T18_VG2.4_Disk_#2 processing summary

SLAC Workshop

090708-10

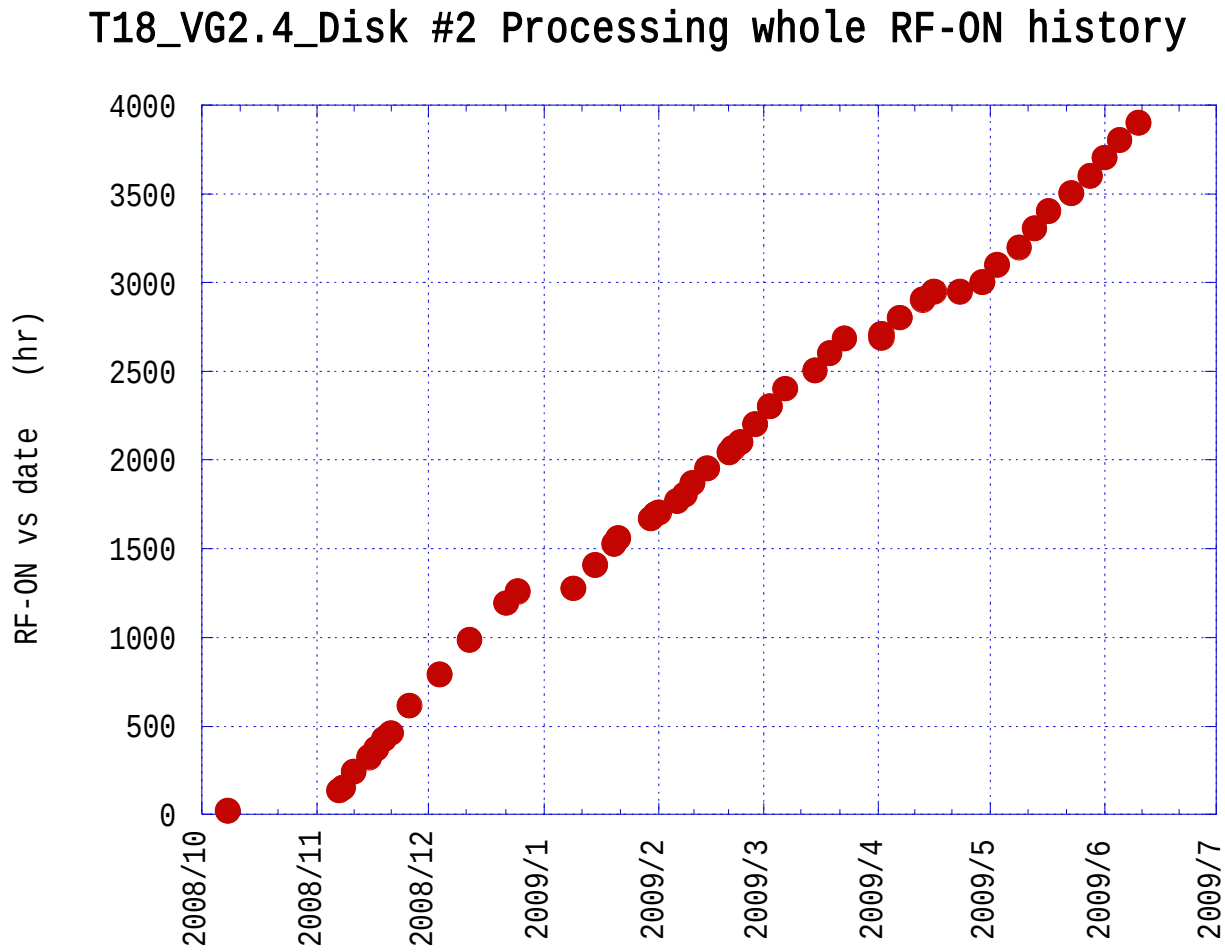
T. Higo and Nextef group

Whole history of T18_#2 processing

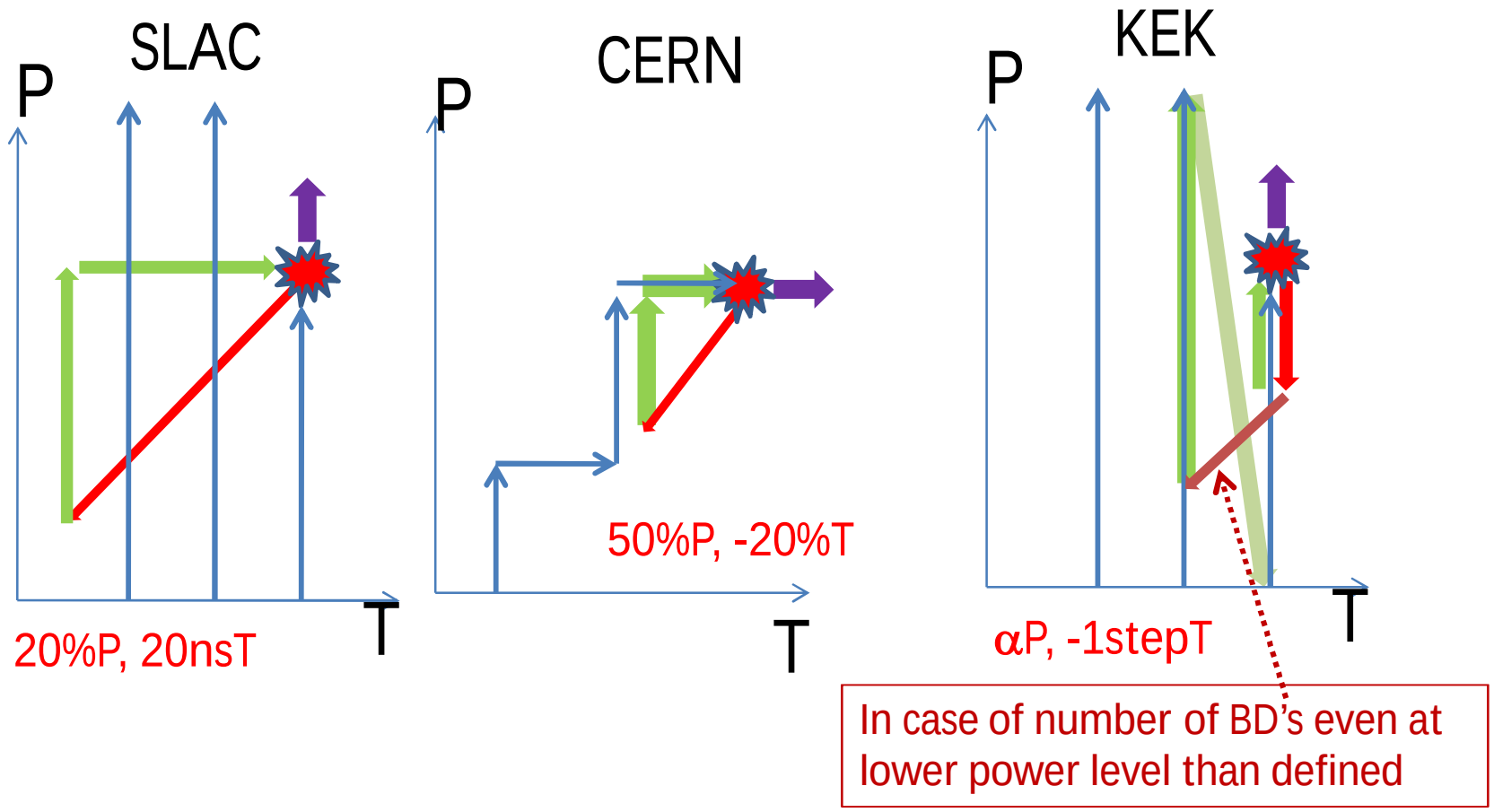
- Installation in Oct. 2008
- Steady-state run at 80MV/m in Dec. 2008
- Higher field in Jan-Feb 2009
- Breakdown rate meas. in Mar.-Apr. 2009
- Longer pulse in latter half of Apr. 2009
- Breakdown rate meas. May 2009
- Various measurement in June 2009
- Finish with 4000 hrs operation

