pC polarimeter: 2-layer detector test

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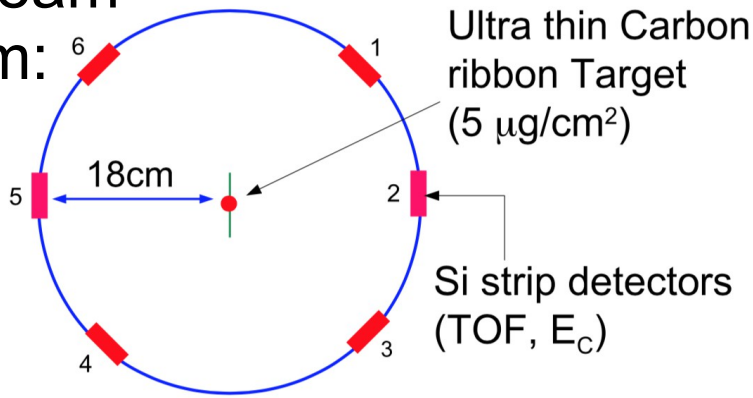
mtg. 02.03.22

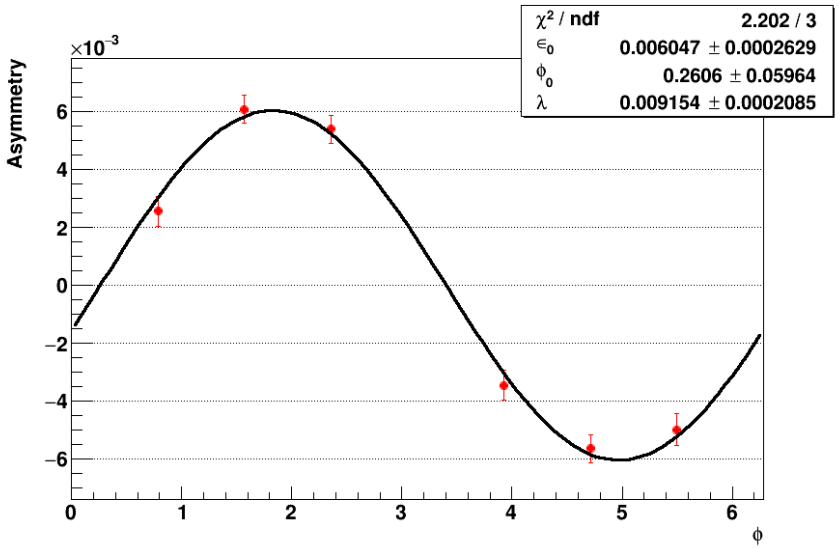
- proton-Carbon (pC) polarimeters @ RHIC
- pC→EIC challenges: backgrounds
- 2-layer detectors @ RHIC (this year):
  correlations Front & Rear detectors

pC polarimeter @ RHIC

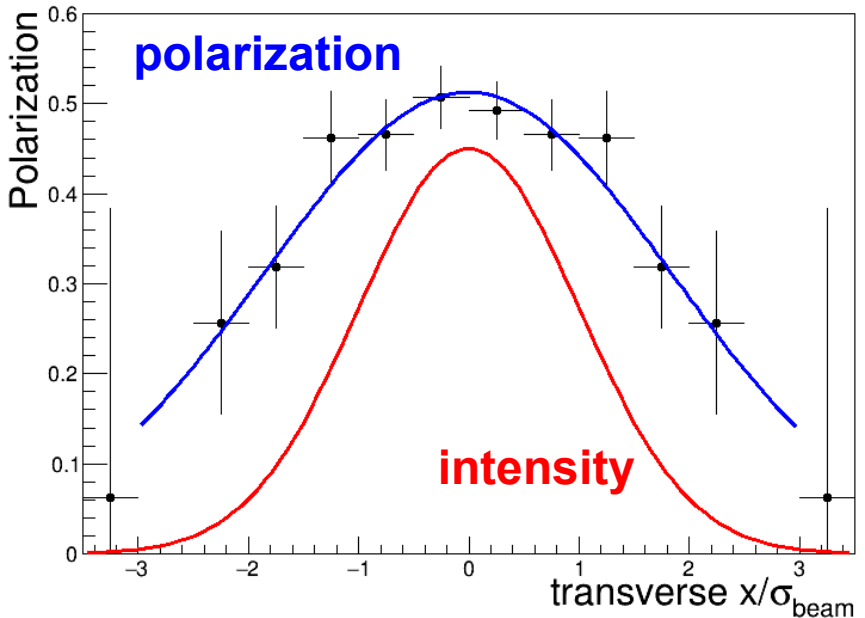
- 6 Si strip detectors around beam
- C target passed across beam:
  P(x) ⇒ polar. profile



- Fit 6 det. asym. w.r.t. beam +/-:
  - max. asymmetry ϵ_0
  - beam spin tilt from vert. ϕ_0
  - asymmetry +/- beam λ



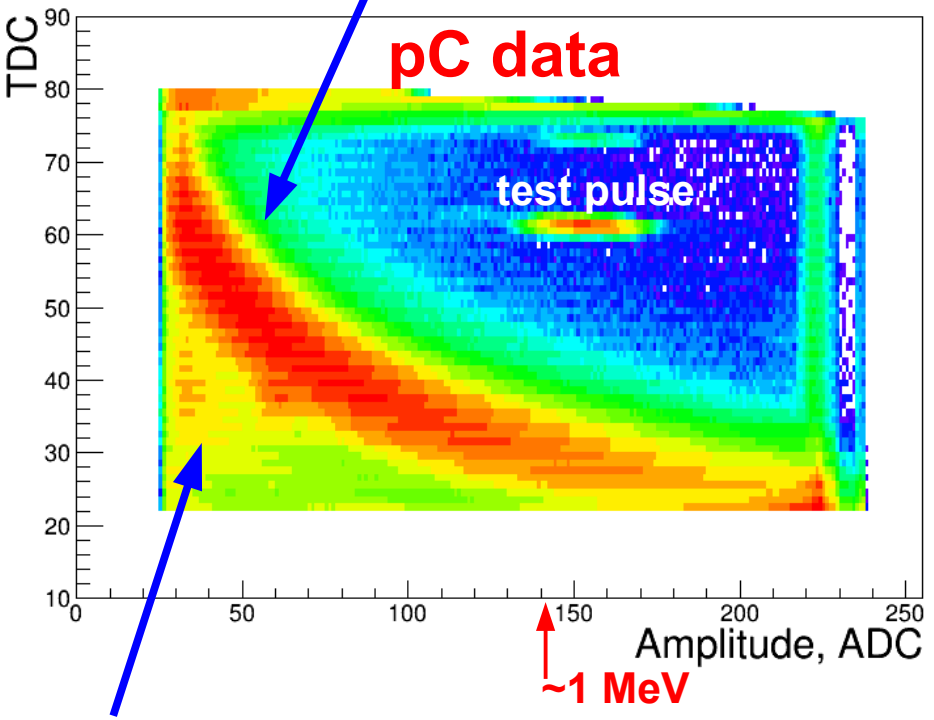
- Measure P in bins of x/σ_{beam}:
  polarization profile $R = (\sigma_{beam}/\sigma_P)^2$



pC @ RHIC: backgrounds

- pC Si detectors measure: ADC → kinetic energy
  TDC → Time Of Flight (TOF)
- TOF vs E_{kin}: signal in TOF $\propto 1/\sqrt{E_{kin}}$ "banana" curve:

1 TDC ≈ 1.2 nS



HERE WILL SHOW A LOT OF THESE TDC vs ADC 'BANANA PLOTS';

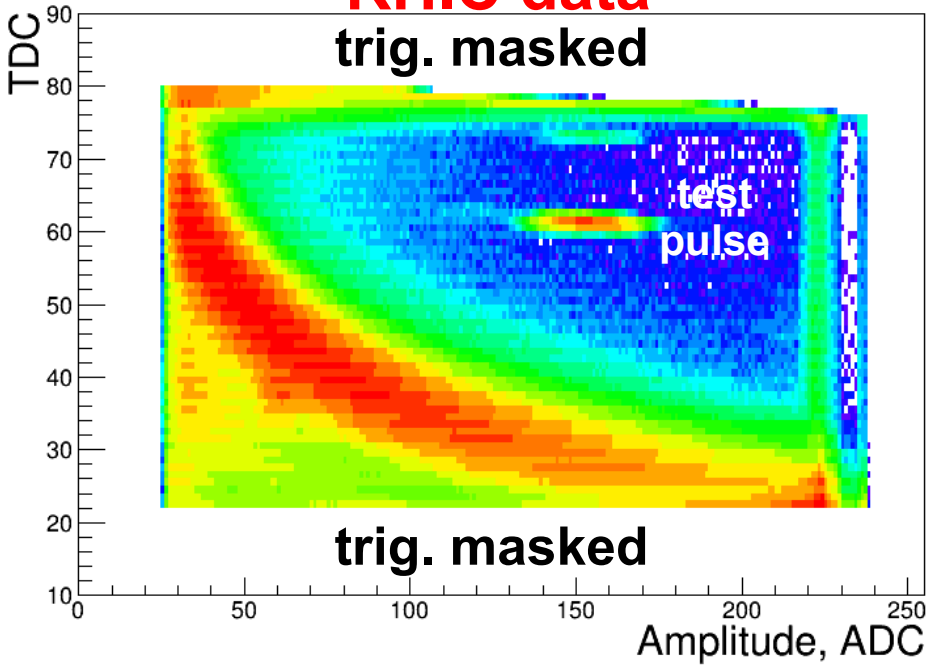
FOCUS: WHAT'S OUTSIDE 'BANANA'

- Clear backgrounds below "banana" curves
  predominantly @ earlier TOFs
- pC: bkg. dilution calibrated in pC/Hjet normalization
- Problematic RHIC→EIC ↘

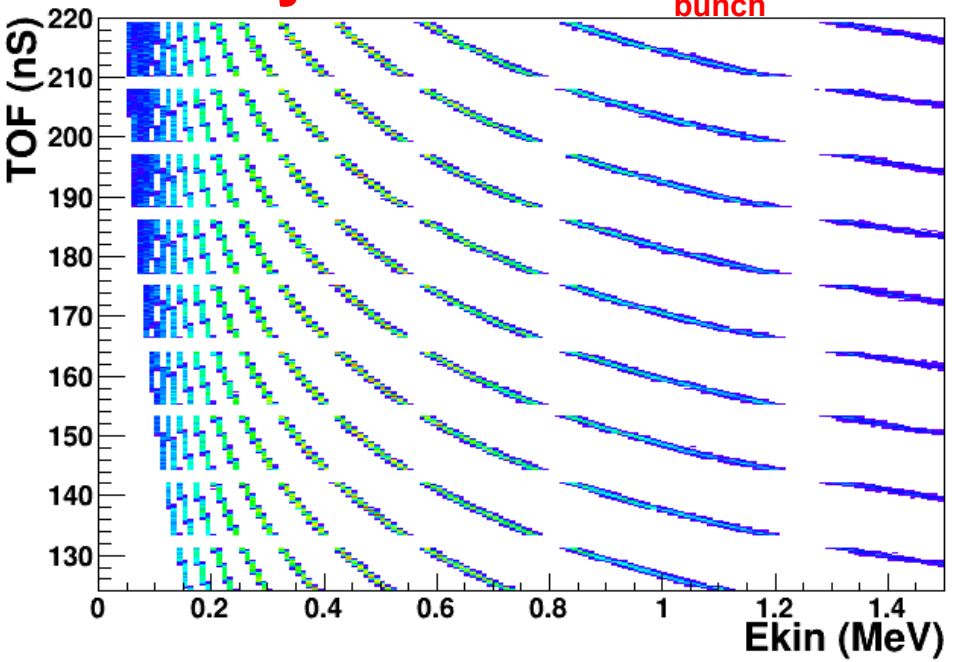
RHIC→EIC: 120→1160 bunches

- Carbon TOF ~20-90 nS; bunch spacing 11 nS
  carbons from several bunch ×ings in system simultaneously:
- EM pulse during beam crossing:
  WFD triggering masked ~ beam ×ing time

