RD53b
S-Curve Fitting

September 19th ,2022

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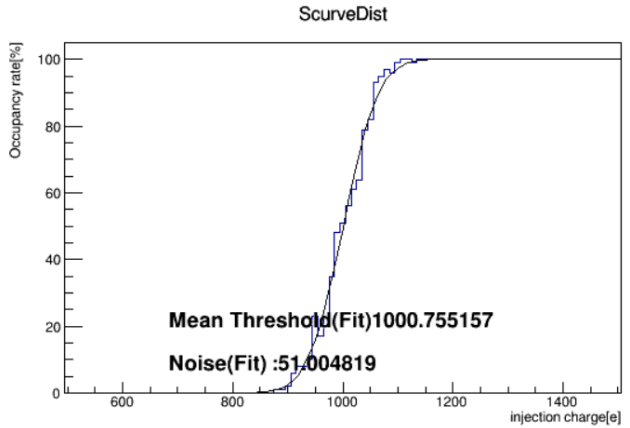
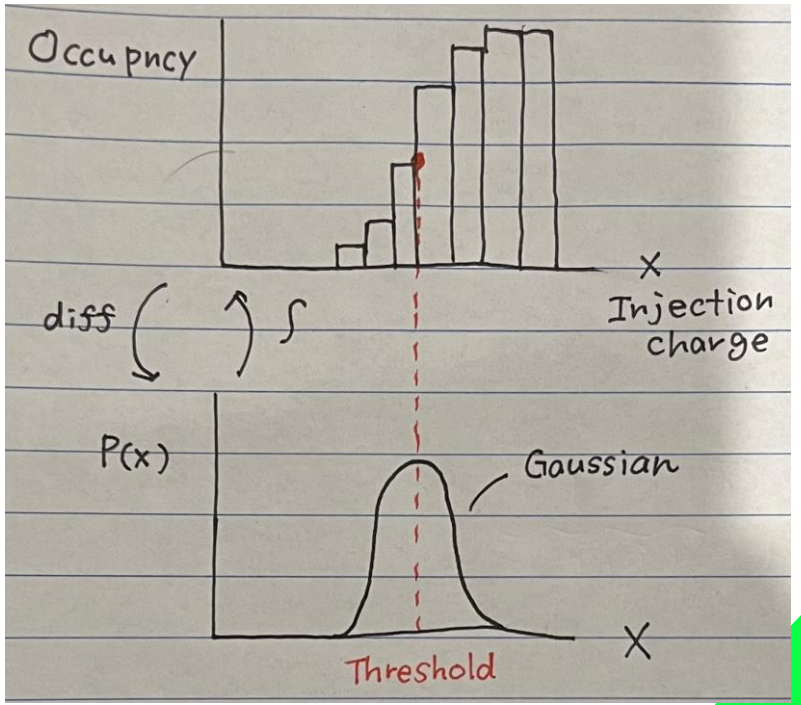
Calculation method

- we usually use **s-curve fitting** to know threshold and noise
  - ideal s-curve: $P_{hit}(x) = \frac{1}{2}\left(2 - E_r f_c\left(\frac{x - threshold}{\sqrt{2} * noise}\right)\right) * 100$
  - Error function $E_r f_c = \frac{2}{\sqrt{\pi}} \int_x^{\infty} exp(-t^2)\, dt$



- What I did: Try to **calculate** threshold and noise by using s-cueve distribution **without fitting**

- Idea is
  - ⓪**Differential equation** of s-curve distribution must be gaussian
  - ①Get discrete derivative from occupancy distribution.
    - $dn(i) = n(i+1) - n(i)$
  - ②Expectation of discrete derivative(=mean of gaussian) must be threshold
    - $Threshold\ E = \sum_{i=0}^{N} x \cdot p(x)$
    - $Noise\ \sigma = \sqrt{Varaiance} = \sqrt{\sum_{i=0}^{N}\left(x^2 \cdot p(x)\right) - threshold^2}$
    - parameter
      - x: injection charge = $(i + 0.5) \times Vcalstep$
      - p(x):probability to get hits in derivative = dn(i)/n_injections



How calculation method work

tuning threshold=2000[e]
step_size=10

- Get the average of 5times threshold scan of **HPK quad module in both fitting and calculation method**
  - Threshold and noise value are **almost same** as fitting results
  - Scan time and analysis time are **almost same** because fitting needs only few seconds
  - **Number of failed fit was decreased!**
    - Number of failed fit = vcalMax>**Thre**>vcalMin, vcalMax-vcalMin>**Noise**>0, fabs(par[2]-/injections-1)<0.1, Chi2>???