Processing history for 9 months

Nextef startup and careful processing



Recovery pass in (T,P) space



Whole BD history of T18_VG2.4_Disk #2

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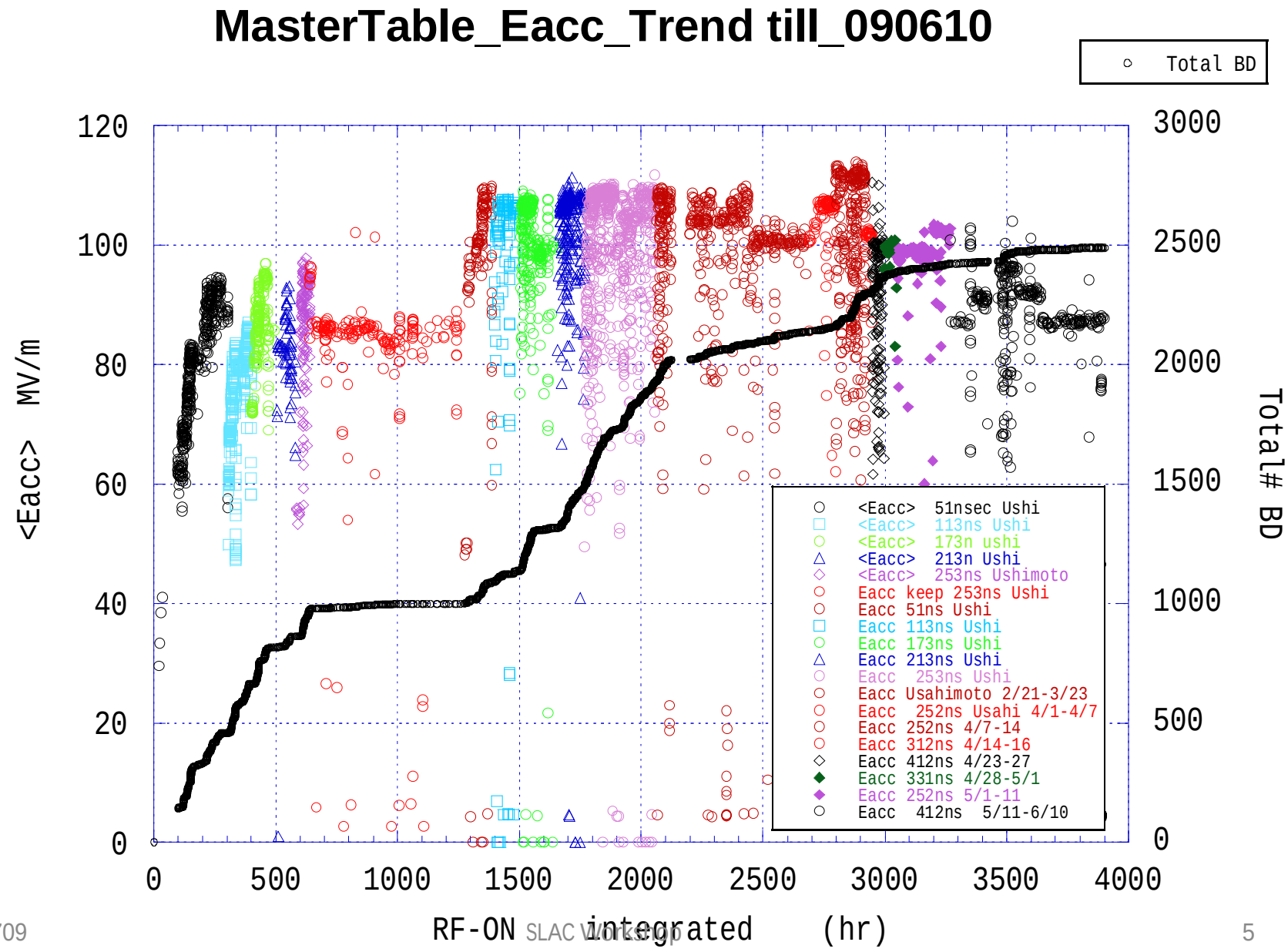
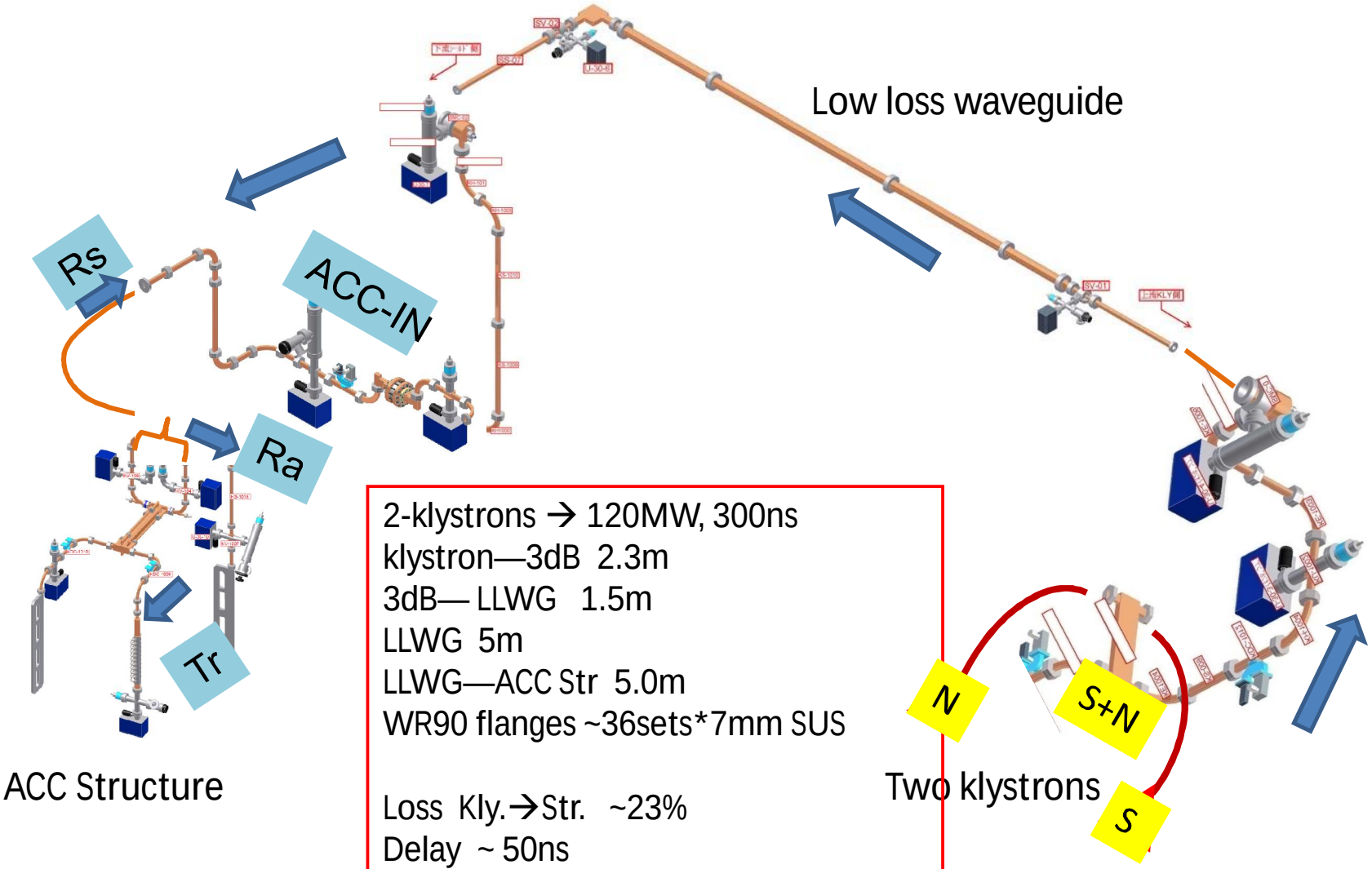