RHIC data



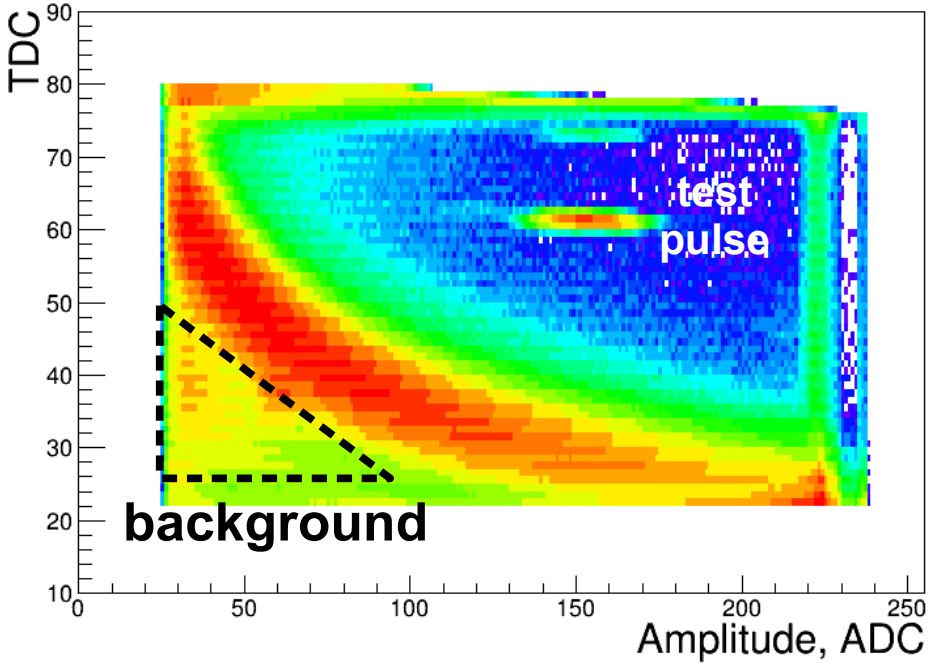
EIC toy MC: smear L_{bunch} 0.2 nS

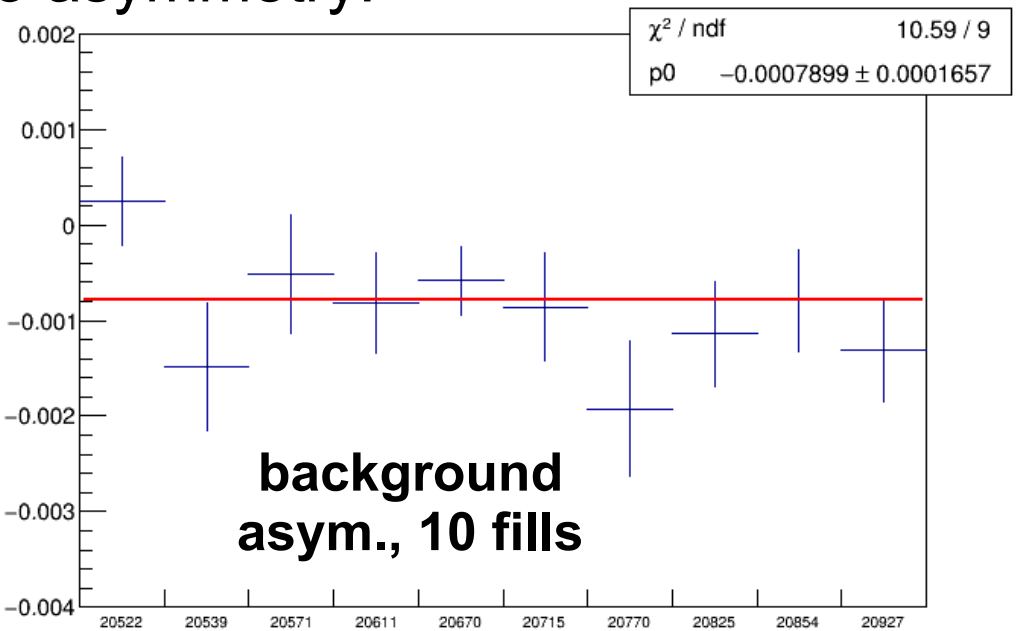


- Need to sort (Ekin,TOF) segments → bunch ×ings
- Tractable problem, but … ↘

RHIC→EIC: Signal/bkg. overlap

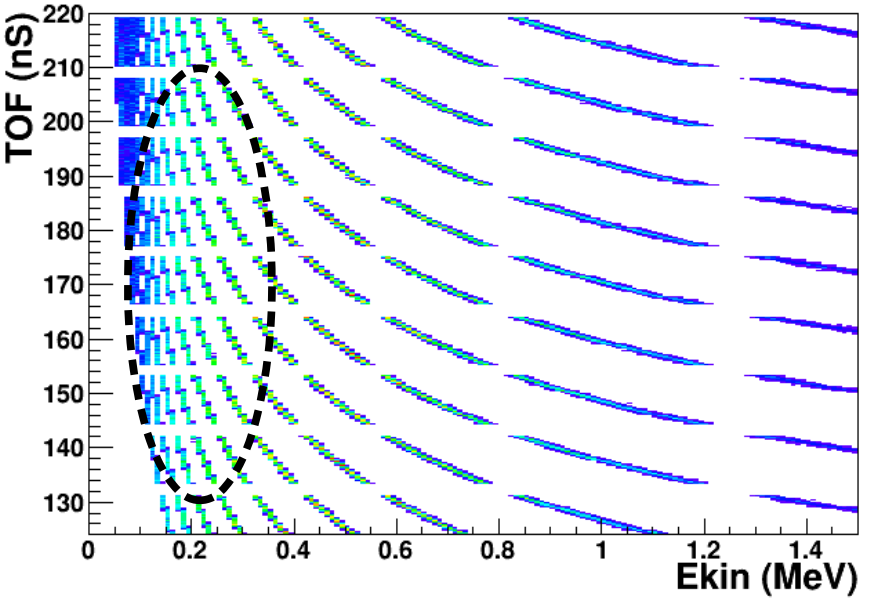
- Non-carbon background under signal, nature unclear
- Events this region small non-zero asymmetry:





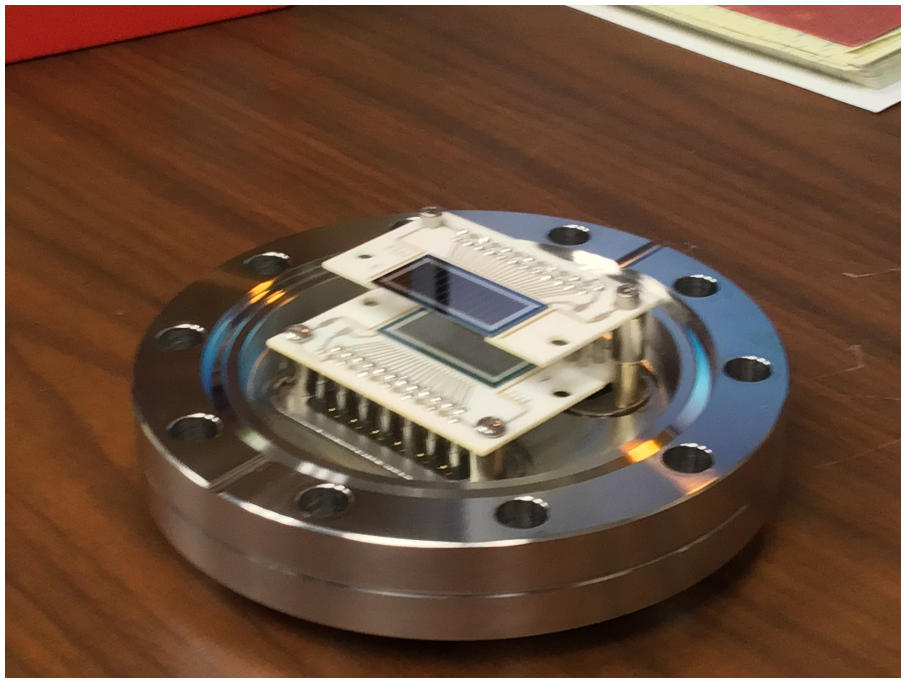
- @ RHIC: asym. calibrated out pC/Hjet
- @ EIC:
  - overlaps w/ adjacent bunches
  - may be same/opposite +/- beam spin
  - dilute/enhance asymmetry
- A real mess...
- Can we tag background?

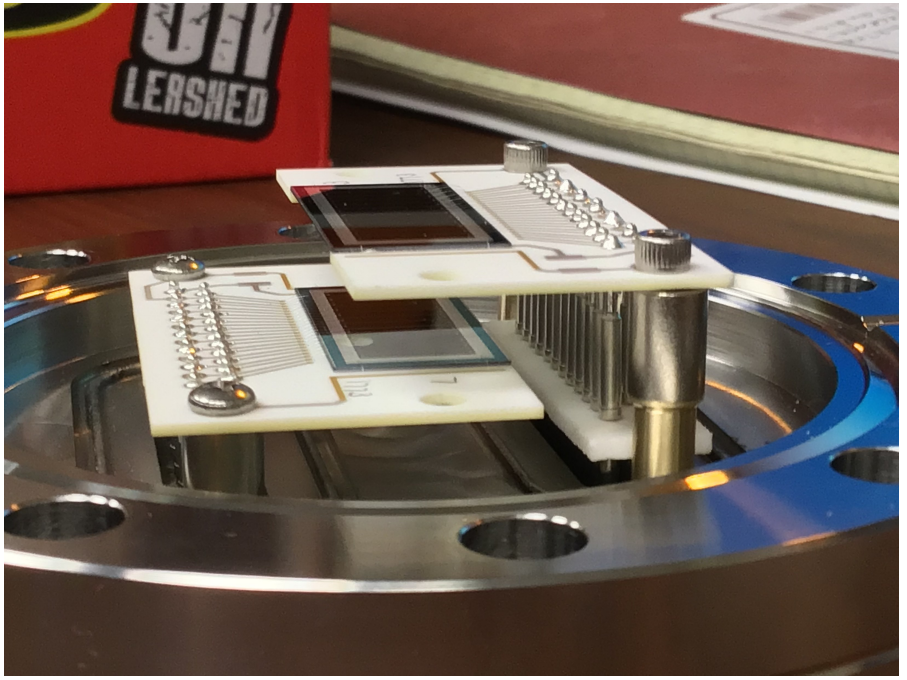
If punch-throughs: 2nd detector layer



2-layer detectors

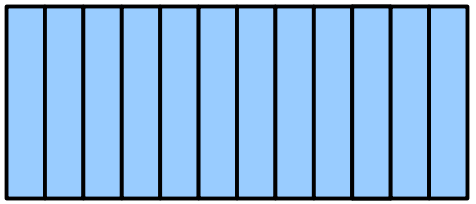
Minimal resources R&D, using existing hardware, DAQ, software...
Normal 1-layer detector, 2nd detector above:



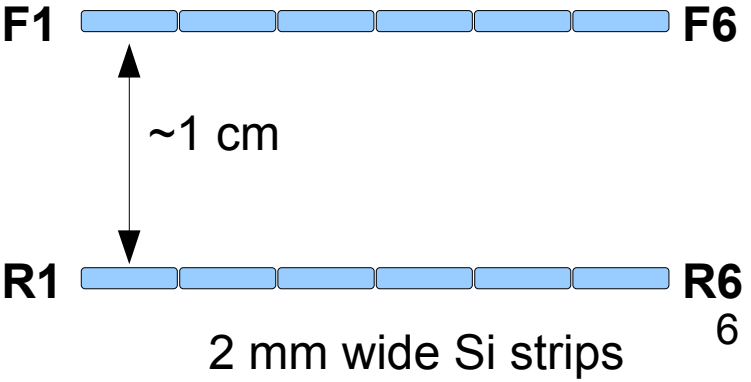


- Working since start of beam Dec. 2021
- Installed port 1 of Blu1U, Yel2U

- Si detectors:
  - 12 × 2 mm wide strips
  - 1 cm long
  - 200-250 μm thick

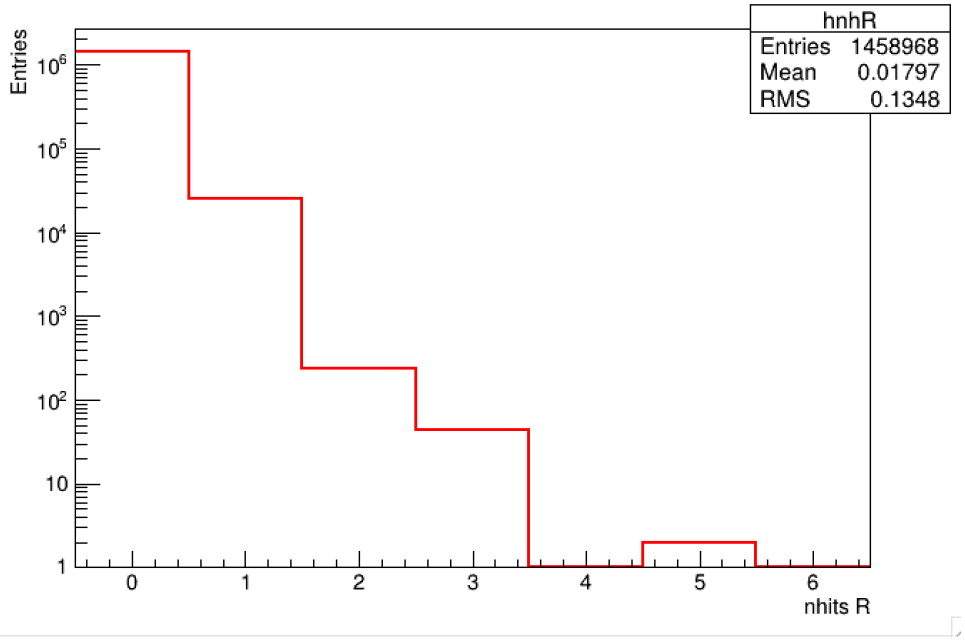


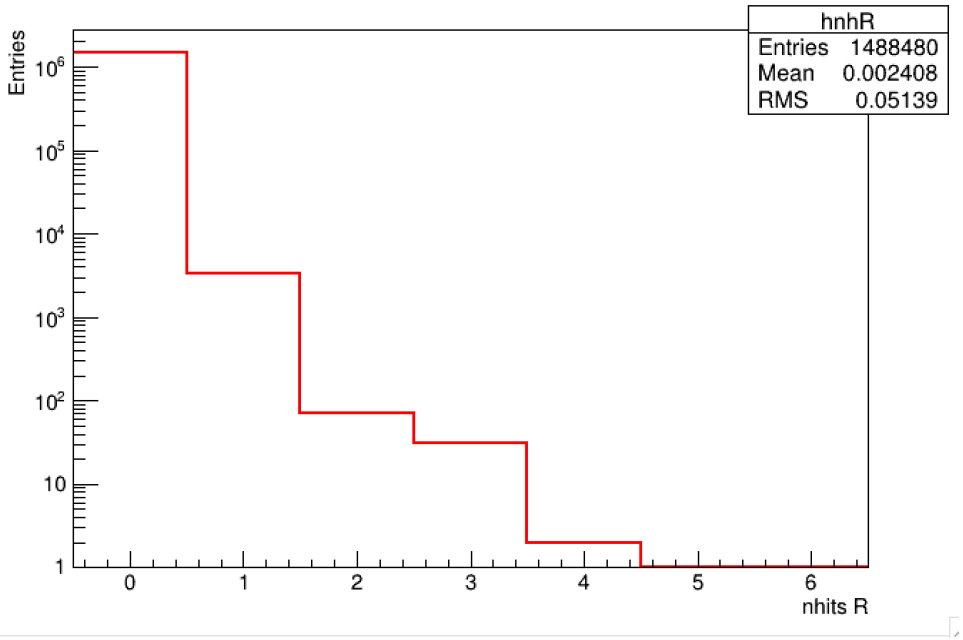
- Readout: 6 Si strips each Front/Rear:



F hits: # R hits

- Events (bunch ×ings) with hit in Front: hit in rear?