Fitting

V1.1 HPK	chip1	chip2	chip3	Chip4
Threshold[e]	1833±0.9	1853±19.5	1846±2.3	1958±46.1
Noise[e]	220.4±0.5	220±0.4	221.8±0.4	323.4±0.5
Failed Fit	612±12	327±11	824±13	2148±21
Scan Time[s]	97.699			
Analysis Time[s]	0.713			

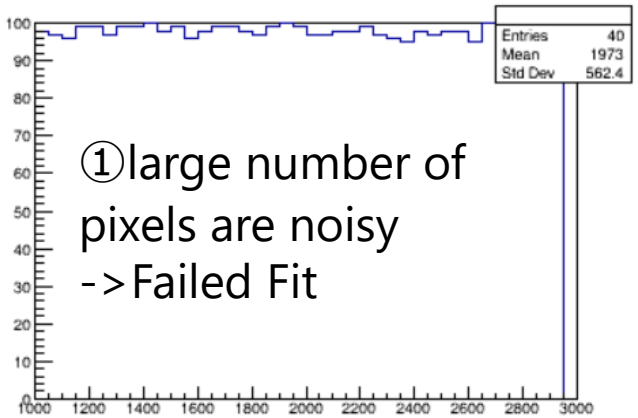
Calculation

V1.1 HPK	chip1	chip2	chip3	Chip4
Threshold[e]	1834±22.4	1844±1.5	1845±1.6	1962±1
Noise[e]	226.6±0.5	225±0	229±0	341.2±0.5
Failed Fit	254±5.1	151±10	280±5.3	1404±10
Scan Time[s]	95.991			
Analysis Time[s]	0.797			

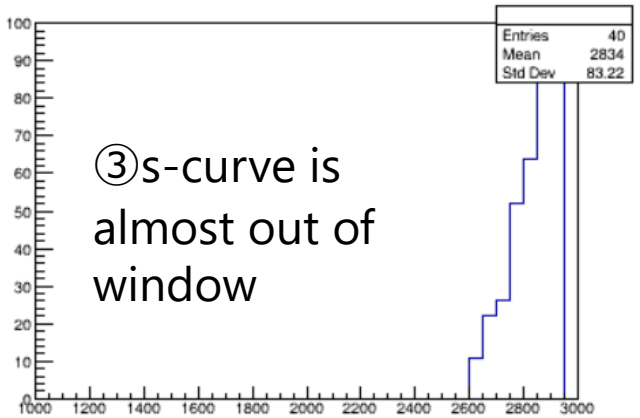
What is failed fit in calculation?**lation method works well in actual threshold scan**
ピクセルバイピクセルで比較

Rare cases

- **These s-curve data must be classified into Failed Fit or data.**
- So, I make these samples by simulation and think about **criteria.**
  - x: Injection charge[e]
  - y: Occumapcy