Nextef: RF monitors along waveguide



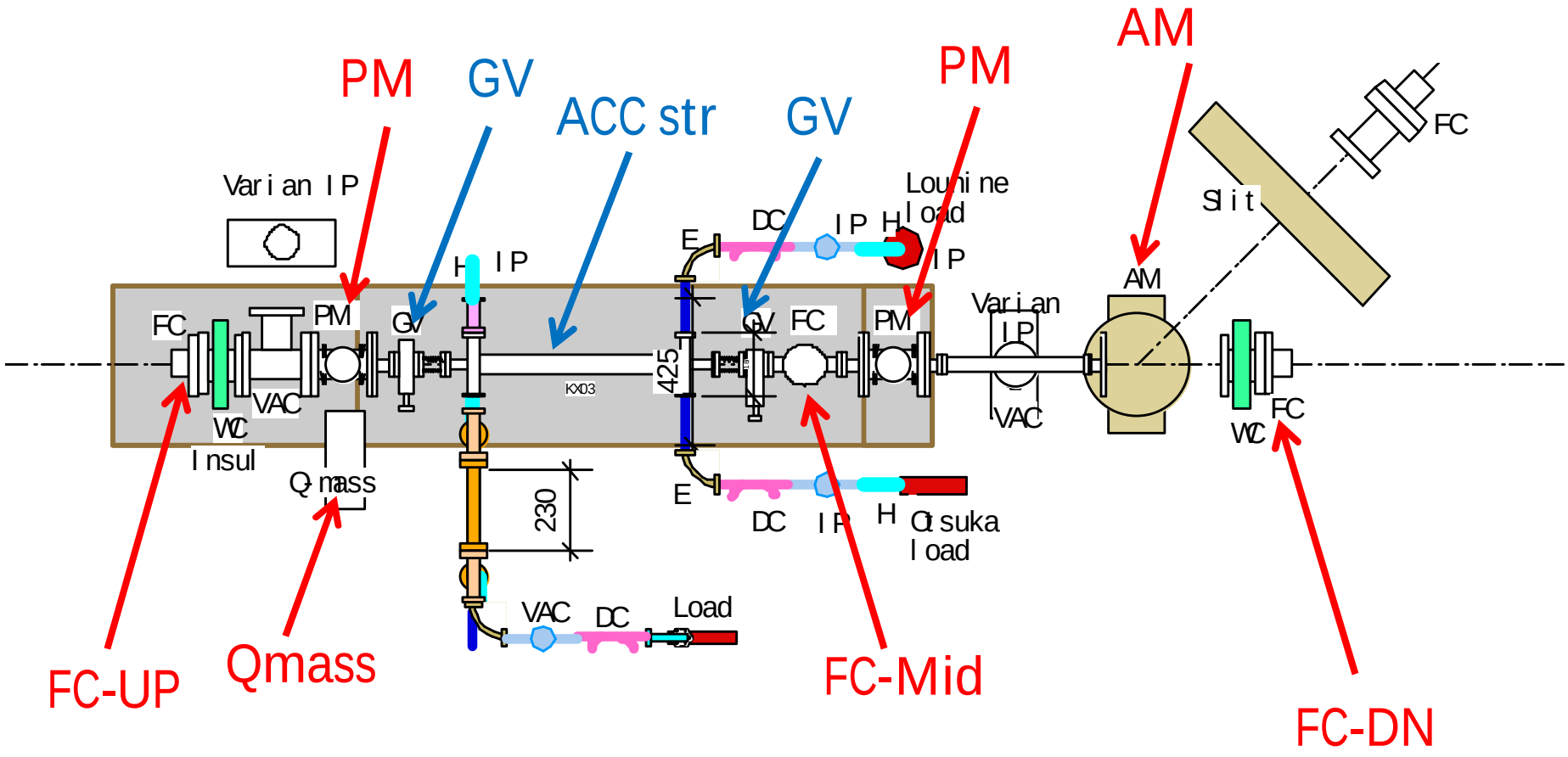
ACC Structure

2-klystrons → 120MW, 300ns
klystron—3dB 2.3m
3dB— LLWG 1.5m
LLWG 5m
LLWG—ACC Str 5.0m
WR90 flanges ~36sets*7mm SUS