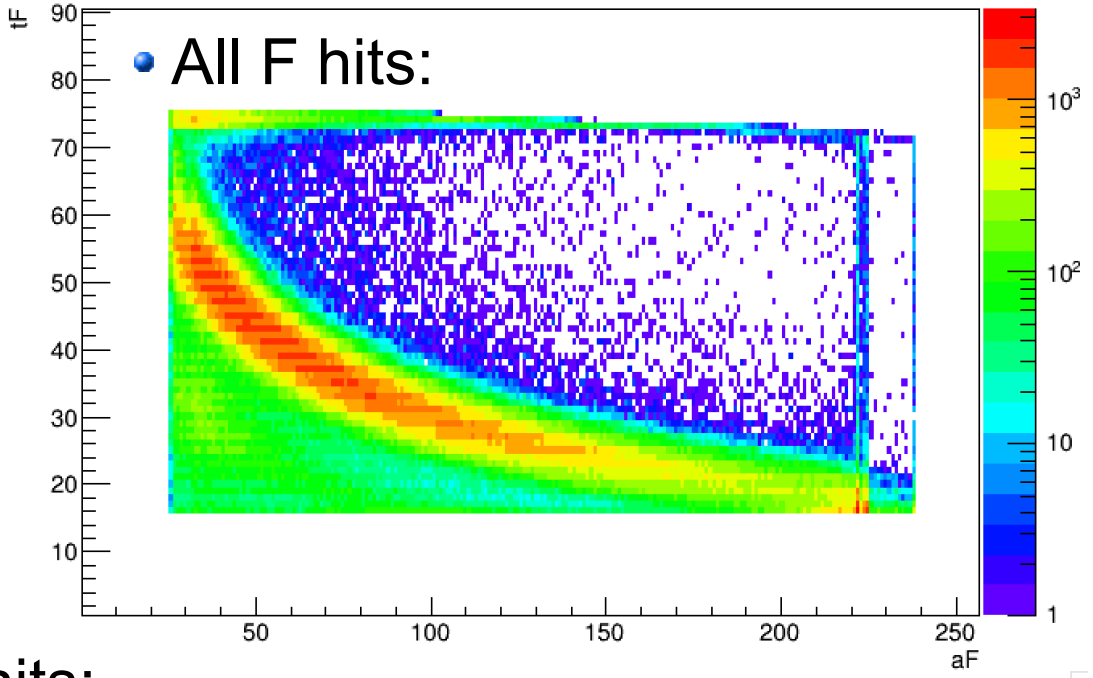


- Blu1: 1.8% have R hits
- Yel2: 0.2% have R hits

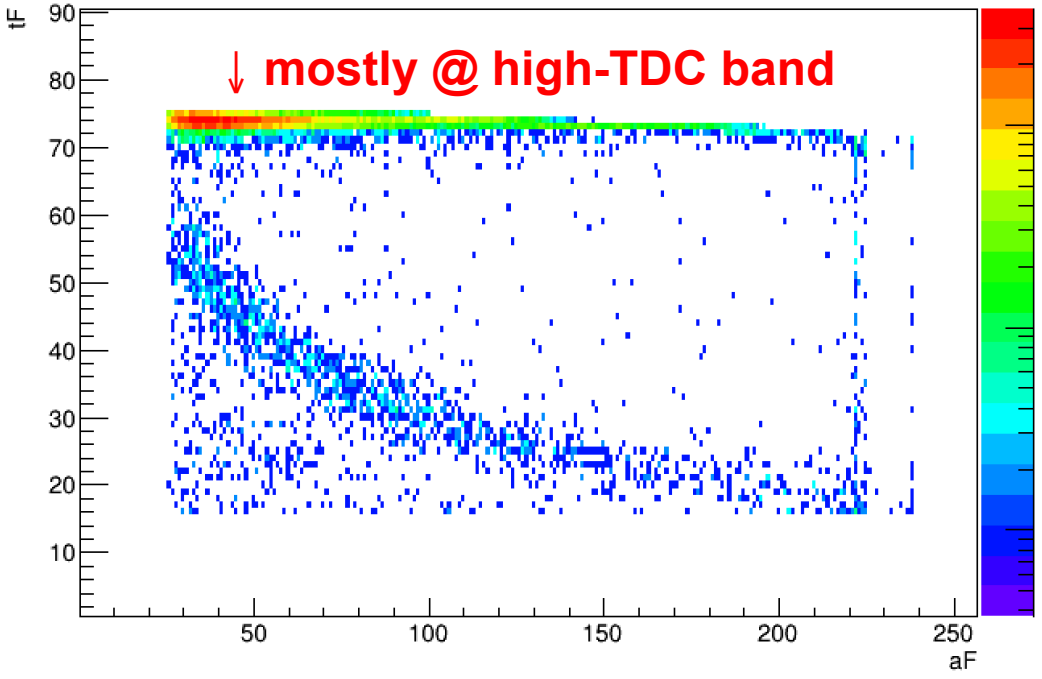
- Blu/Yel different DAQ TDC windows, different sensitivity to beam induced prompts (clarified in next slides)
- Focus here on Blu1, more R hits
- Focus on nhitsR = 1, avoid ambiguity which R hit

Front T vs A, R hits / no R hits

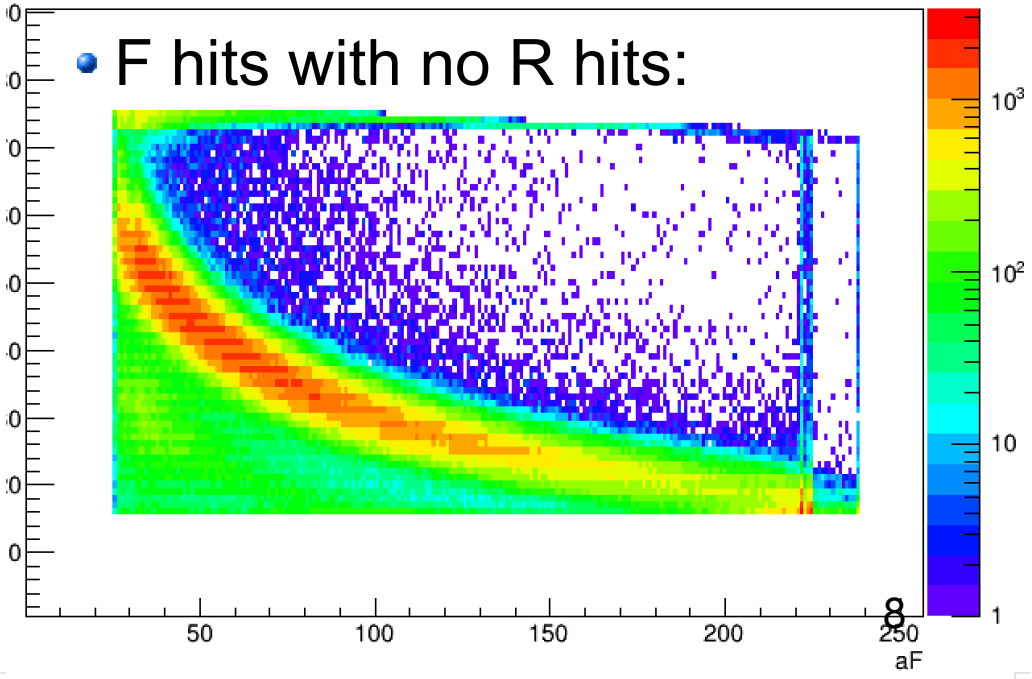
- All F hits:



- F hits with R hits:



- F hits with no R hits:



High-TDC feature

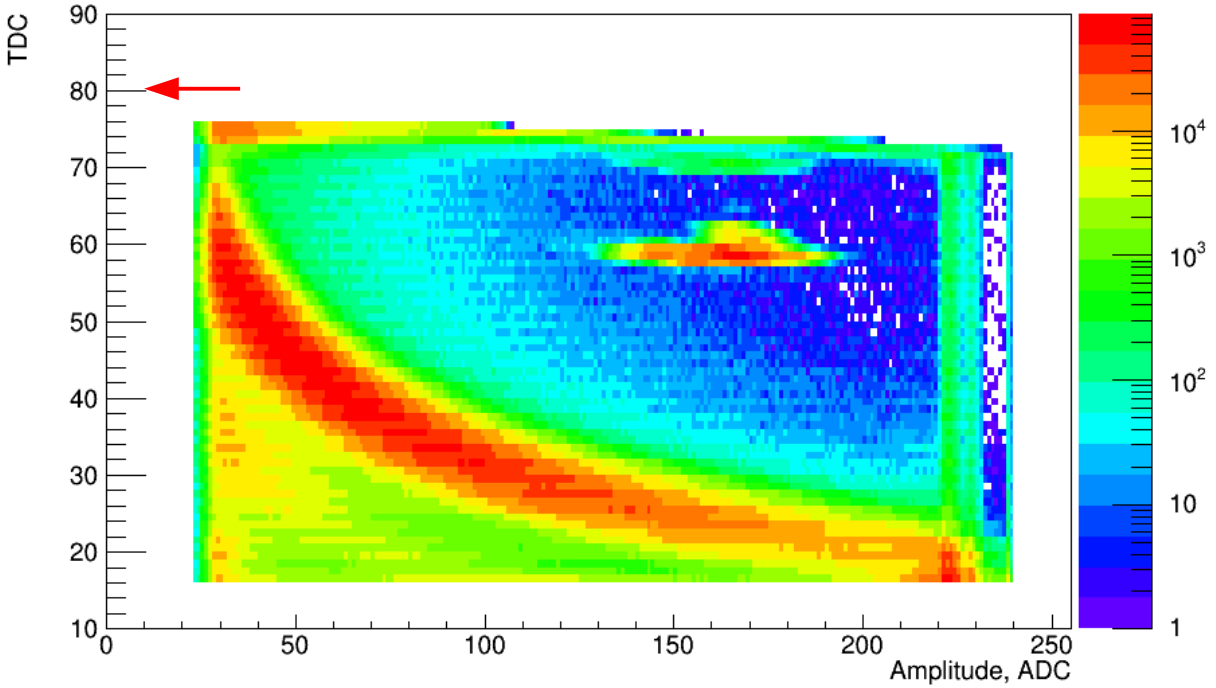
Bunch ×ing period = 90 TDCs

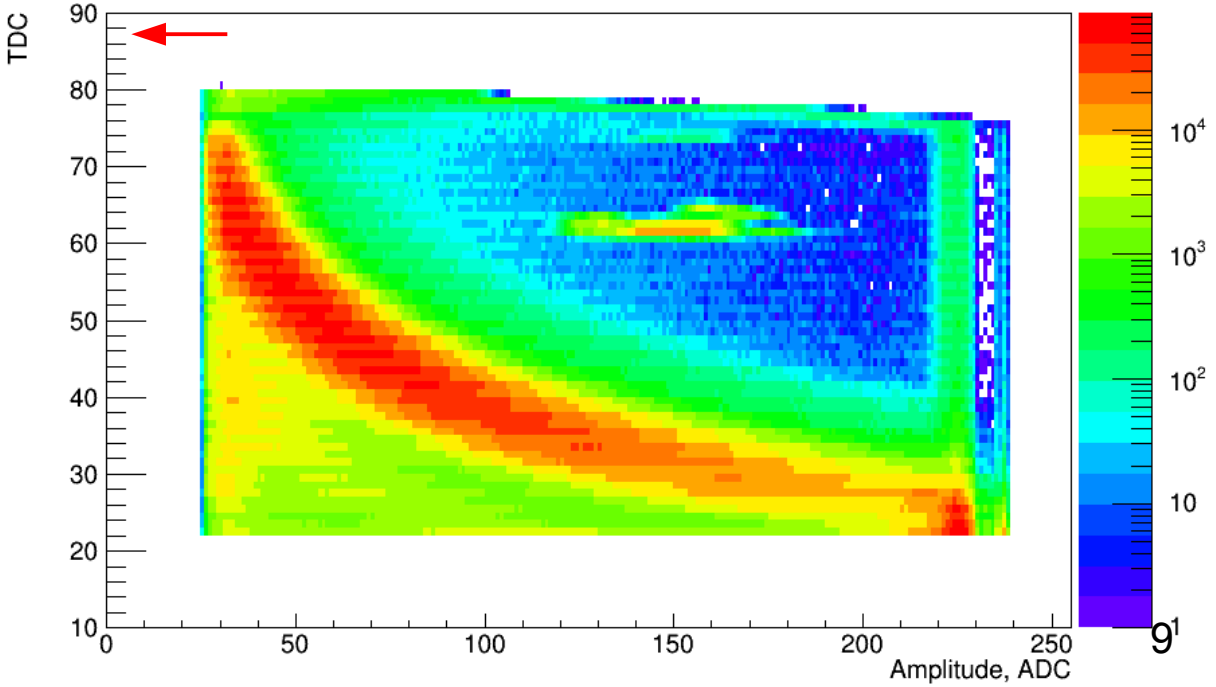
Blue

- Bunch ×ings @
  -10 TDCs, 80 TDCs
  (details extra slides)
- High-TDC feature:
  prompts from start of
  beam pulse

Yellow

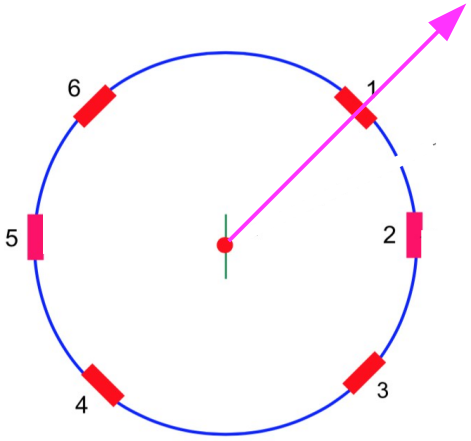
- Bunch ×ings @
  -3 TDCs, 87 TDCs
- End of DAQ window
  earlier in beam pulse
- High-TDC feature
  fewer events,
  fewer prompts