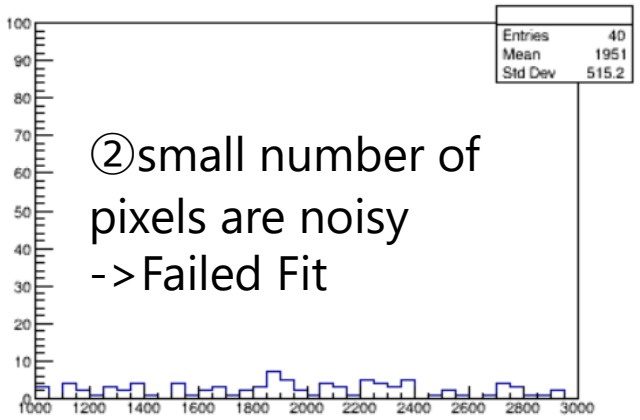


①large number of pixels are noisy
->Failed Fit

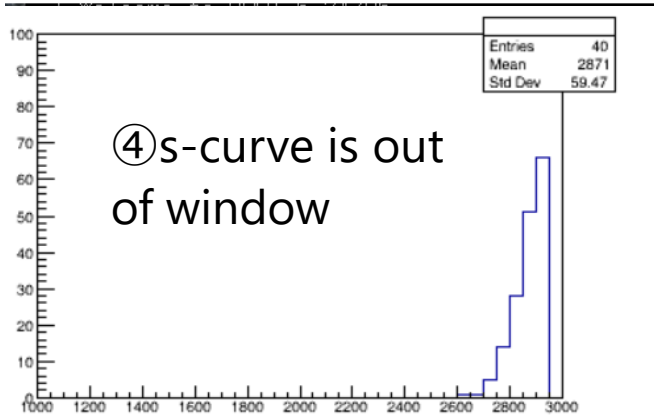


③s-curve is almost out of window

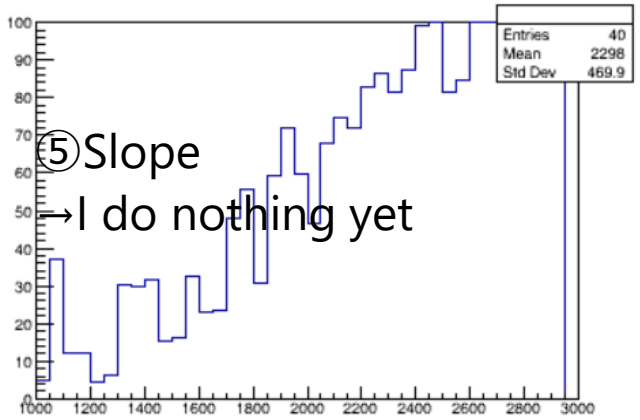
vcalMin: 1000
vcalMax:3000
vcalBins:40
vcalstep:50
n_injections:100



②small number of pixels are noisy
->Failed Fit



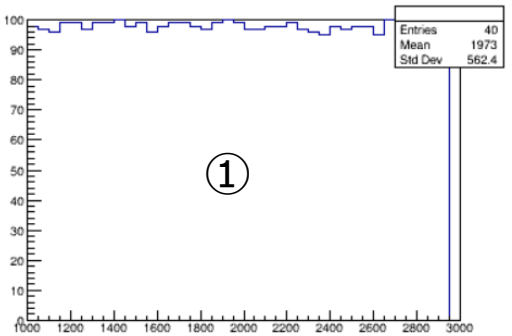
④s-curve is out of window

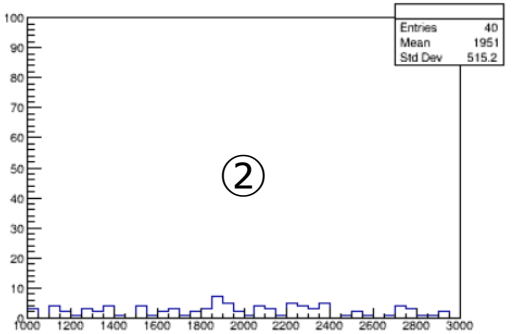


⑤Slope
→I do nothing yet

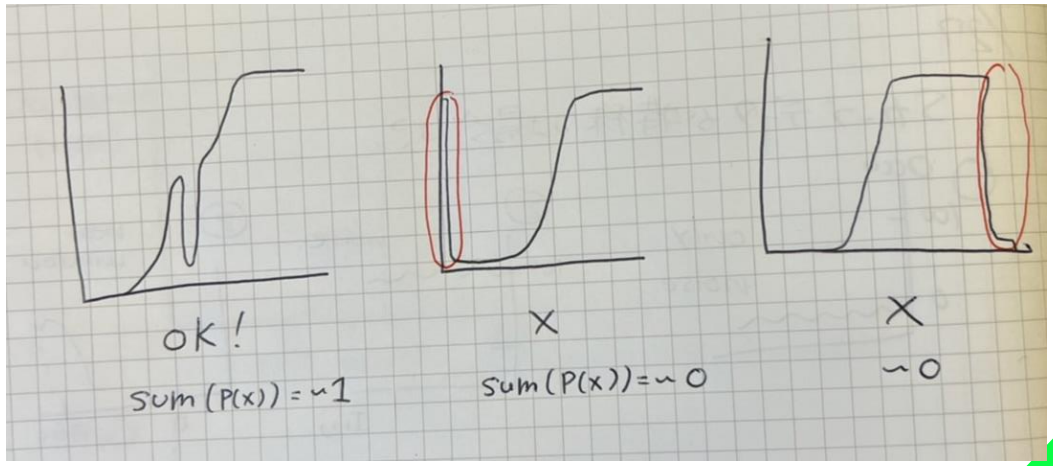
case①② | Threshold & noise results

- **Of cource, Results are strange.**
  - Threshold = ~0
    - $Threshold\ E = \sum_{i=0}^{N} x \cdot p(x)$
    - $\sum_{i=0}^{N} p(x) = 0$
    - p(x)= ($n(i+1) - n(i)$)/n_injections
  - Noise = unexpected
    - $Noise\ \sigma = \sqrt{\sum_{i=0}^{N}\left(x^2 \cdot p(x)\right) - threshold^2}$





- [To solve it] classify these pixels as **a failed fit**
  - Criteria of **Threshold**
    - because threshold is likely around 0
    - for example: Threshold<vcalMin or Threshold<500
  - Criteria of **sum(p(x))**
    - because sum(p(x)) is likely around 0
    - for example: p<0.5 && -0.5<first_p<0.5 && -0.5<last_p<0.5
      - first_p is a p of most left part bin
      - last_p is a p of most right part bin