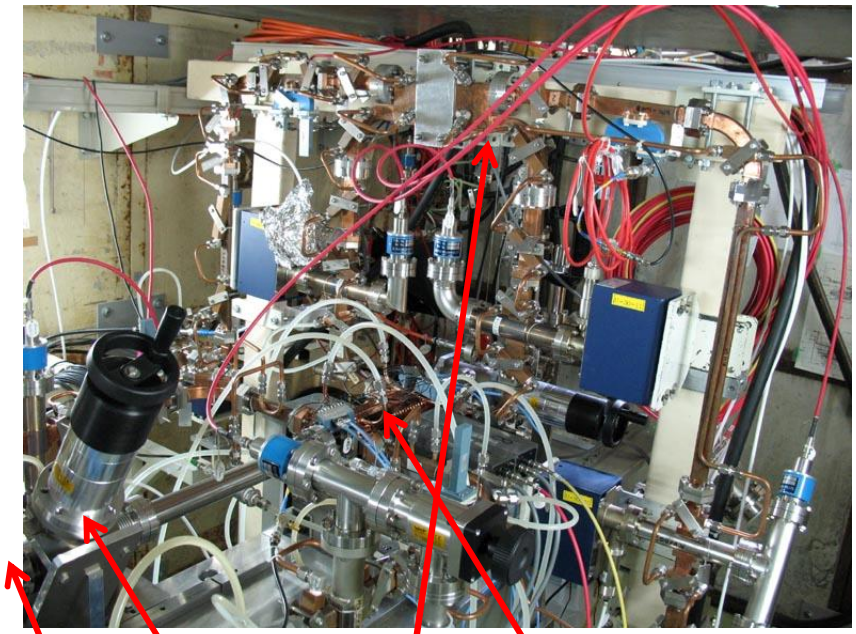
Loss Kly.→Str. ~23%
Delay ~ 50ns

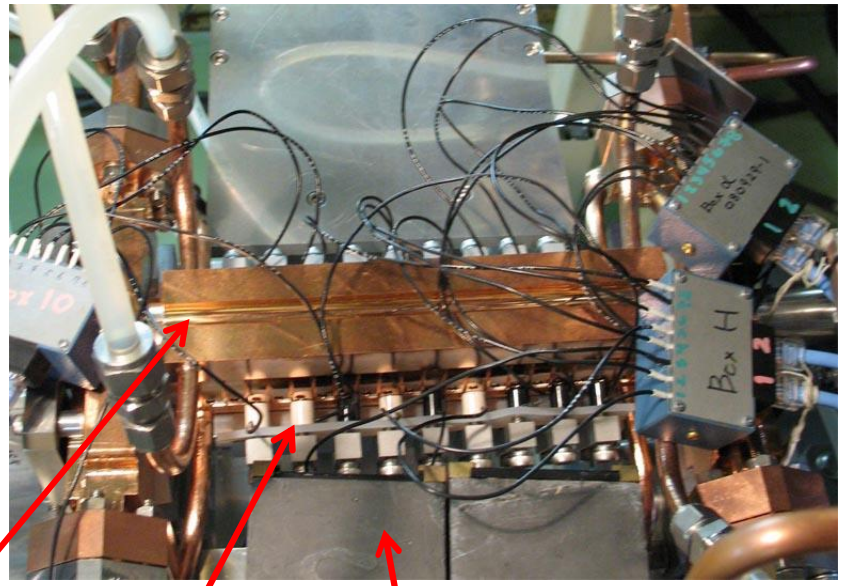
Two klystrons

Nextef: Monitors along beam axis



Now T18_VG2.4_Disk #2 has been processed since late October





FC

GV

SLAC
3dB hybrid

T18_VG2.4_Disk

Acoustic sensors

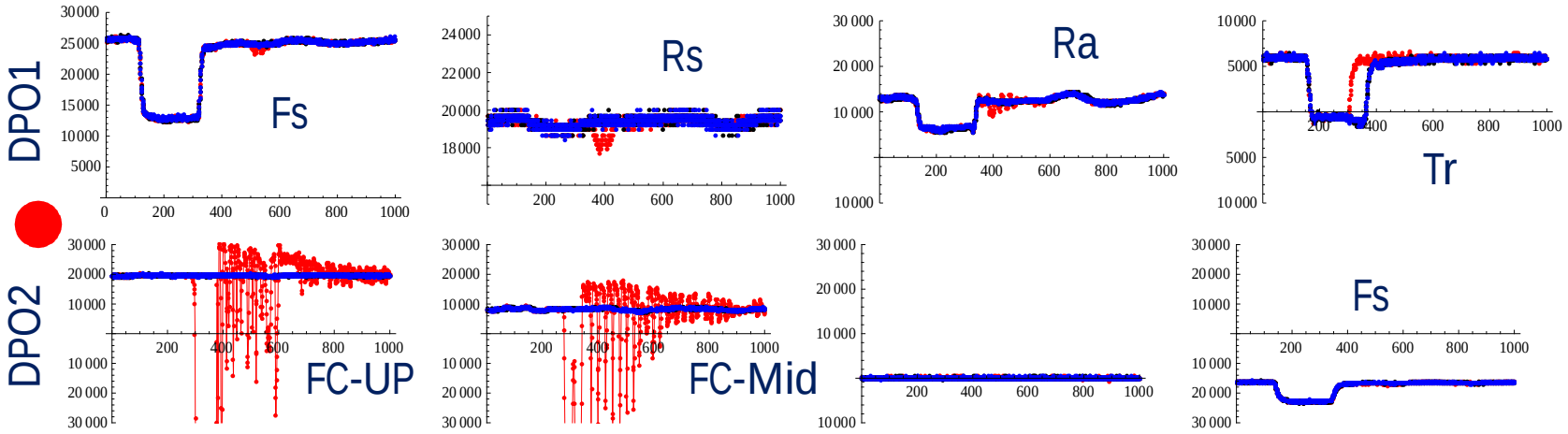
Plastic scintilator & PMT

(These are not used effecively.)

Big breakdown followed by a breakdown from the very first pulse

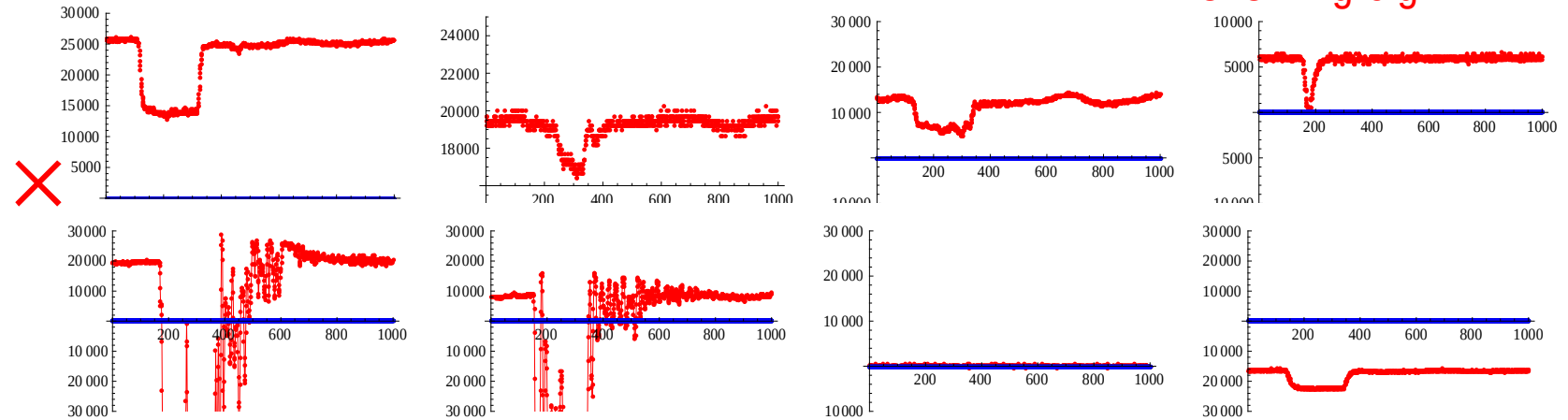
file number= 3 20081124_210211_1 Red=final, black=previous pulse and blue=-2nd pulse