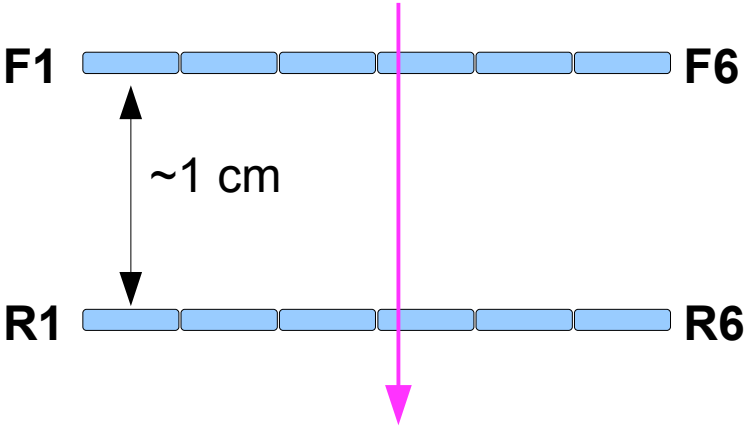




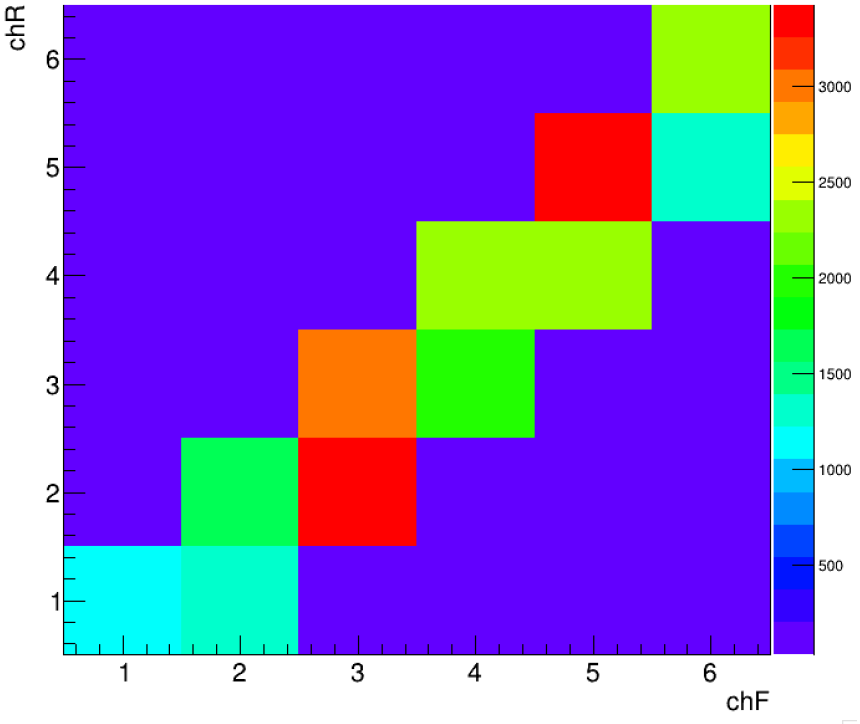
F+R hits: channel correlation

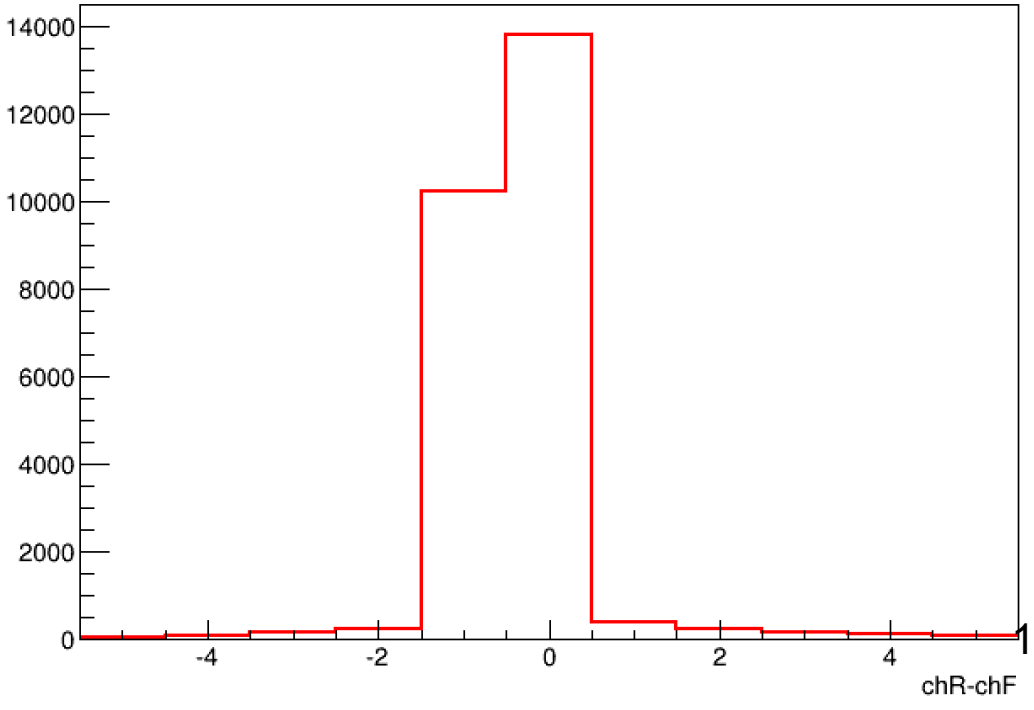
- Prompts from beam/target ⊥ detector planes:





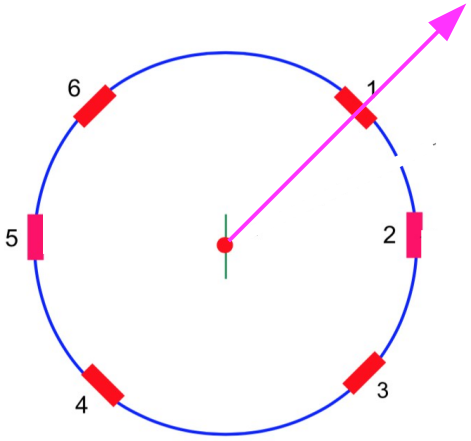
- Chan. # R ≈ F (±1, misalignment):

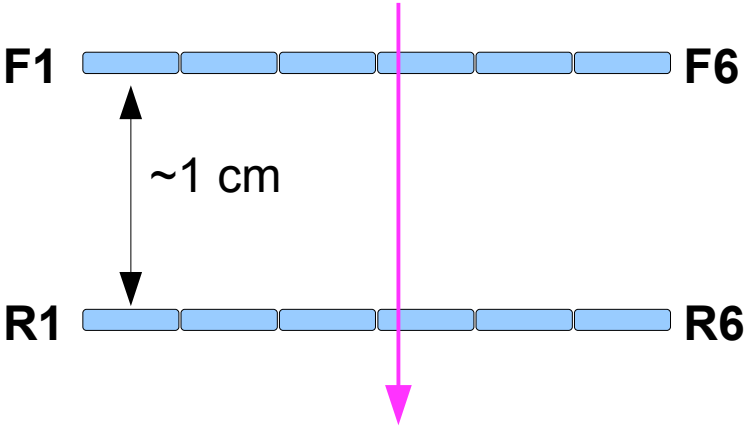




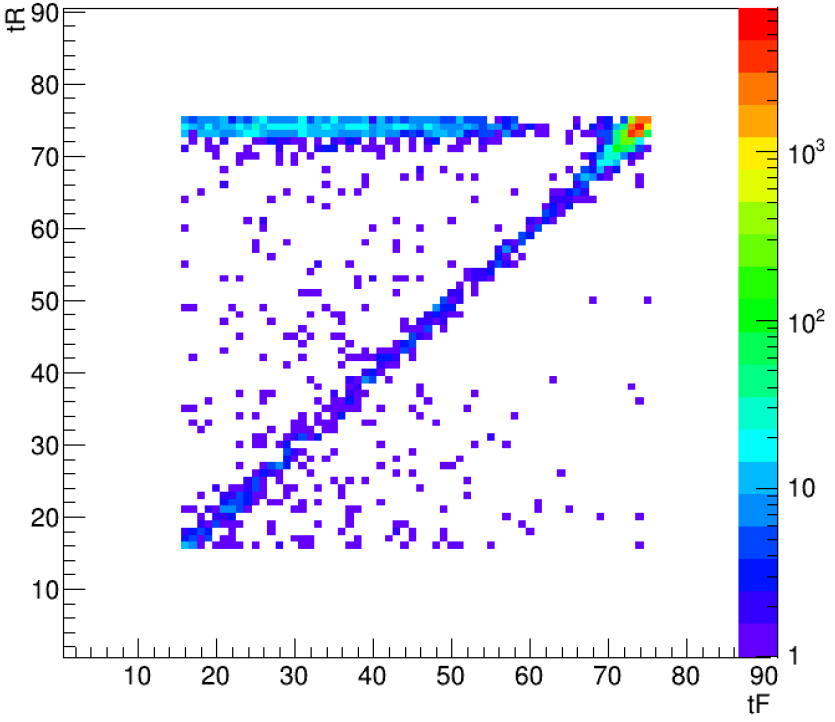
F+R hits: time correlation

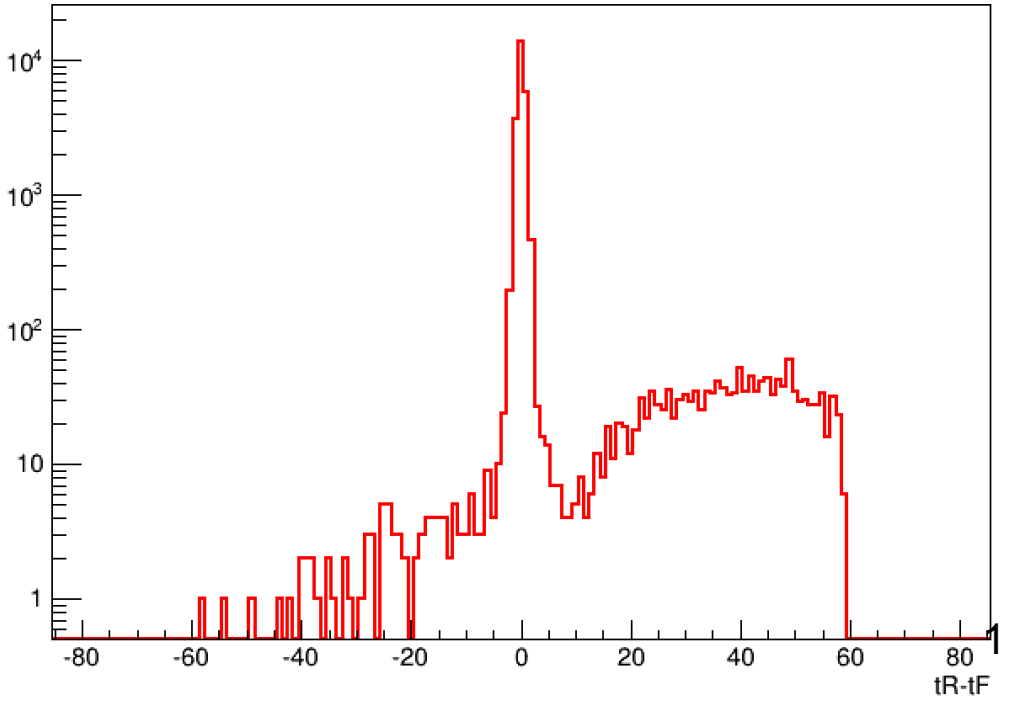
- Prompts from beam→target v ≈ c; 1 cm Δt~30 pS





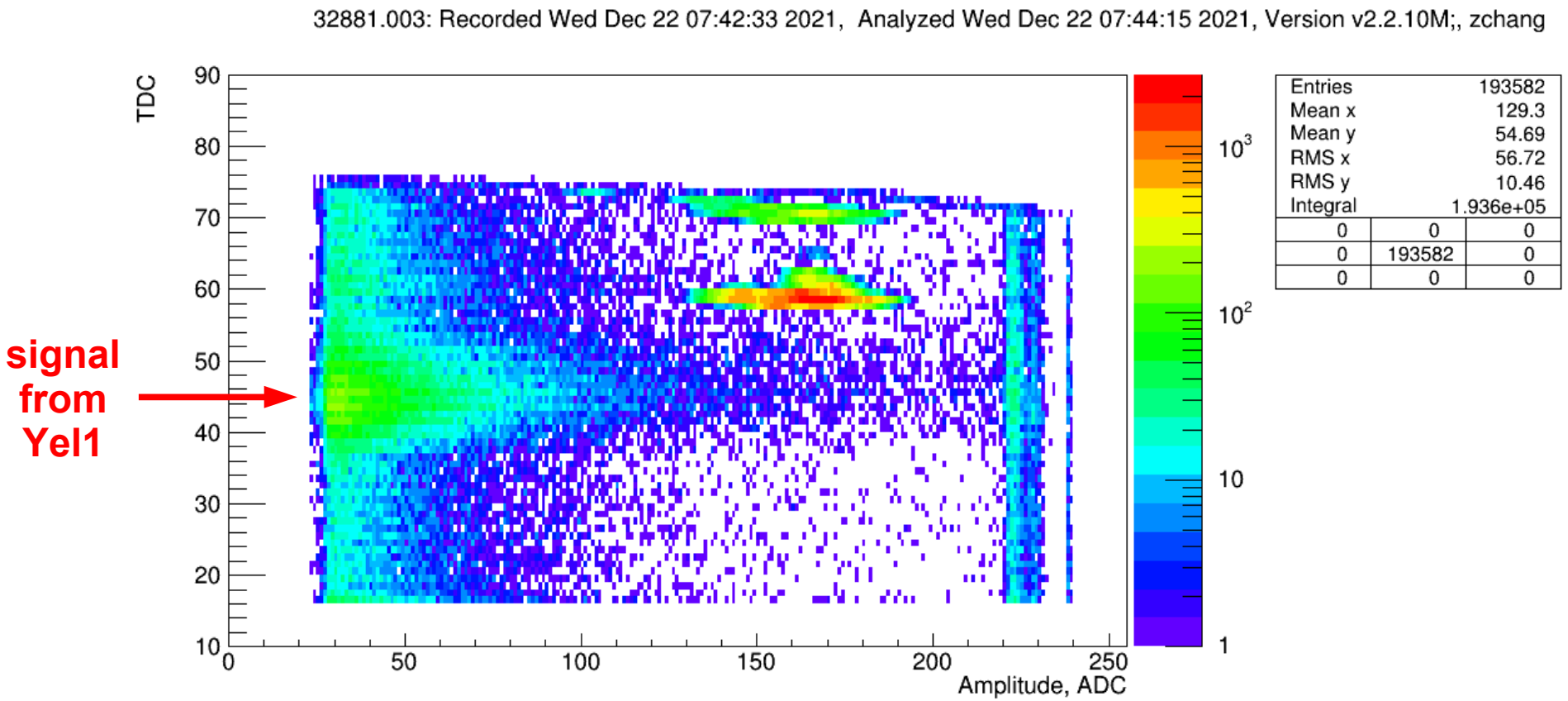
- TDC F ≈ R:





aside: Hits from Yel→Blu

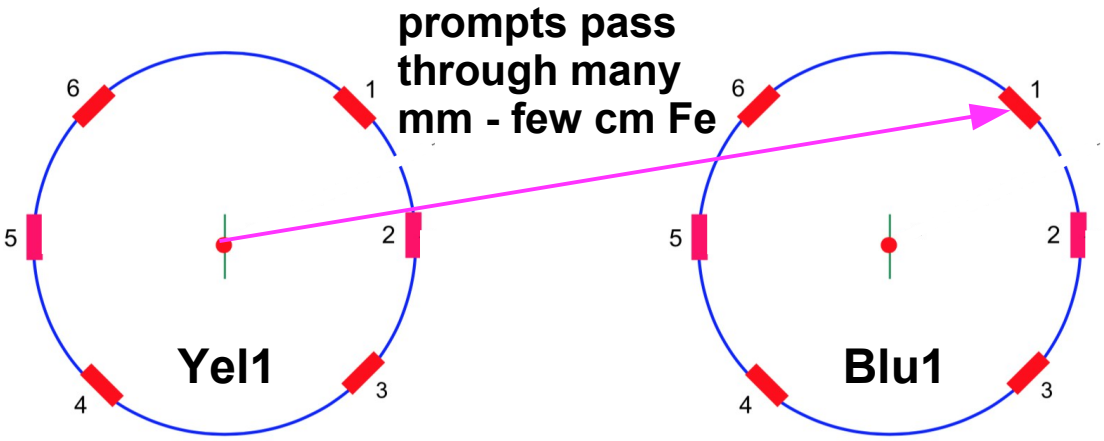
- MCR ops sometimes in error operate
  Blu, Yel polarimeters simultaneously
- Here Blu1 while Yel1 in operation, Blu empty bunches:

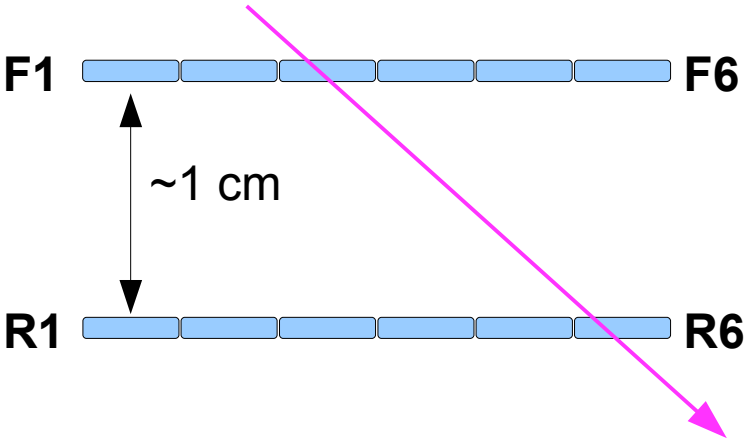


- @ pC polarimeters: Yel bunches filled in Blu abort gap
  Yel, Blu beams pass at different times
- Select hits from Yel1: 40<TDC<50