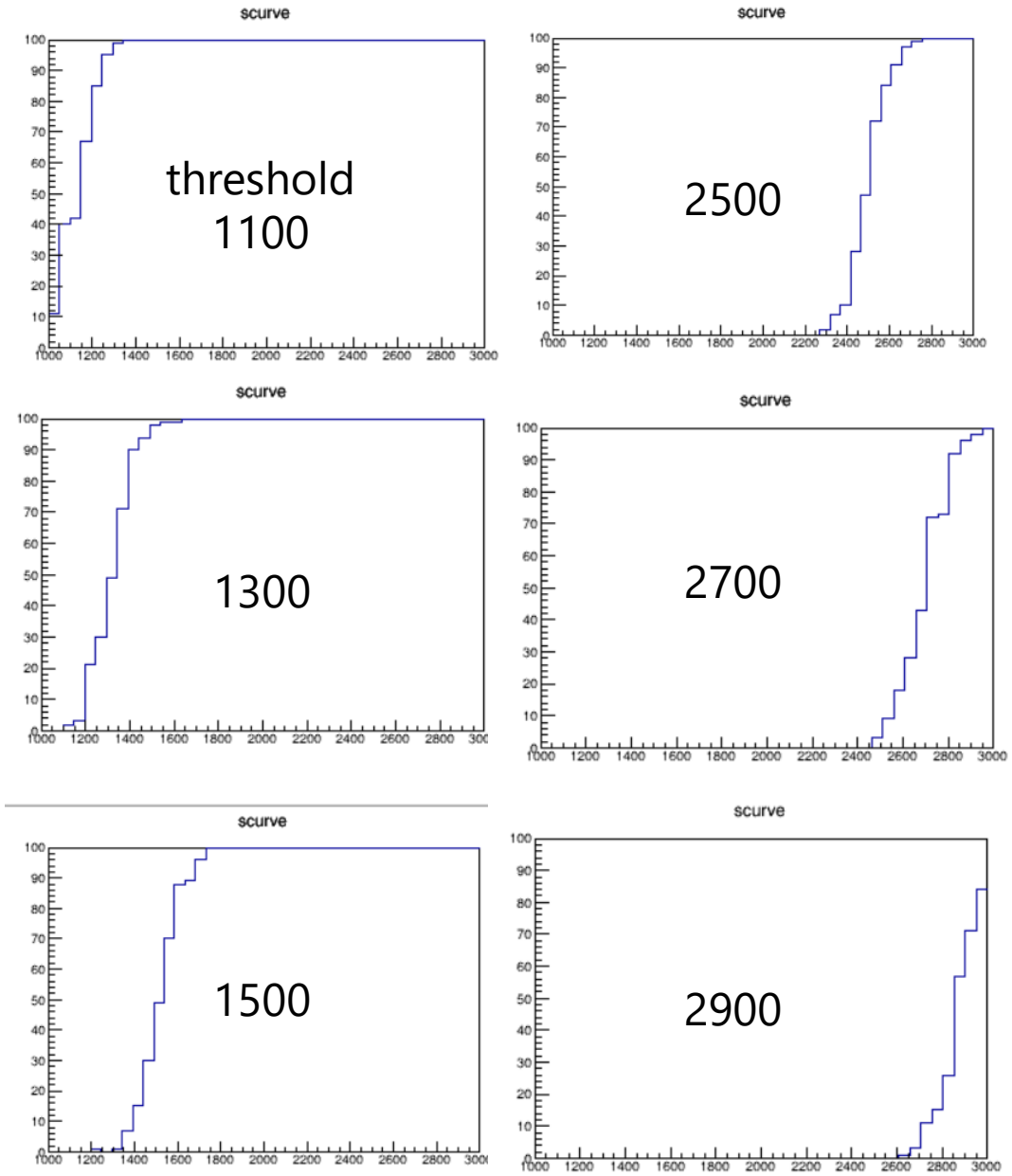
case③④|Threshold & noise results

- **Results depends on the distance from edge window**
  - In edge part, threshold difference get large
  - **Is this failed fit? or do we need to get threshold value?**
    - I think it is difficult to derive precise threshold in this case

オレンジグラフはFailed Fitに分類する。
pのガウシアンを求めて、面積が対象じゃなければ
Failed Fit
Threshold-Noise＜vcalMinとか？

Setting threshold[e]	1100	1300	1500
Threshold result[e]	998	1297	1502
Noise result[e]	358	96	101

Setting threshold[e]	2500	2700	2900
Threshold result[e]	2505	2709	2407
Noise result[e]	98	110	1053



Summary

- Calculation method works well in ideal threshold data.
  - The benefit is **the number of failed fit pixels**
- Next, we need to think about **criteria** for rare cases
  - we should discuss more
- **This is my last day in LBNL. Thank you for teaching me for this 10 months!**