Nominal BD

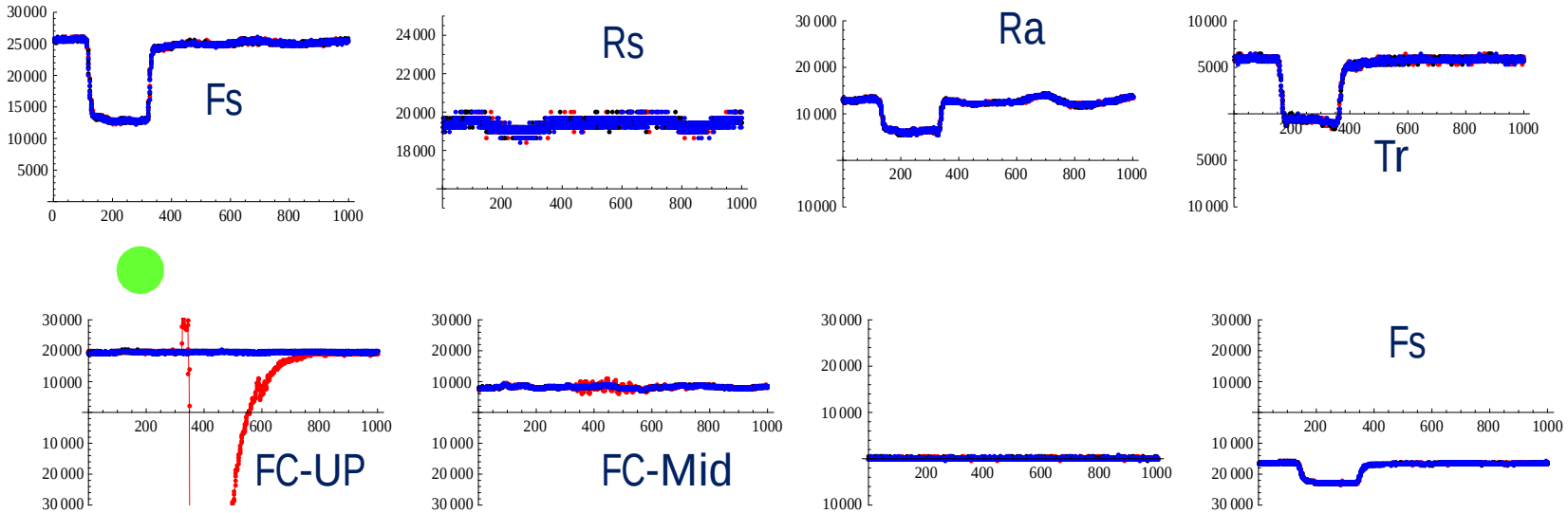


file number= 4 20081124_210301_1 Red=final, black=previous pulse and blue=-2nd pulse

1st pulse BD, following big BD



Current burst toward upstream



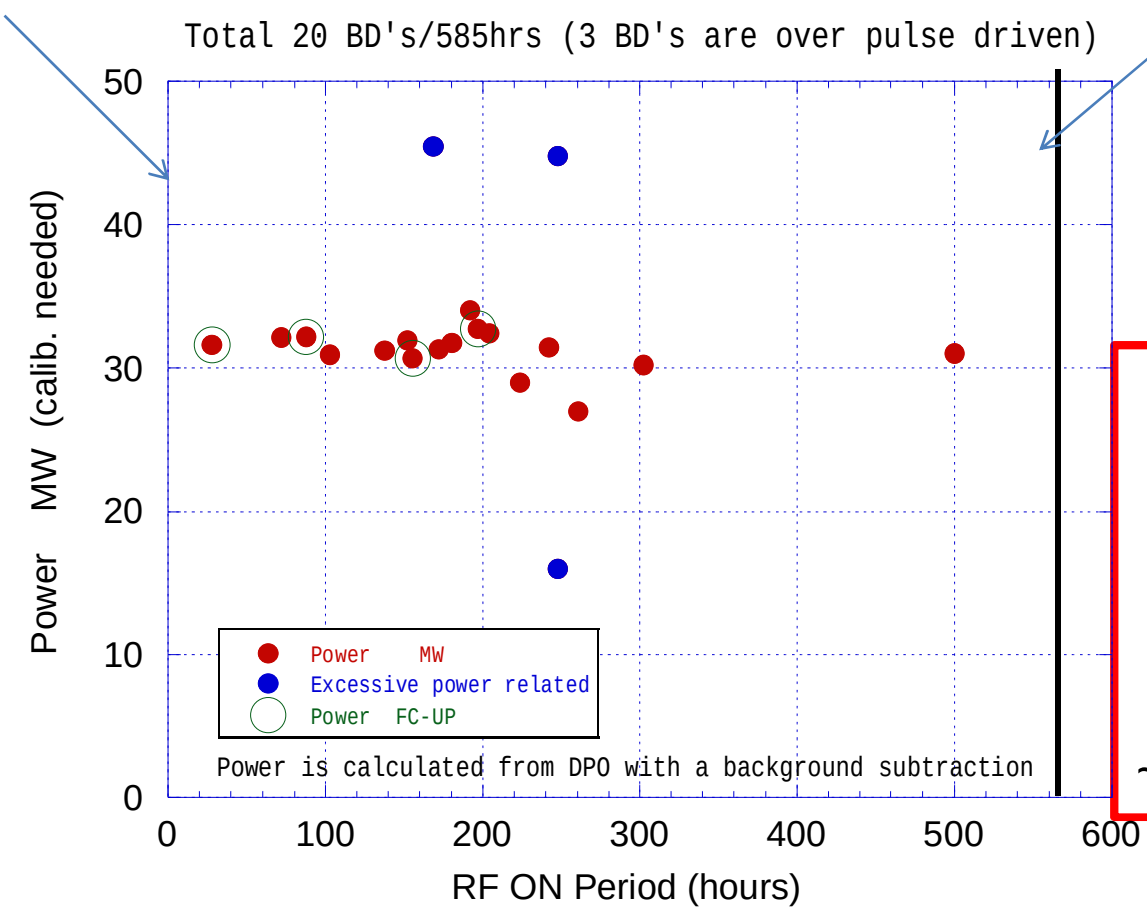
Rare event but need to understand the mechanism

- One out of 100 breakdowns
- Abrupt big burst in current only to upstream
- no change in RF pulse shape

Power at BD's and BDR during 27 days at 80MV/m (35MW) during RF-ON from 700 ~ 1200 hours since startup