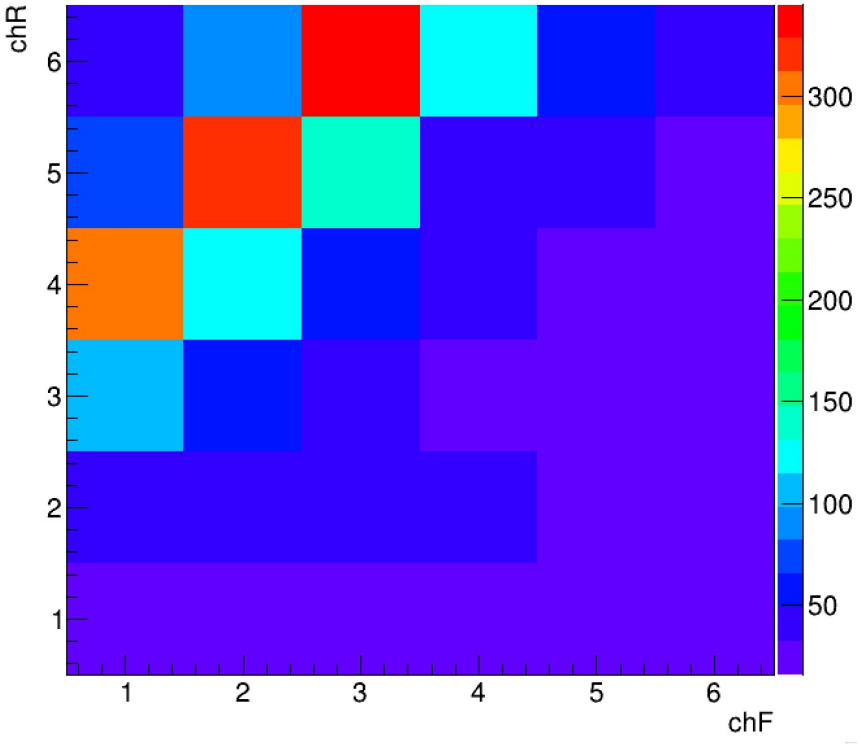
aside: Hits from Yel→Blu

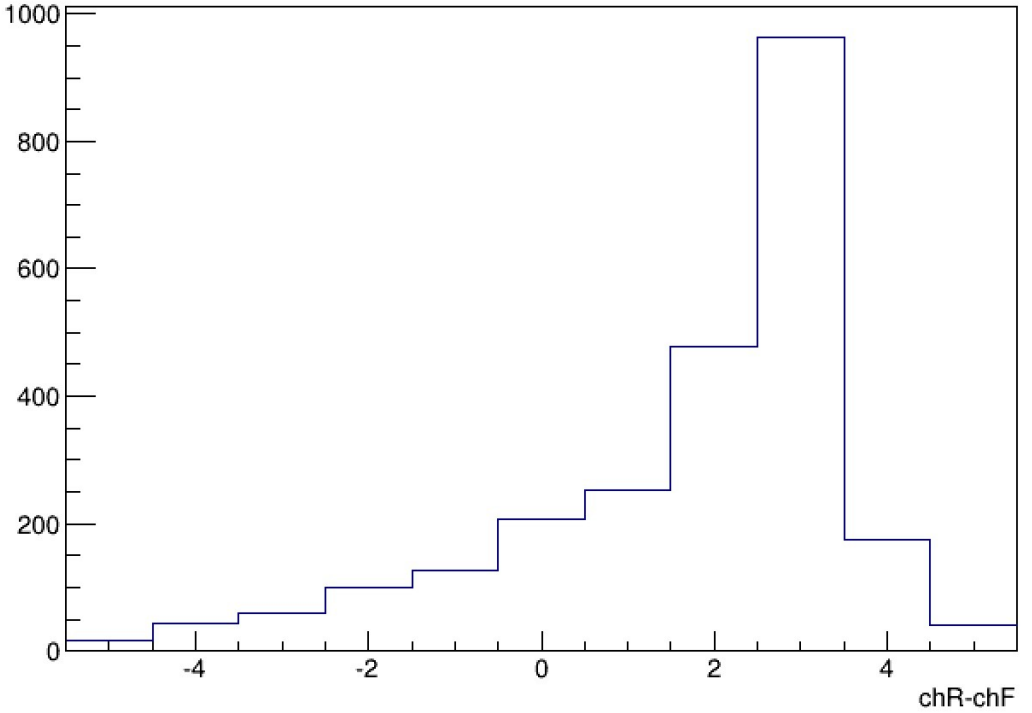
- Prompts from Yel beam → Blu det. 1 **not** ⊥ detector planes:





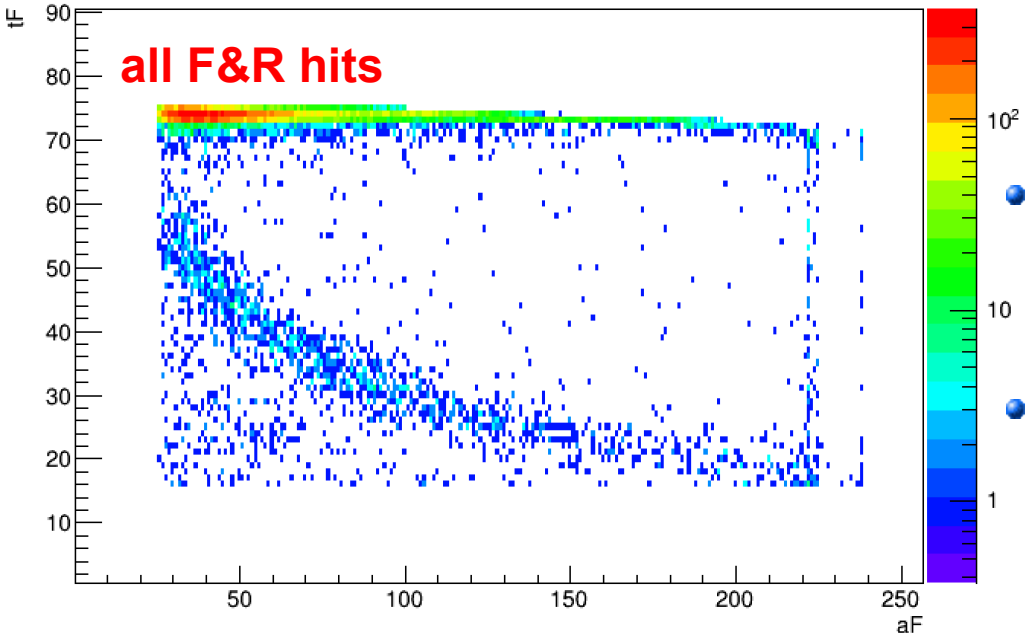
- Chan. # R ≈ F+3:



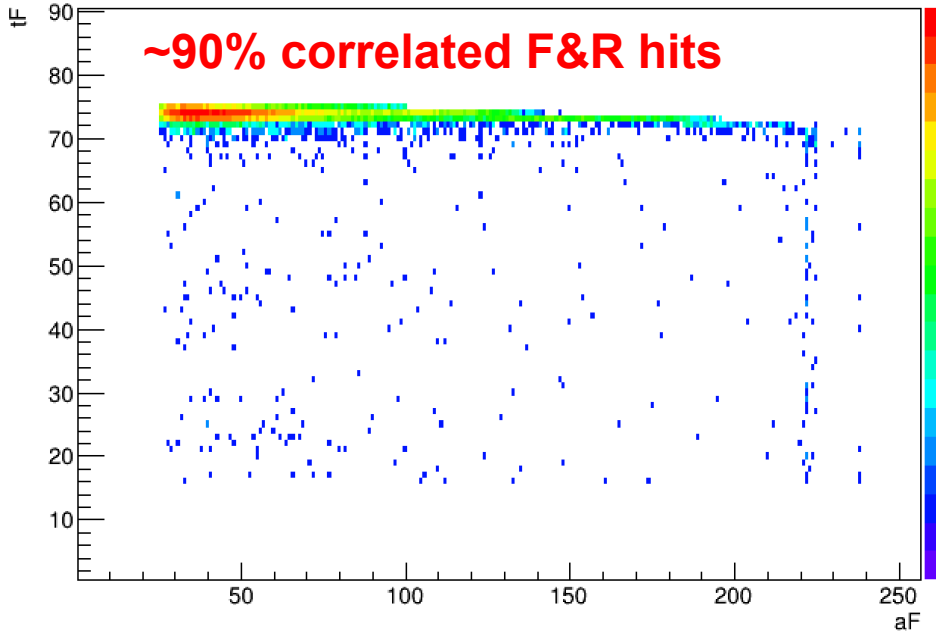


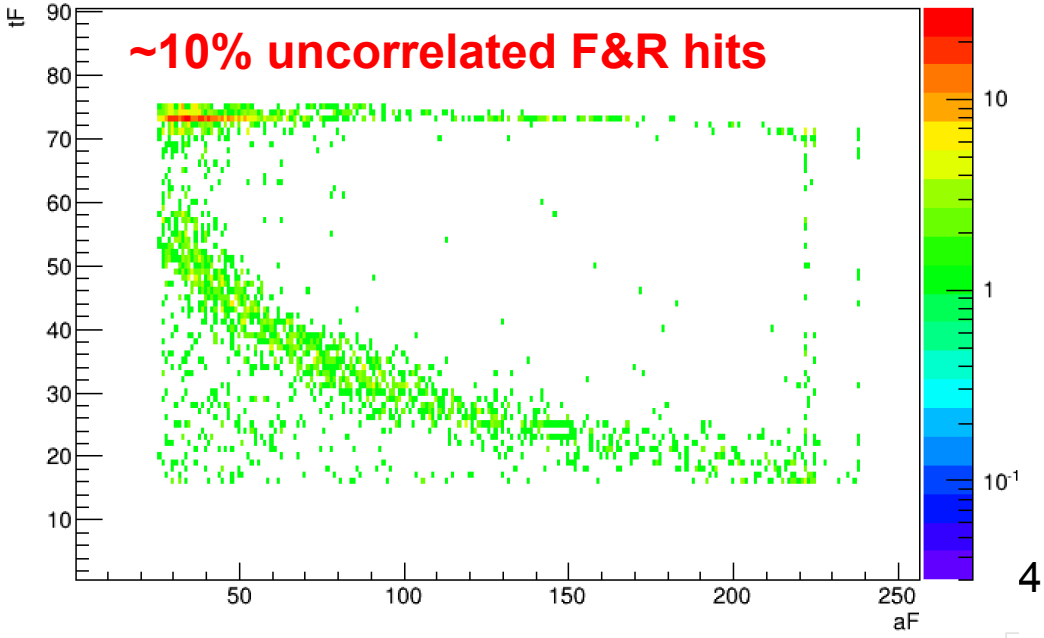
Hits correlated / uncorrelated

- Many F&R hits correlated in position (chan. #) & time
- Define correlated F&R hits: chR = chF (-1) ← chan. #
  |tF-tR| ≤ 1 TDC ← time



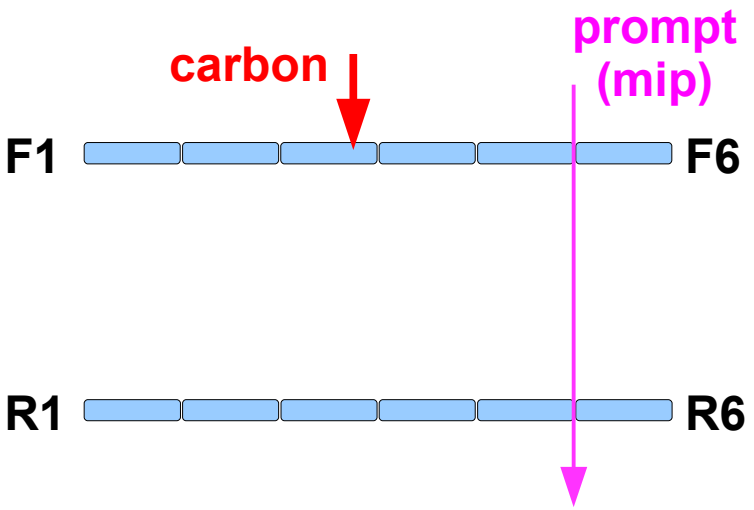
- Correlated: clean selection of hi-TDC beam induced prompts, mip-like
- Uncorrelated: large carbon component, range out in F; F&R hits from different particles



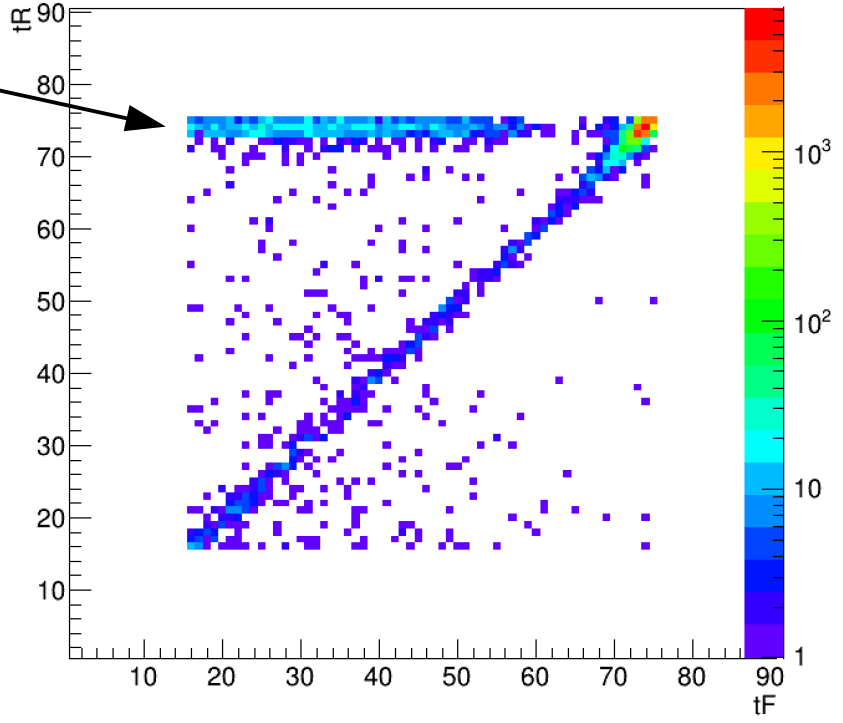


Uncorrelated prompts

- Possible scenario:
  - carbon ranges out in few μm in F (Si 200-250 μm), no signal in R
  - prompt maybe too little E in F to trigger*, or pass through gap in F, & hit R strip with enough E to trigger



