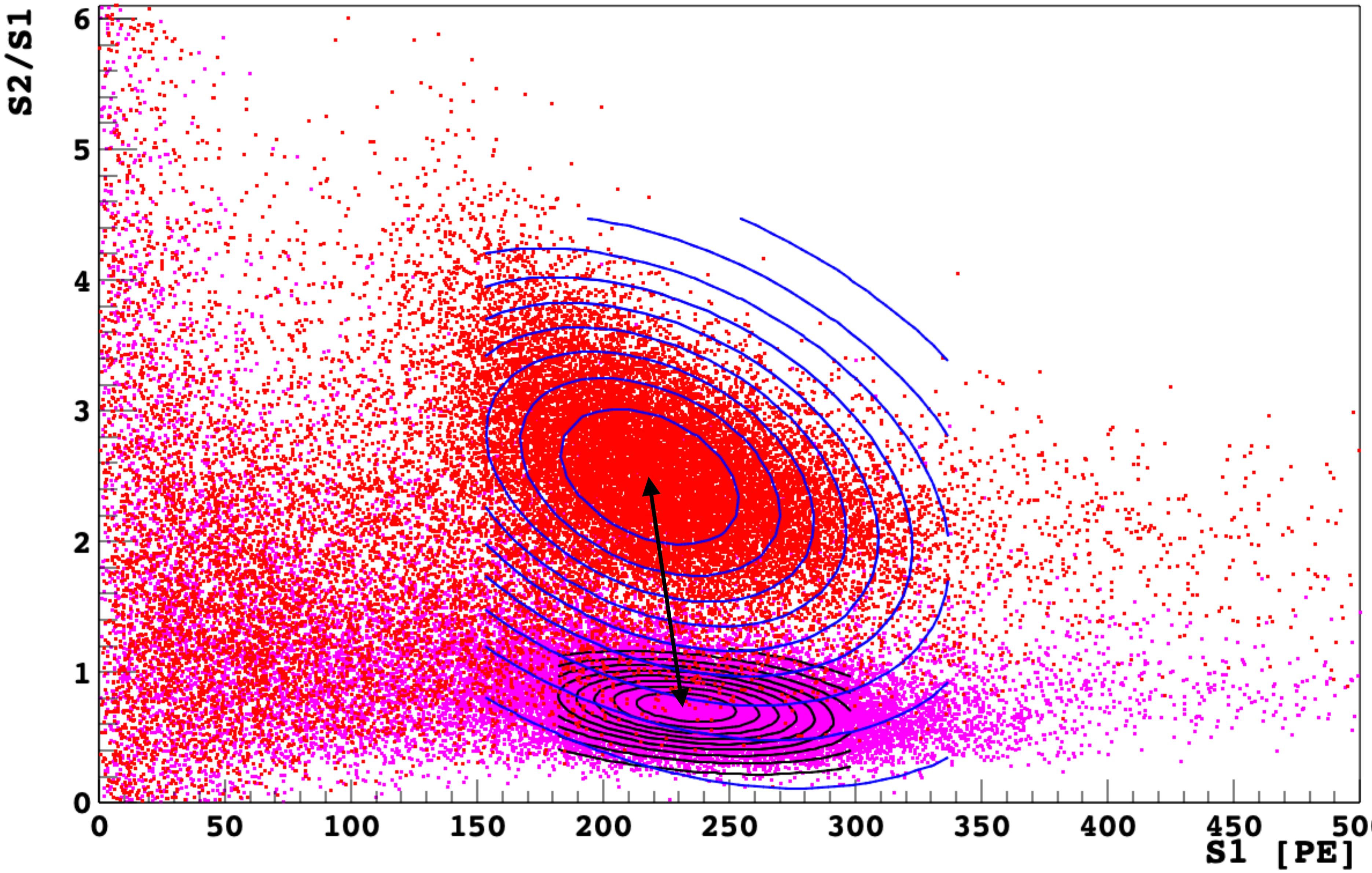
Add current ReD σ_{S1} and σ_{S2}



Extreme case: 2 x σ_{S1} and σ_{S2}

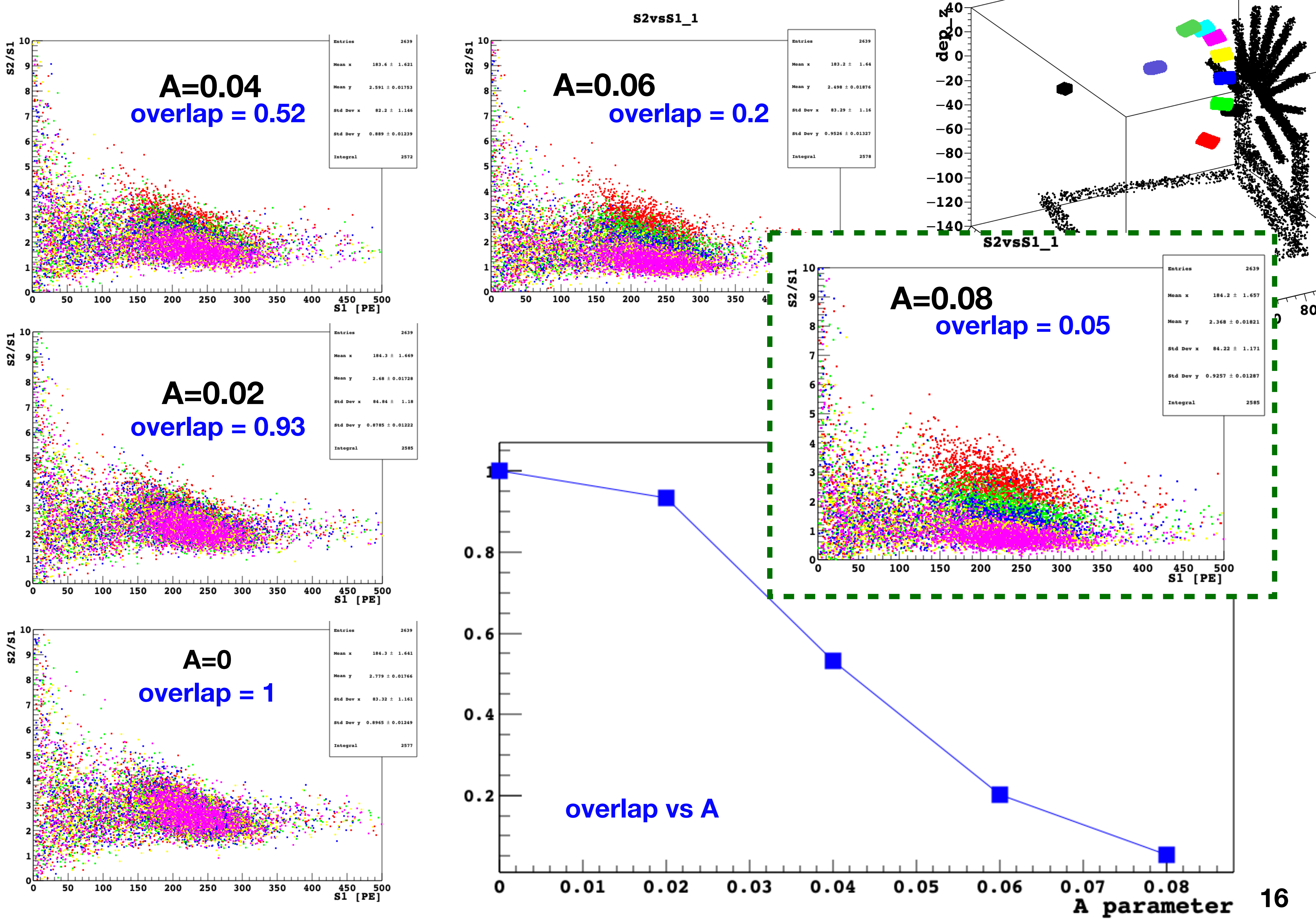


Preliminary distance estimate

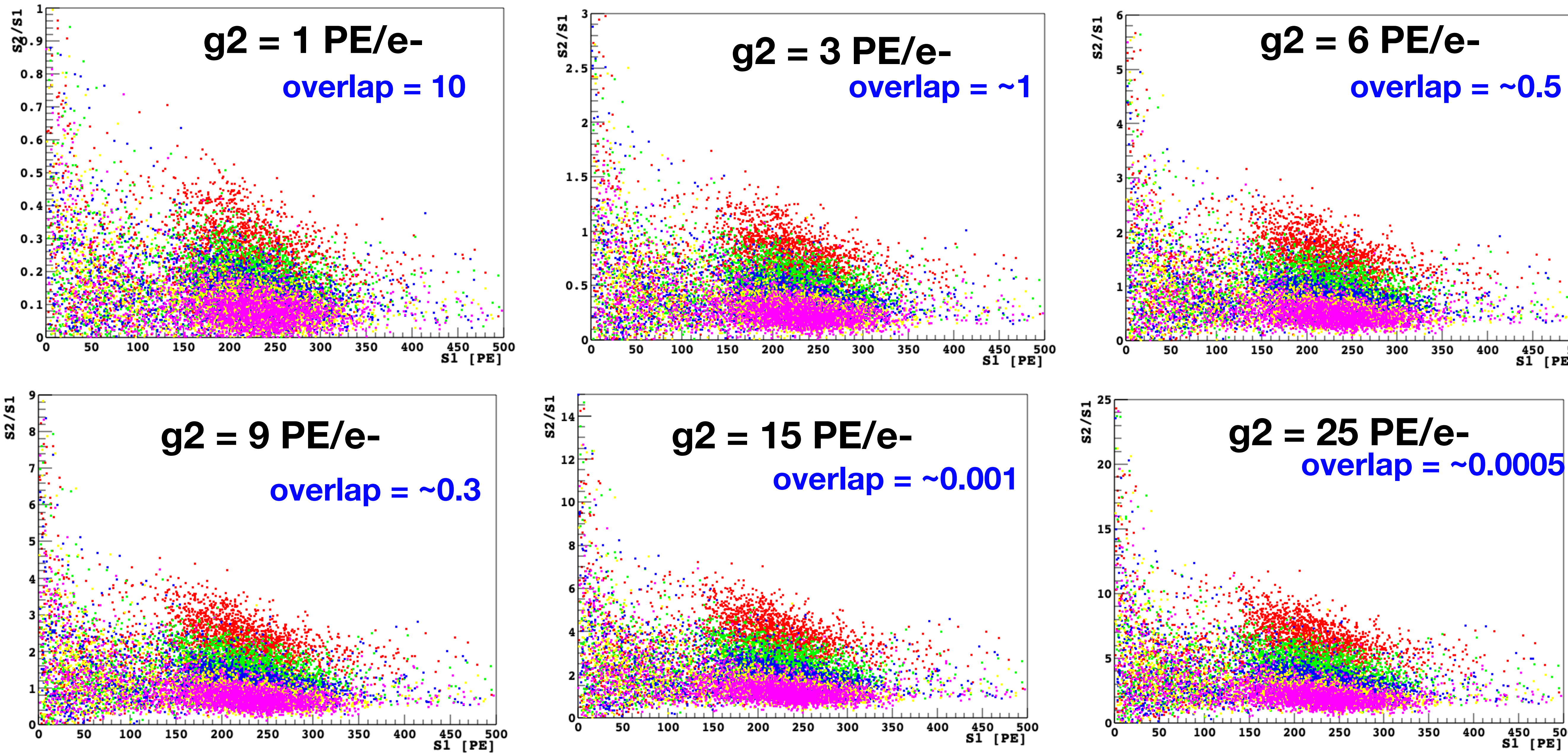


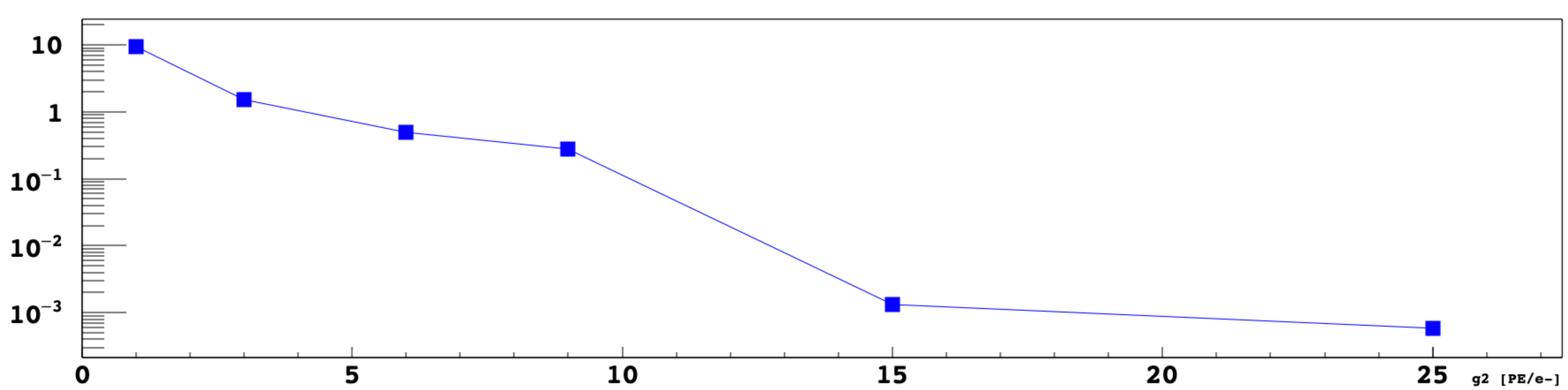
A relative estimate of the separation between the peaks can be done using a fit of T//E and T⊥E peaks with bivariate gaussians. Then take the product of the normalized functions and integrate. A more refined approach will include all the peaks and a LL.

The directional effect on S2/S1 vs S1



S2/S1 vs S1 as a function of g2





Conclusions

Tool is basically ready, may need some refinement

Normalize to correct statistics and evaluate the impact

Develop analysis and define strategy