Started at 10:00 on Nov. 28

Finished at 9:00 on Dec. 25



566 hrs run / 643 hrs = 88% ON

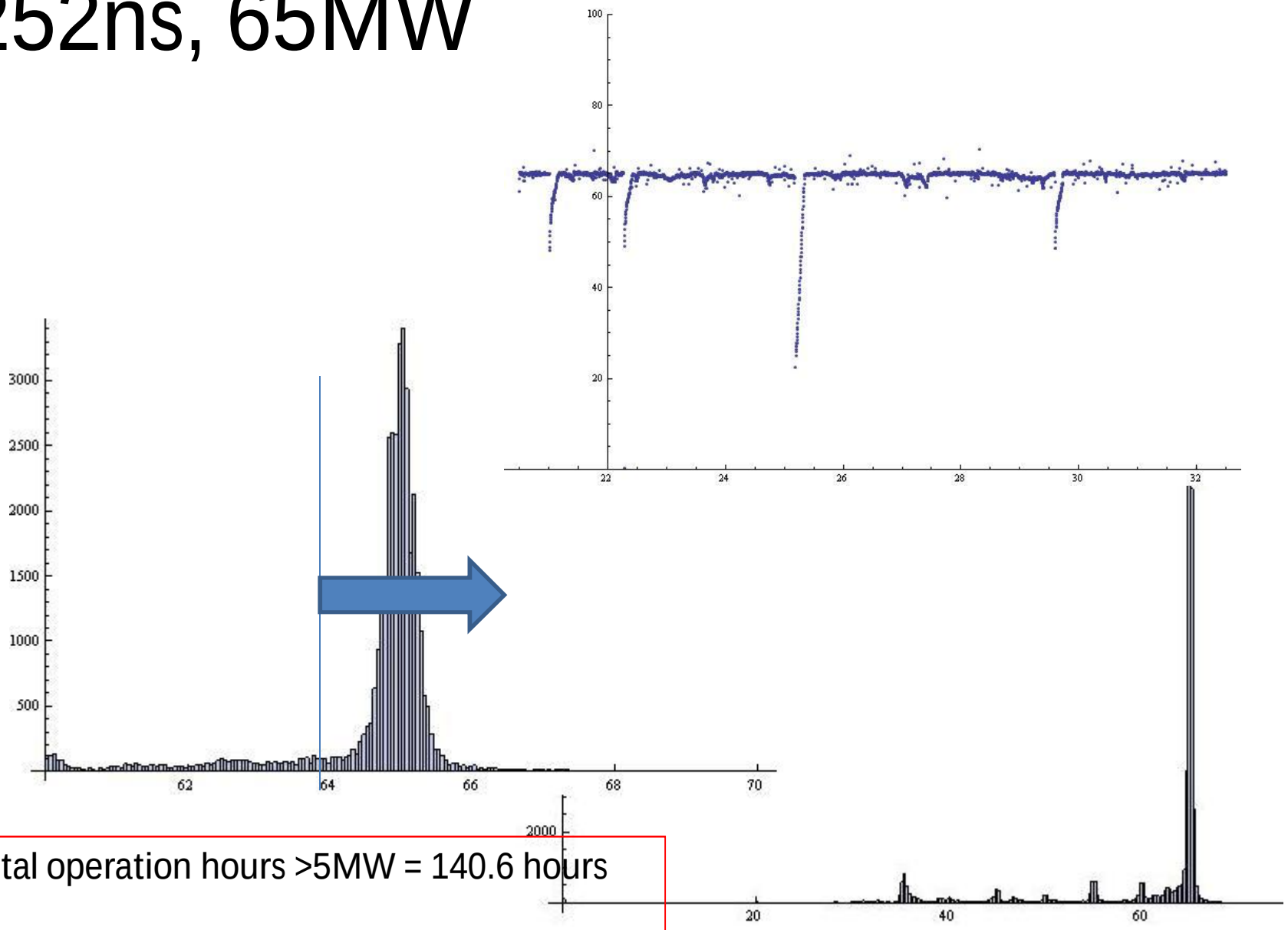
BDR

~17 str. BD / 566 hr

~0.030 BD/hr/str

~0.75 x10^{-6} BD/Pulse/m

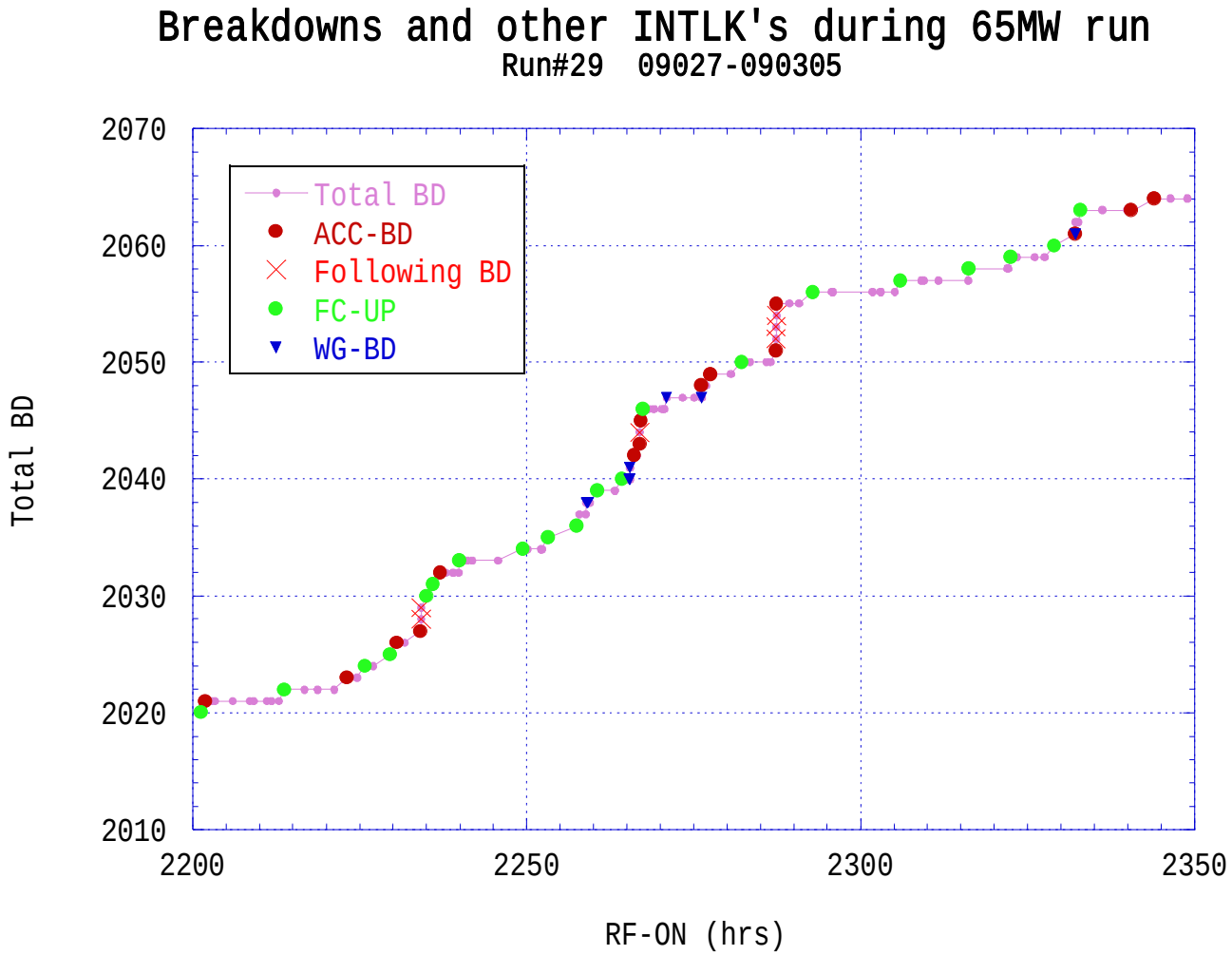
252ns, 65MW



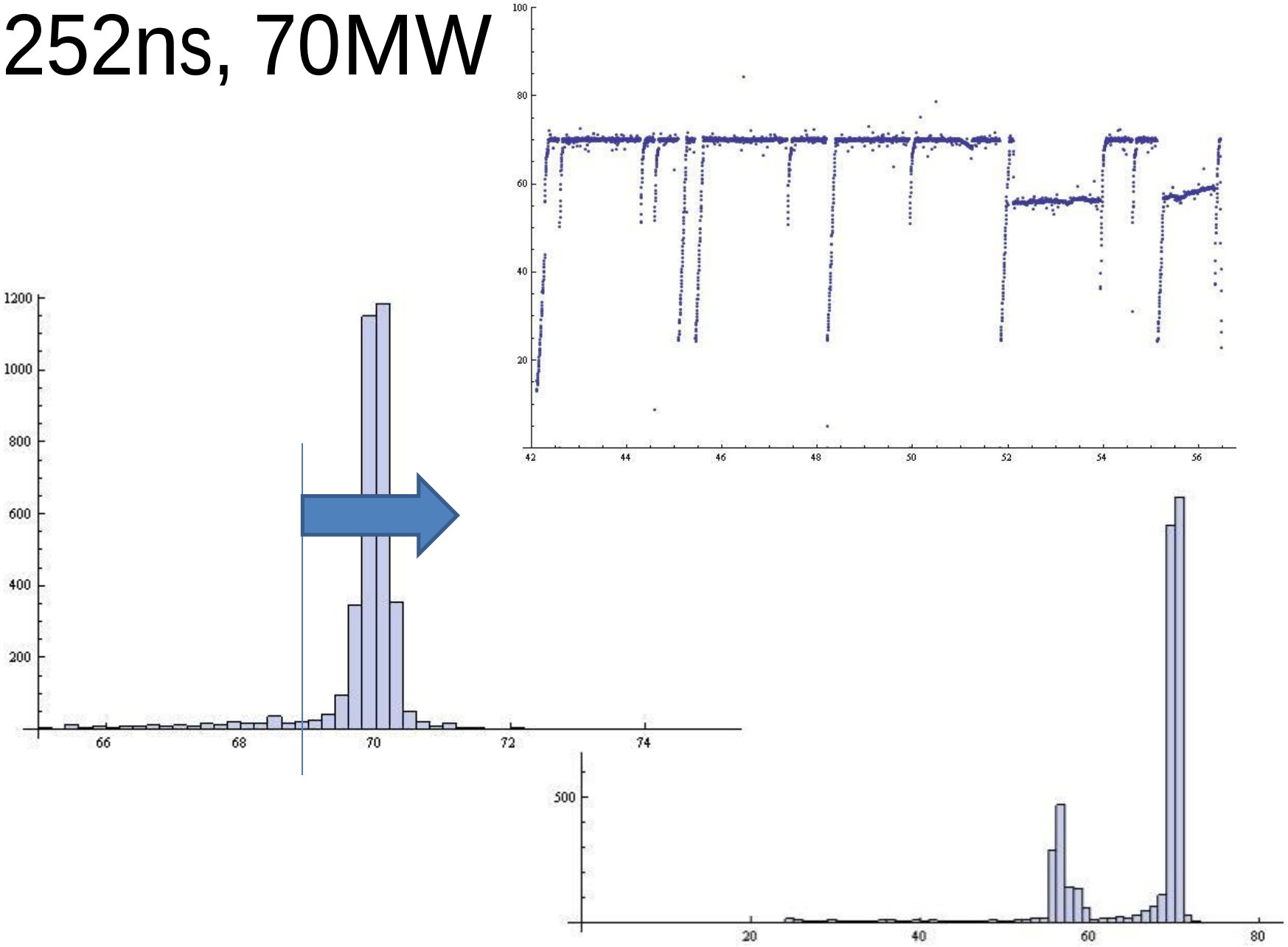