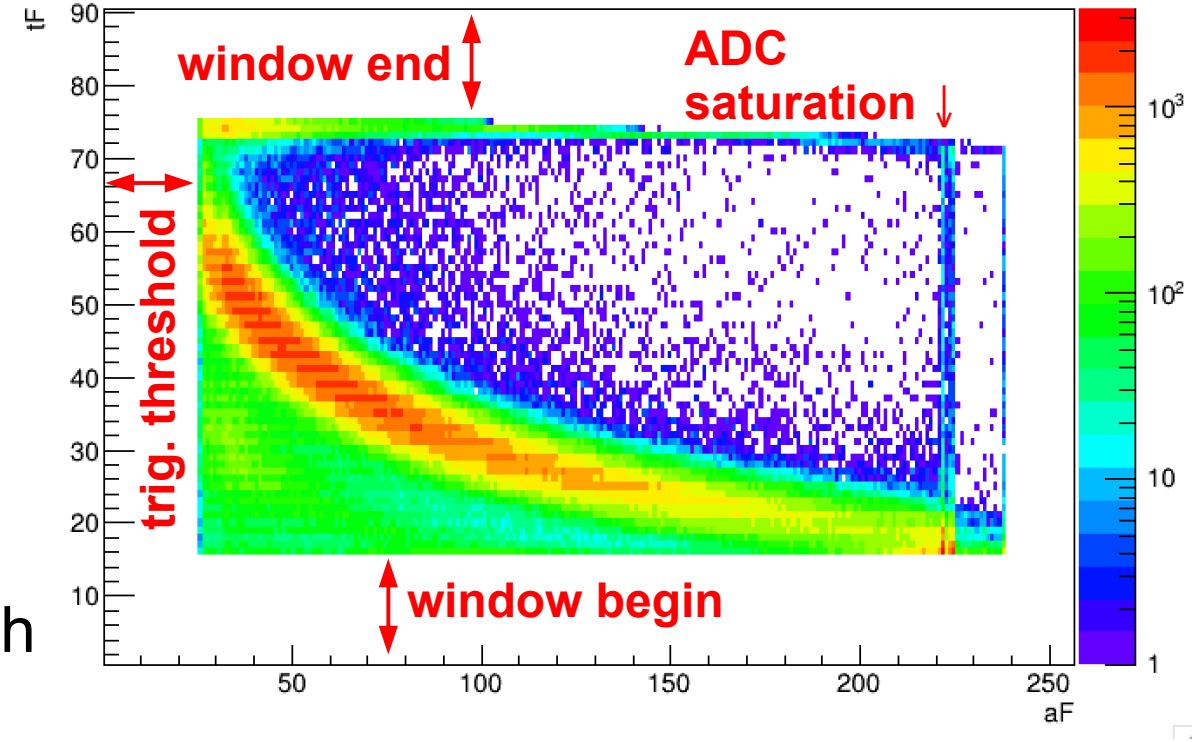
- This would also explain the high tR feature in tR vs tF:



*mips
- mip in Si: 3.876 MeV/cm (PDG)
- 200-250 μm: 80-100 keV
- trig. t.h. ~200 keV
  we trigger mips on high end of Landau dist.

Further studies

- We can move edges of DAQ window, extend E, TOF ranges



- Can adjust with config. files:

Change individual channels

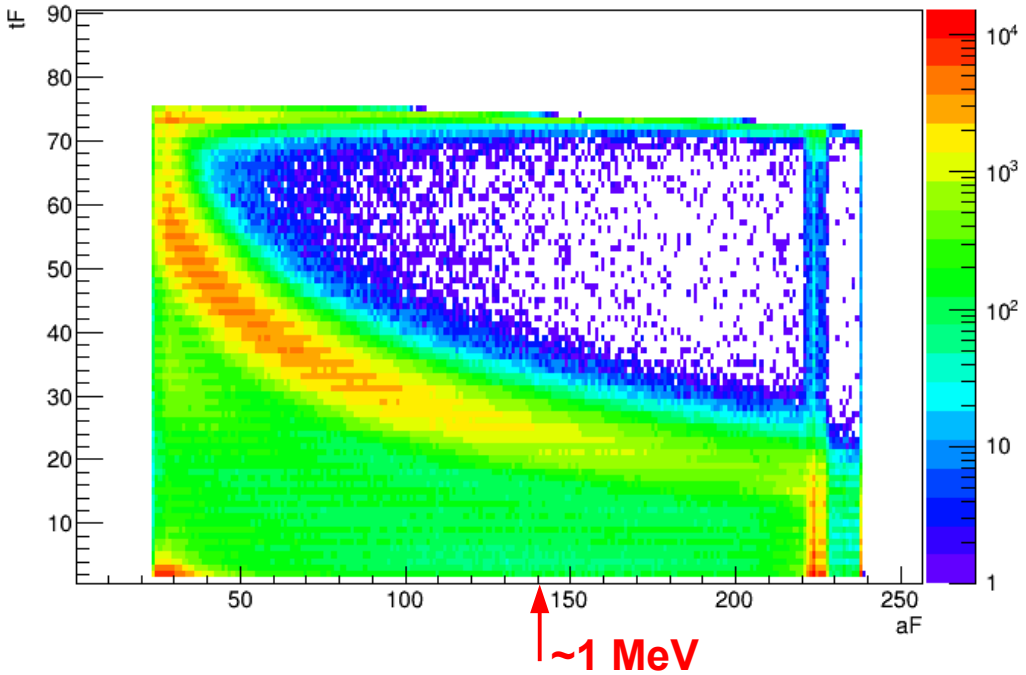
- Later window end:
  - just get more beam prompts ✘
- Earlier window begin:
  - see faster particles, some punch throughs? ✔

Global change all channels

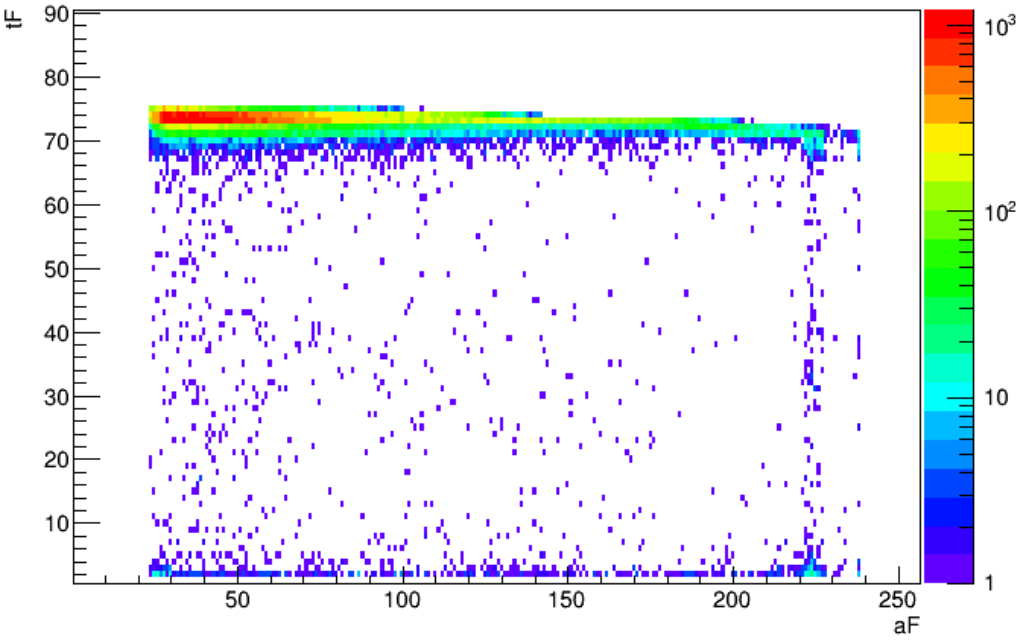
- Lower trig. threshold:
  - lower E but noise? ✘
- Above ADC saturation, apply attenuators 3×, 5×, 10×: higher E fragments, punch throughs? ✔

Low-TDC region

- Move start TDC range to 0:
  - All F hits:



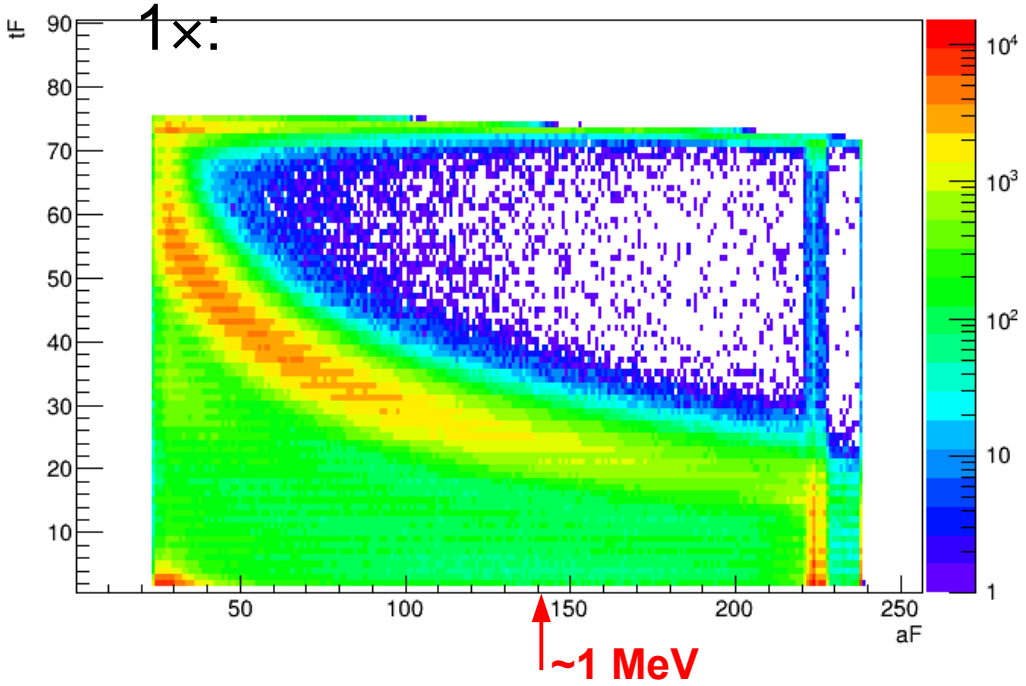
  - Correlated F+R hits:



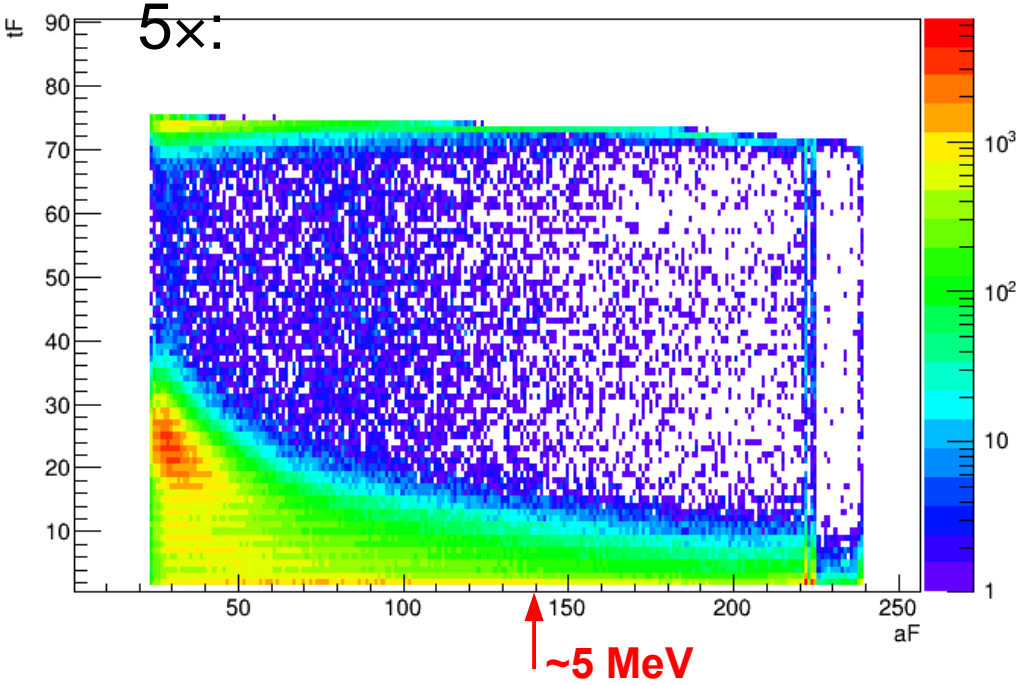
- Can see trailing edge of beam pulse (peak @ -10 TDCs), in addition to leading edge next beam pulse (@ 80 TDCs)
- No other new features

Low-TDC, high-ADC region

- Move start TDC range to 0, ADC attenuator 5×:
  - All F hits, 1×:



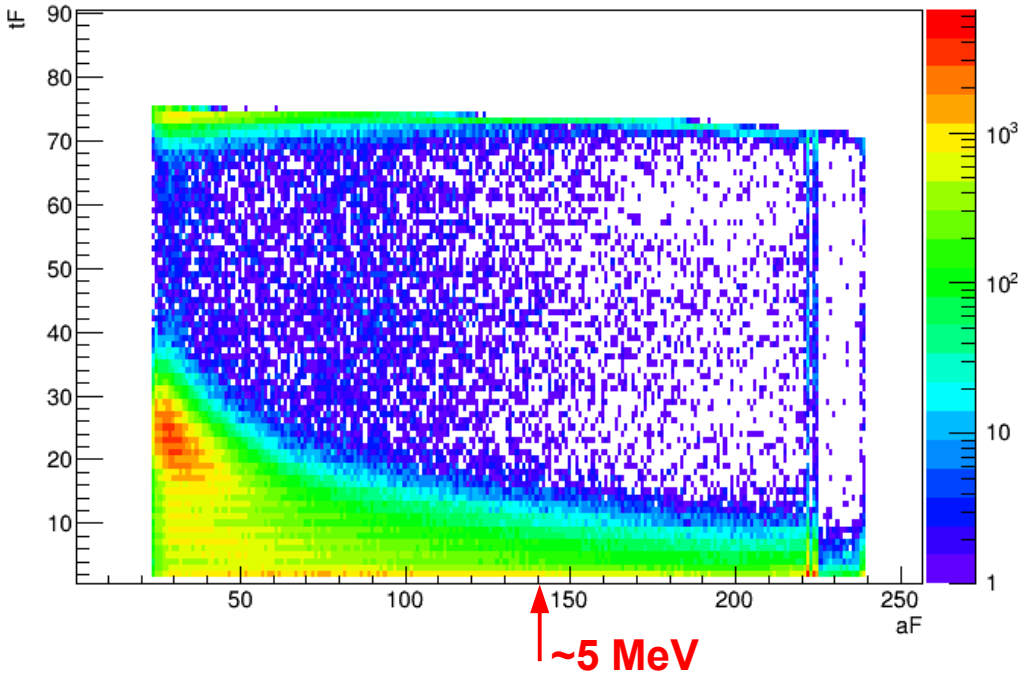
  - All F hits, 5×:



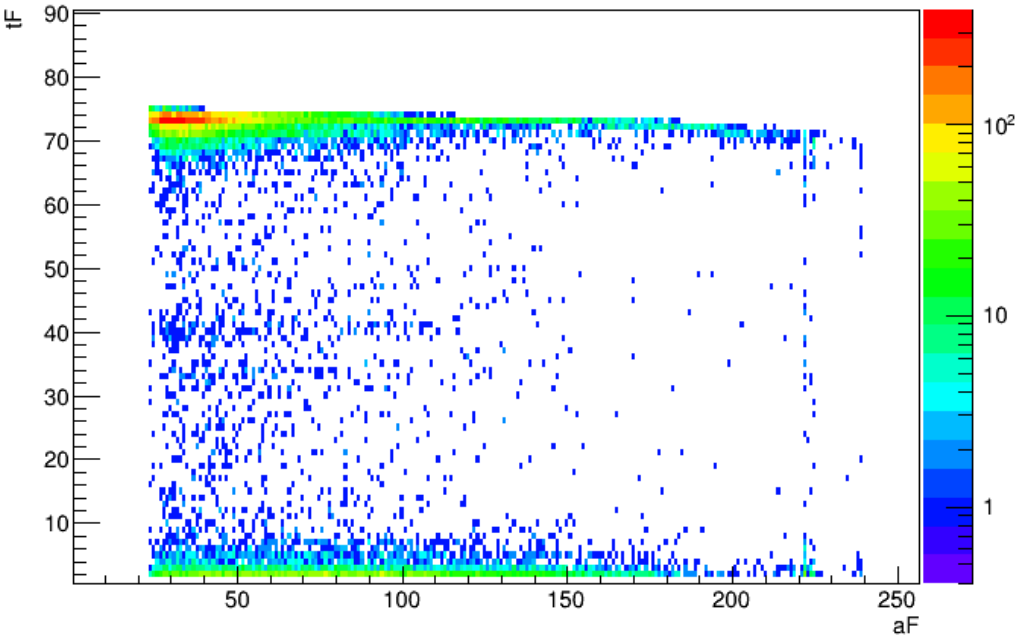
  - Can see 1× features above ADC saturation

Low-TDC, high-ADC region

- Move start TDC range to 0, ADC attenuator 5×:
  - All F hits:



  - Correlated F+R hits:



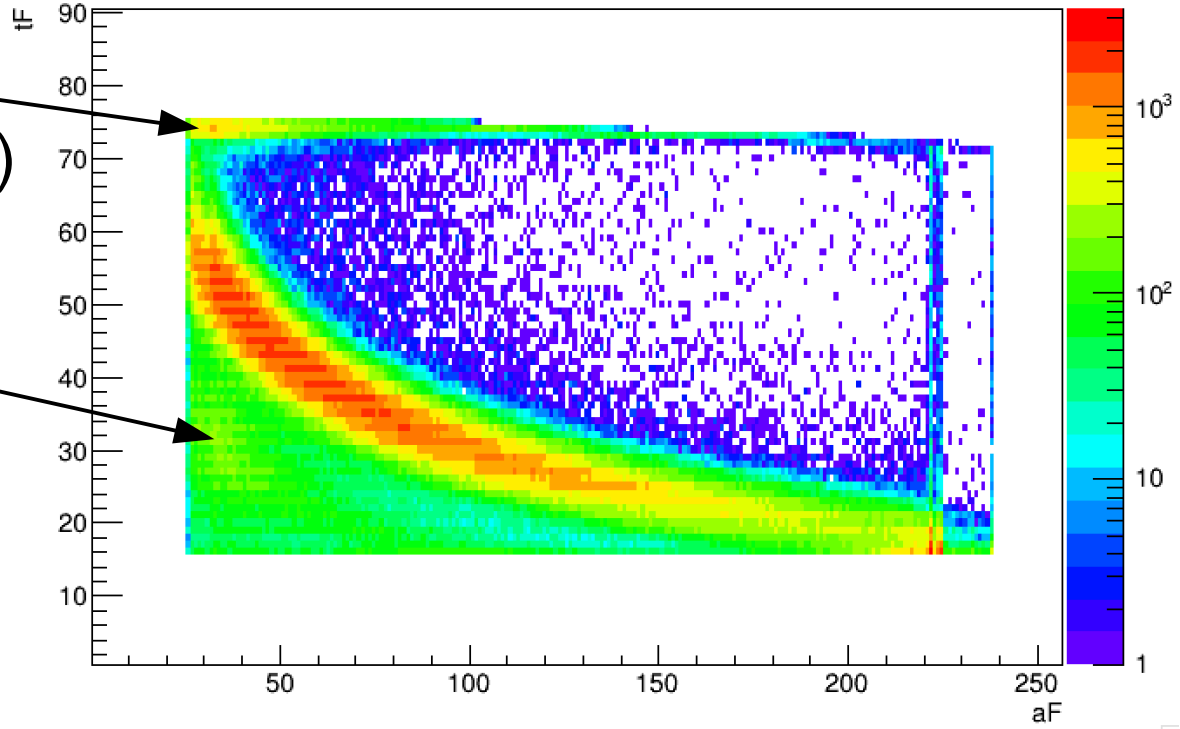
  - Can see:
    - trailing edge of beam pulse (peak @ -10 TDCs),
    - leading edge next beam pulse (@ 80 TDCs)
  - No other new features
  - Had hoped to see proton punch throughs ☹ (extra slide)

Summary

- My conclusions so far, for present 2-layer detectors:

- Pretty clean selection of beam induced prompts (mips)

- No capability for tagging 'below banana' background
- This was anticipated: these particles are too slow to penetrate front detector



- Present detectors too thick (200-250 μm) for slow ion punch-through
- Thinner detectors?
- R&D in AGS polarimeter?

Extras

Data analysis (details for experts)

- pC data comes as string of hits each channel with info including:
  rev - RHIC revolution # (# orbits around ring)
  bcn - RHIC bunch # 0-119
  amp - pulse amplitude (max. sample)
  tdc - CFD time ¼ p.h.
- Also 2 readout channels for test pulse leading, trailing edges
- **Unique bunch ×ing ID: 120*(rev)+bcn: unique events**

Tree for analysis:

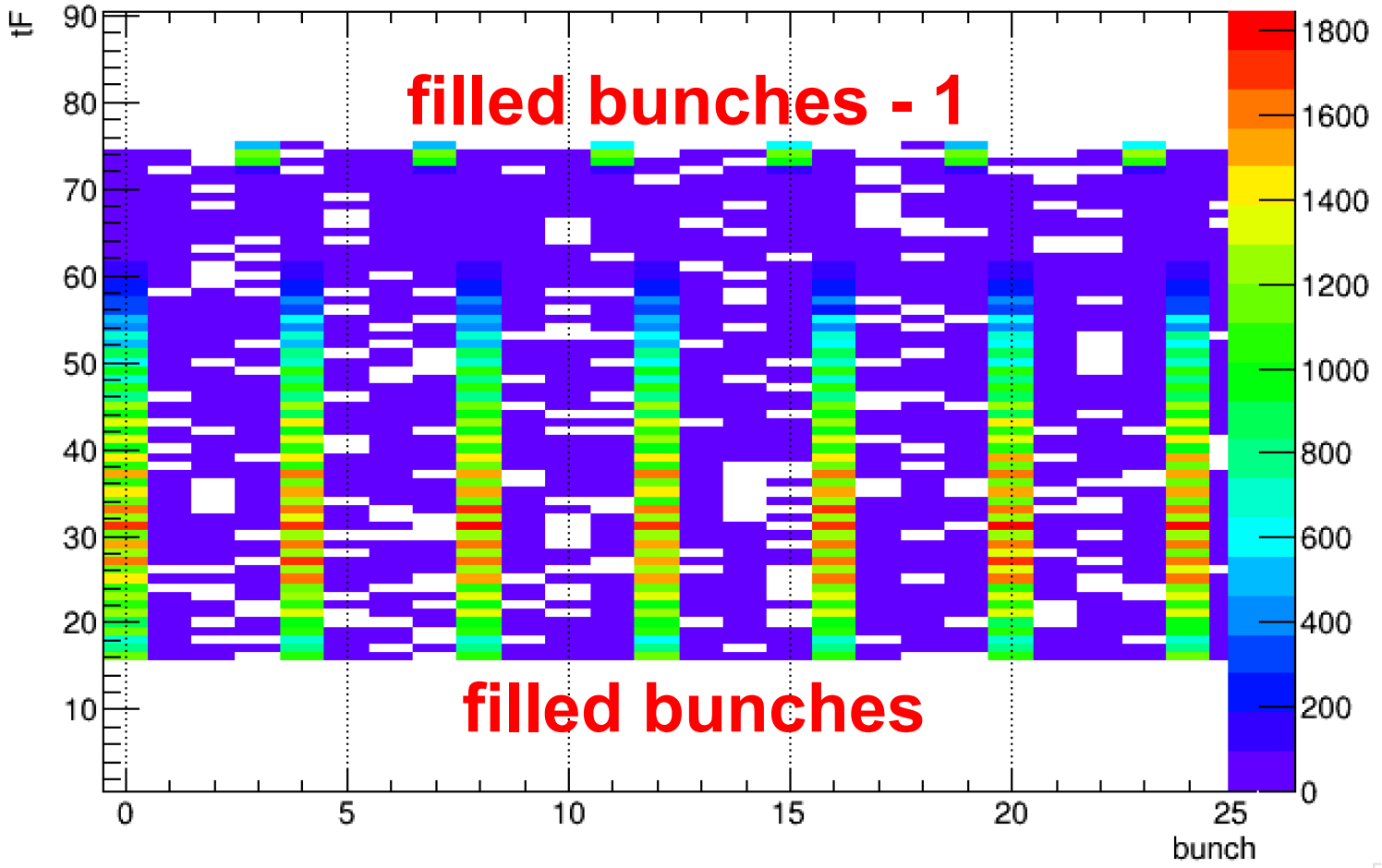
- Select hits in Front detector chan. 1-6, save amp & tdc
- Look for same bunch ×ing ID:
  - Flag test pulses
  - Count hits in Rear detector chan. 1-6
  - Save amp & tdc for highest amp Rear hit

So far:

- Only looked at handful of measurements
- Limited to few M events / measurement (array size)
- Could use help: setup tree makes on pol01/02
  increase array sizes

High-TDC feature

- Fill w/ 28 bunches, tdc vs bunch #:



- High-TDC events are beam prompts from next bunch

Beam ×ing: t_0

Rough estimate: where is t_0 on our plots?

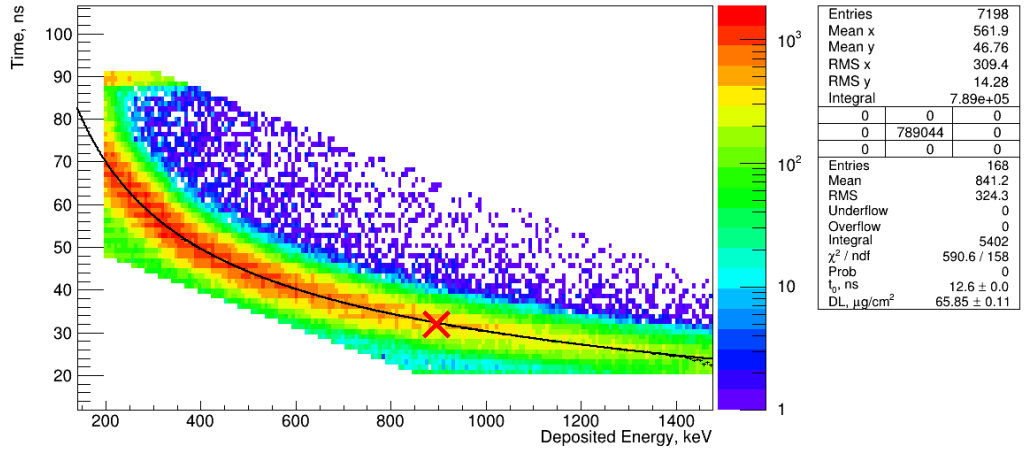
$$E = \frac{1}{2}Mv^2 = \frac{Md^2}{2T^2} \Rightarrow T = d\sqrt{\frac{M}{2E}}$$

nS plots:

- d = 18 cm/c = 0.6 nS; M = 12×10^3 MeV/c^2
- @ E = 1 MeV, T = 46 nS
- On this plot: t_0 ≈ 32-46 nS = -14 nS

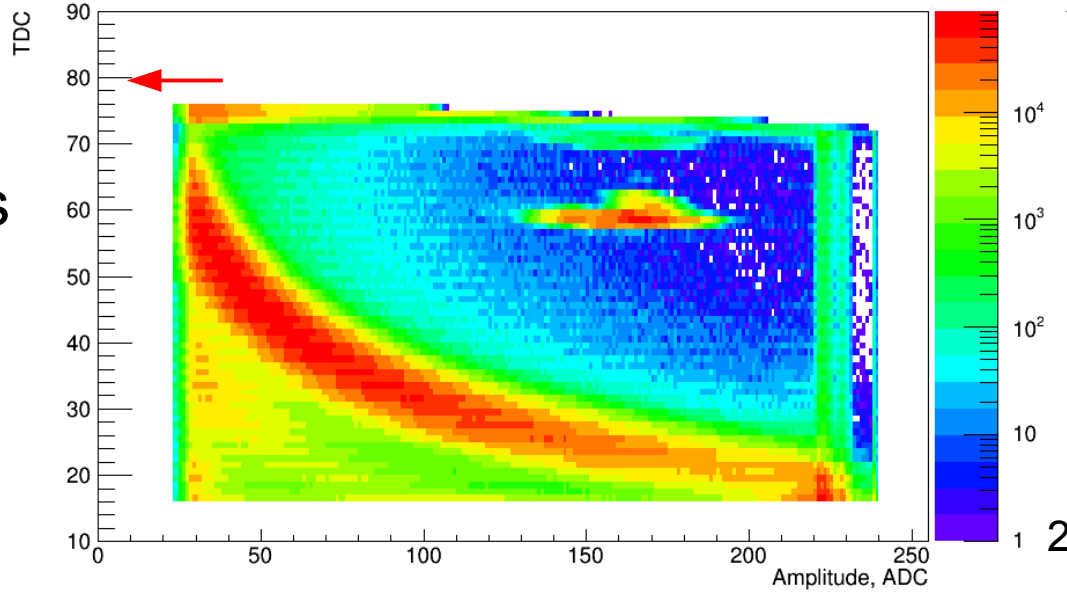
  (fit result t_0 = 12.6 nS;

  I think fit t_0's are actually -t_0)