Total operation hours >5MW = 140.6 hours

Period ACC-IN > 64 MW = 91.7 hours

Appearance of breakdowns at 65MW run



252ns, 70MW


100
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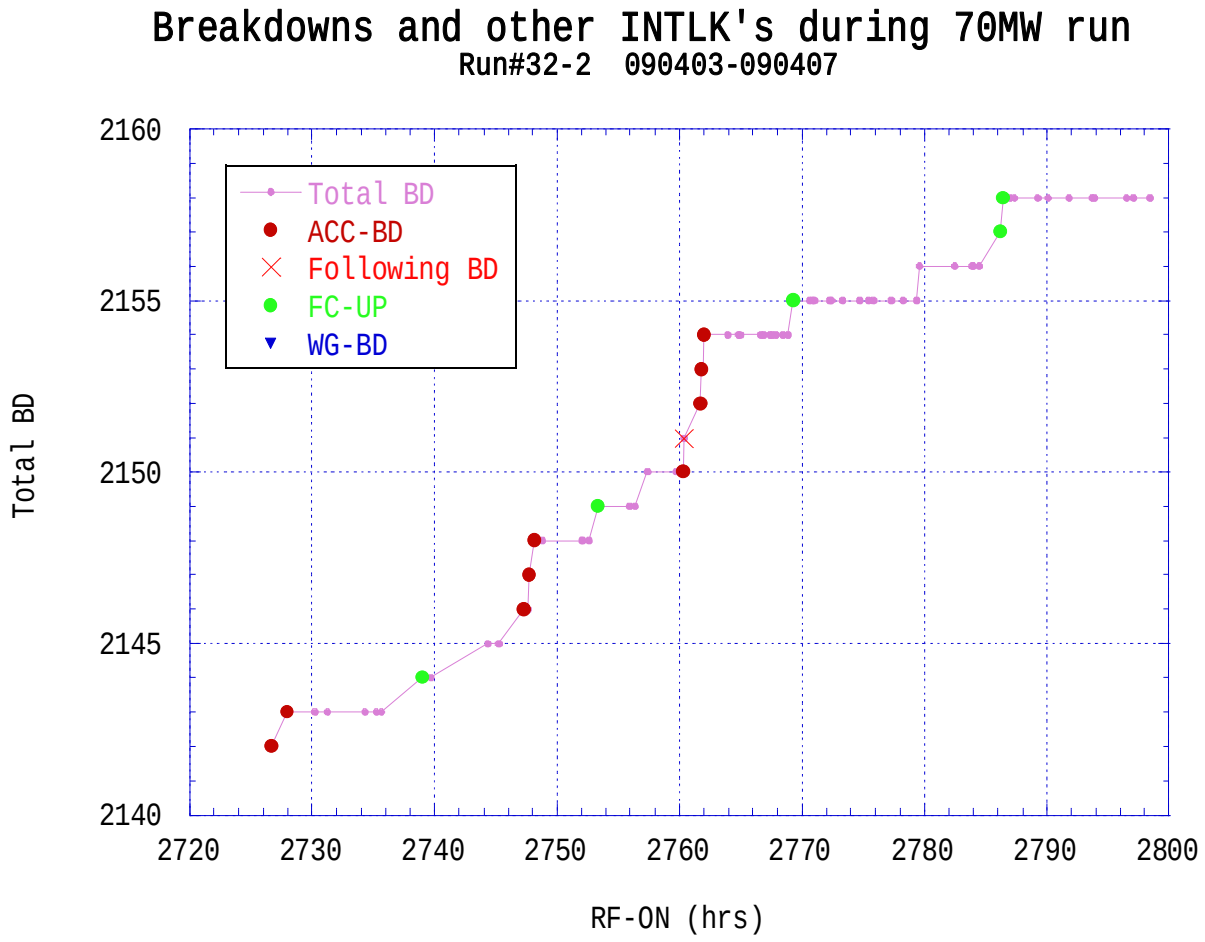
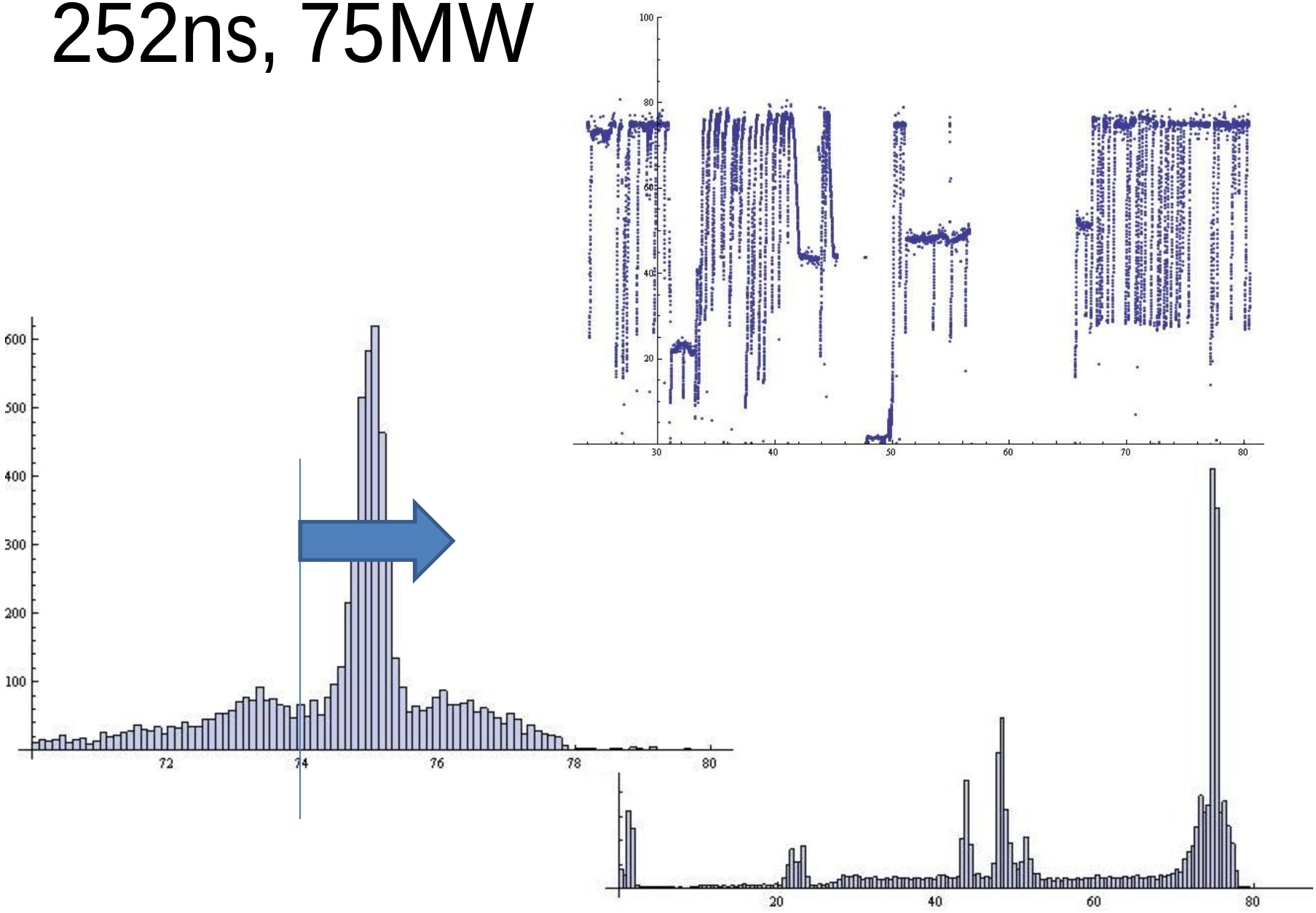
Appearance of breakdowns at 70MW run