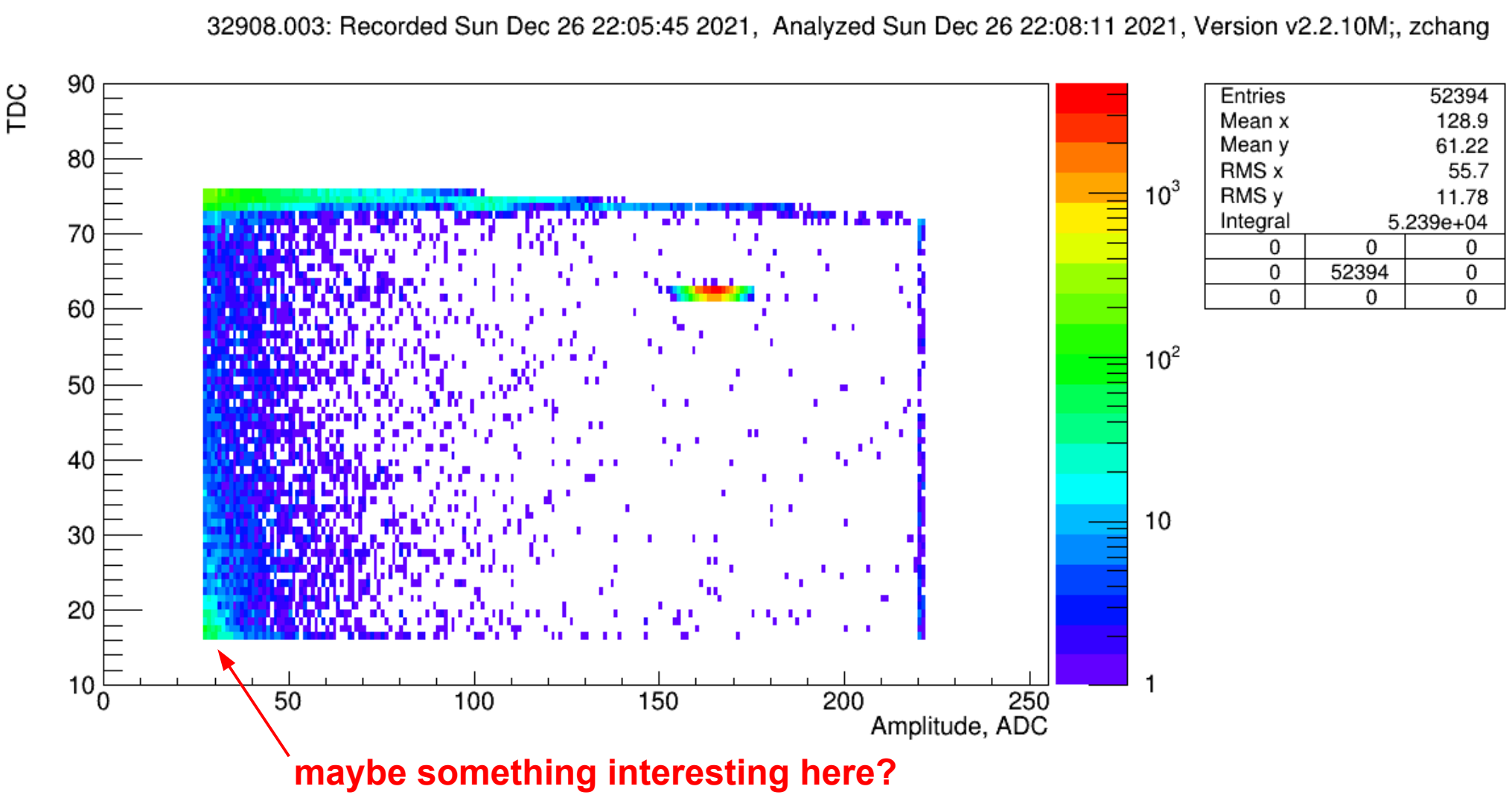
TDC plots:

- 1 TDC = 1.2 nS
- t_0 = -12 nS, TCD_0 = -10 TDCs
- End of DAQ range 90 TDCs
- Next bunch TCD_0 = 80 TDCs
- High-TDC feature is start of prompts from beam pulse

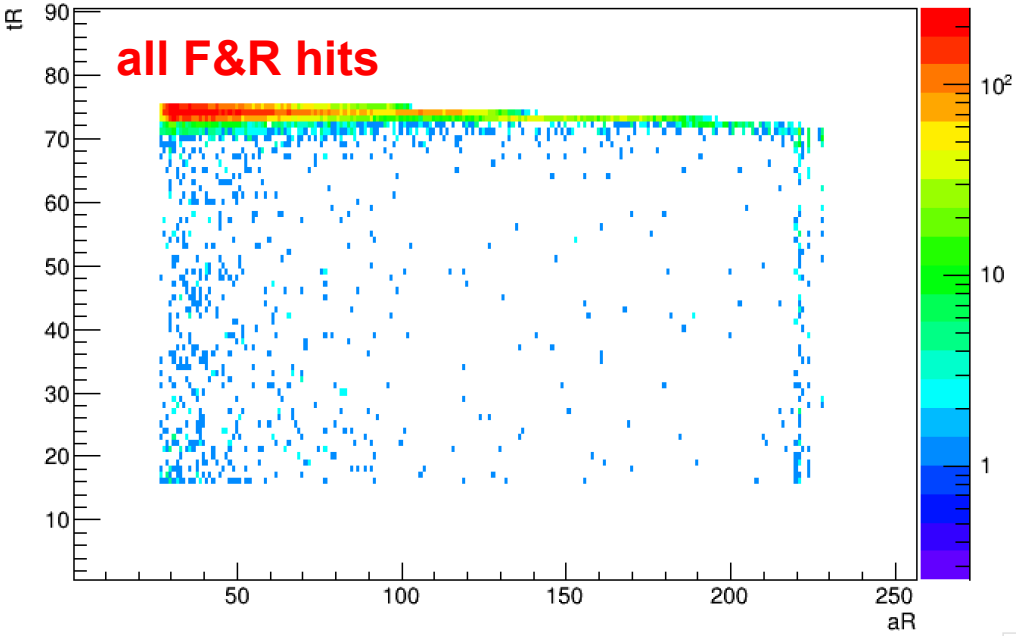


Rear T vs A, all R hits

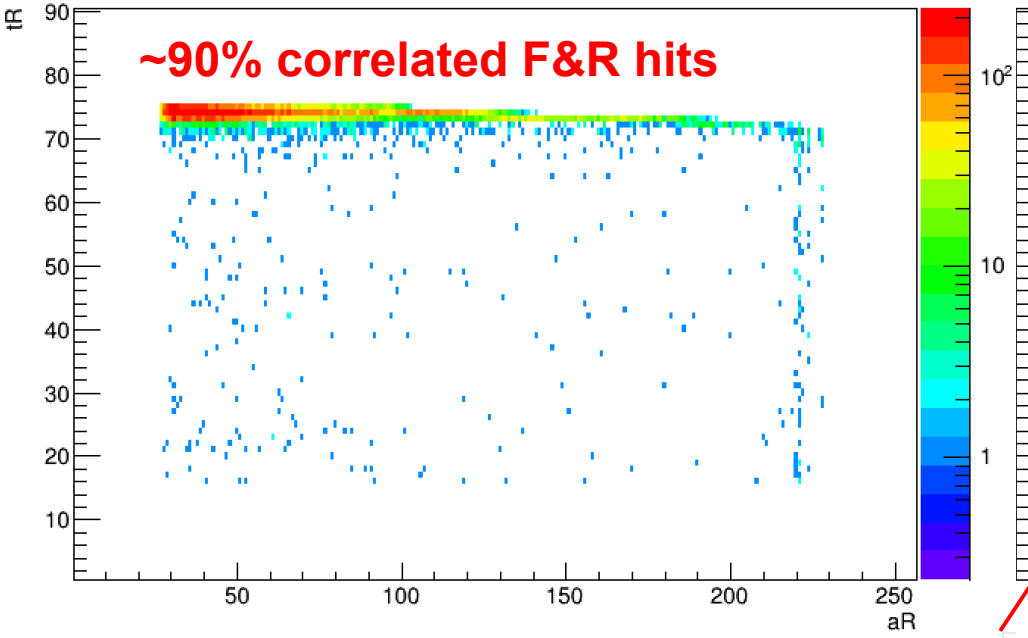
- Hits in R mostly beam induced prompts:

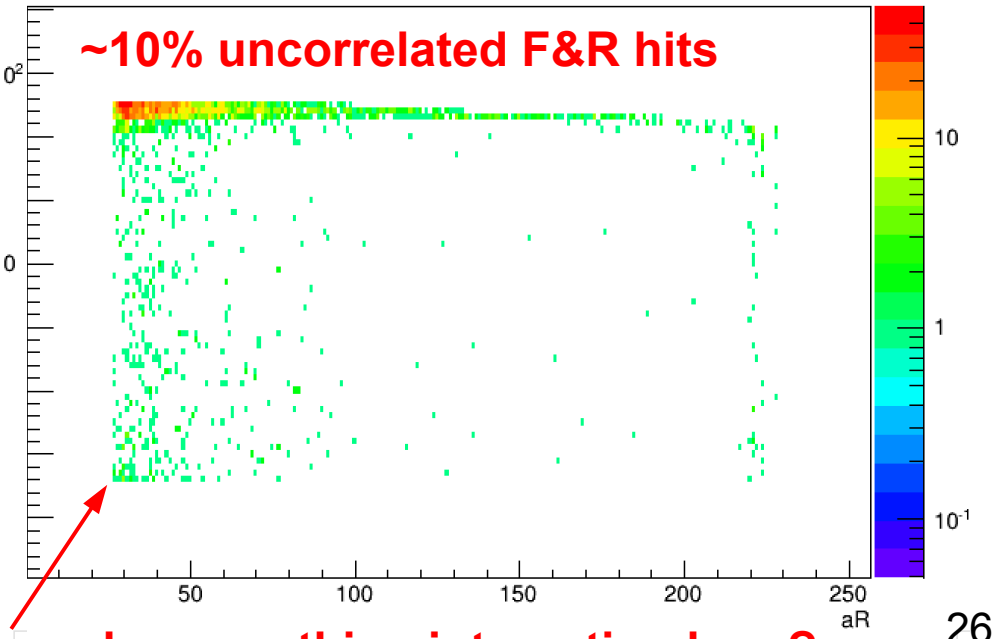


Rear T vs A, F&R hits



- Hits in R mostly beam induced prompts



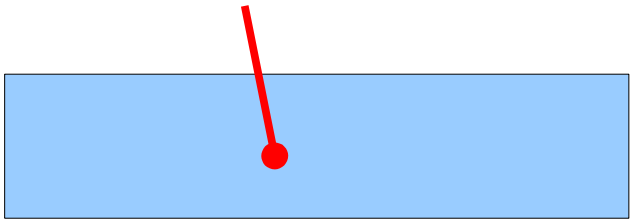


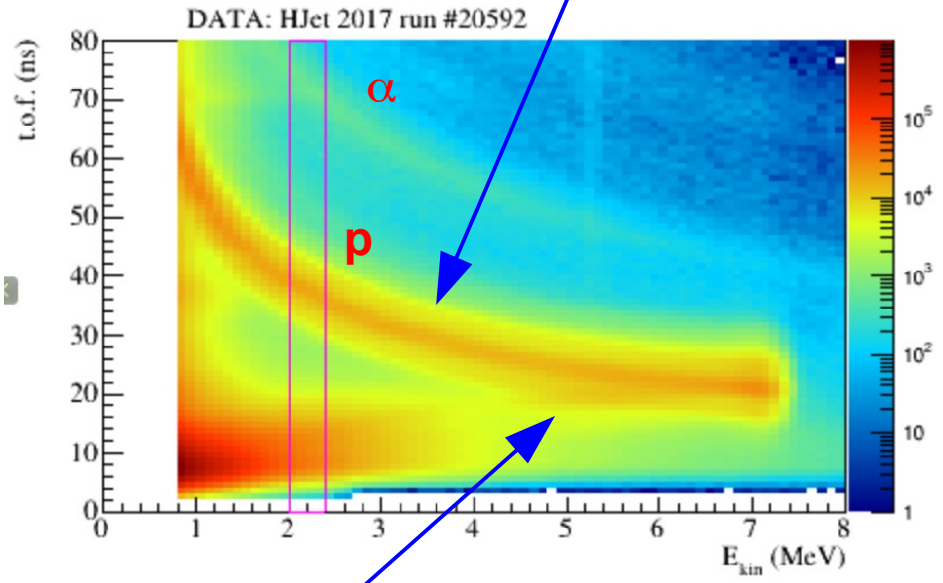
maybe something interesting here?

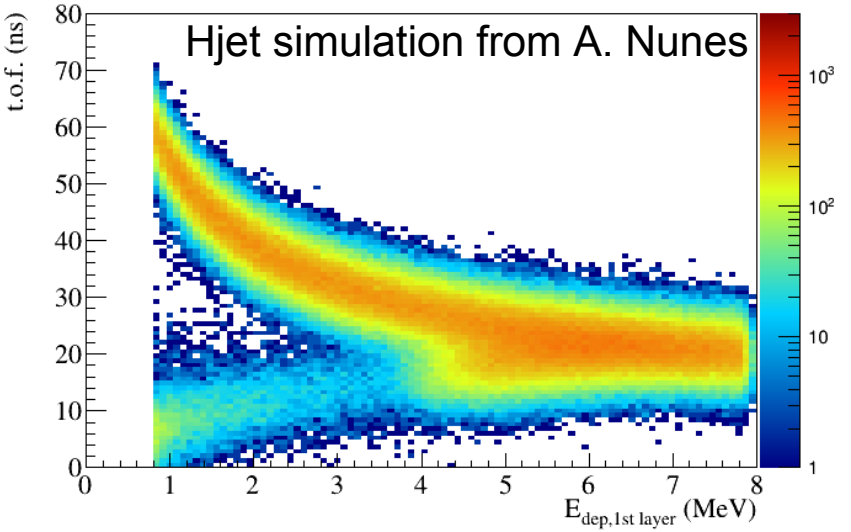
Background sources

Guided by simulations

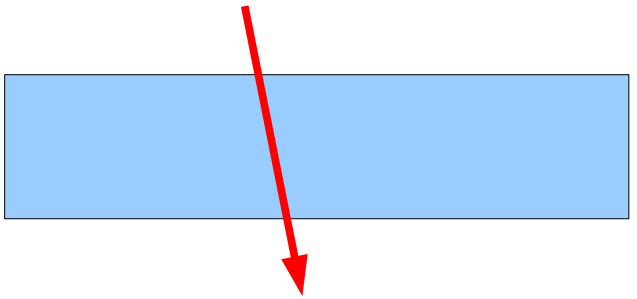
- "Banana" curve:
  - stop inside detector, E fully contained
  - follows TOF $\propto 1/\sqrt{E_{kin}}$ curve until cutoff 7-8 MeV







- Limb downward from right of "Banana" curve:
  - "punch-throughs" pass through detector
  - lower TOF → higher E_{kin} → smaller dE/dx
- Accumulation @ lowest E_{kin}, TOF:
  - pileup of very high E_{kin} p, π



Test hypothesis: add 2nd detector layer, tag "punch-throughs"