252ns, 75MW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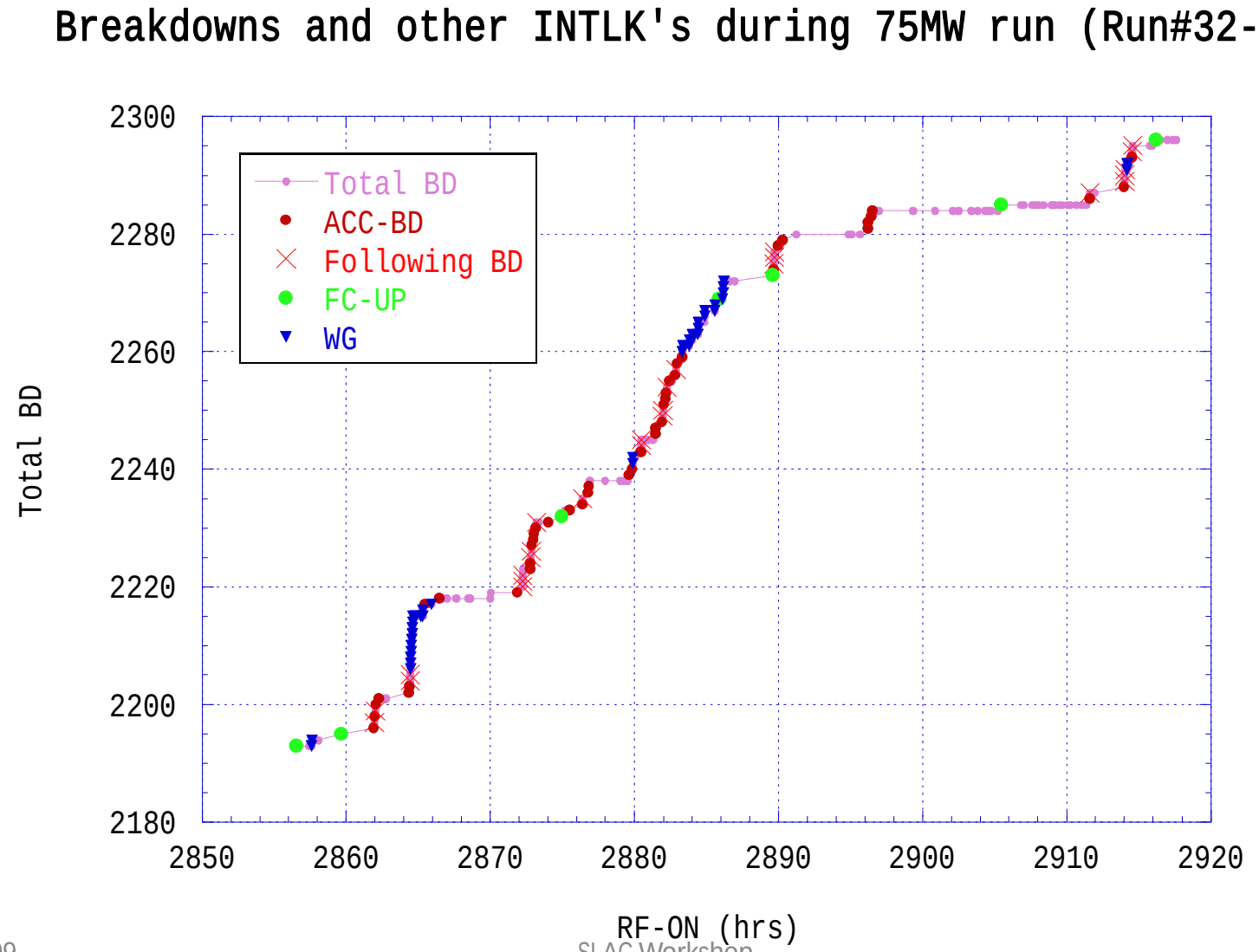
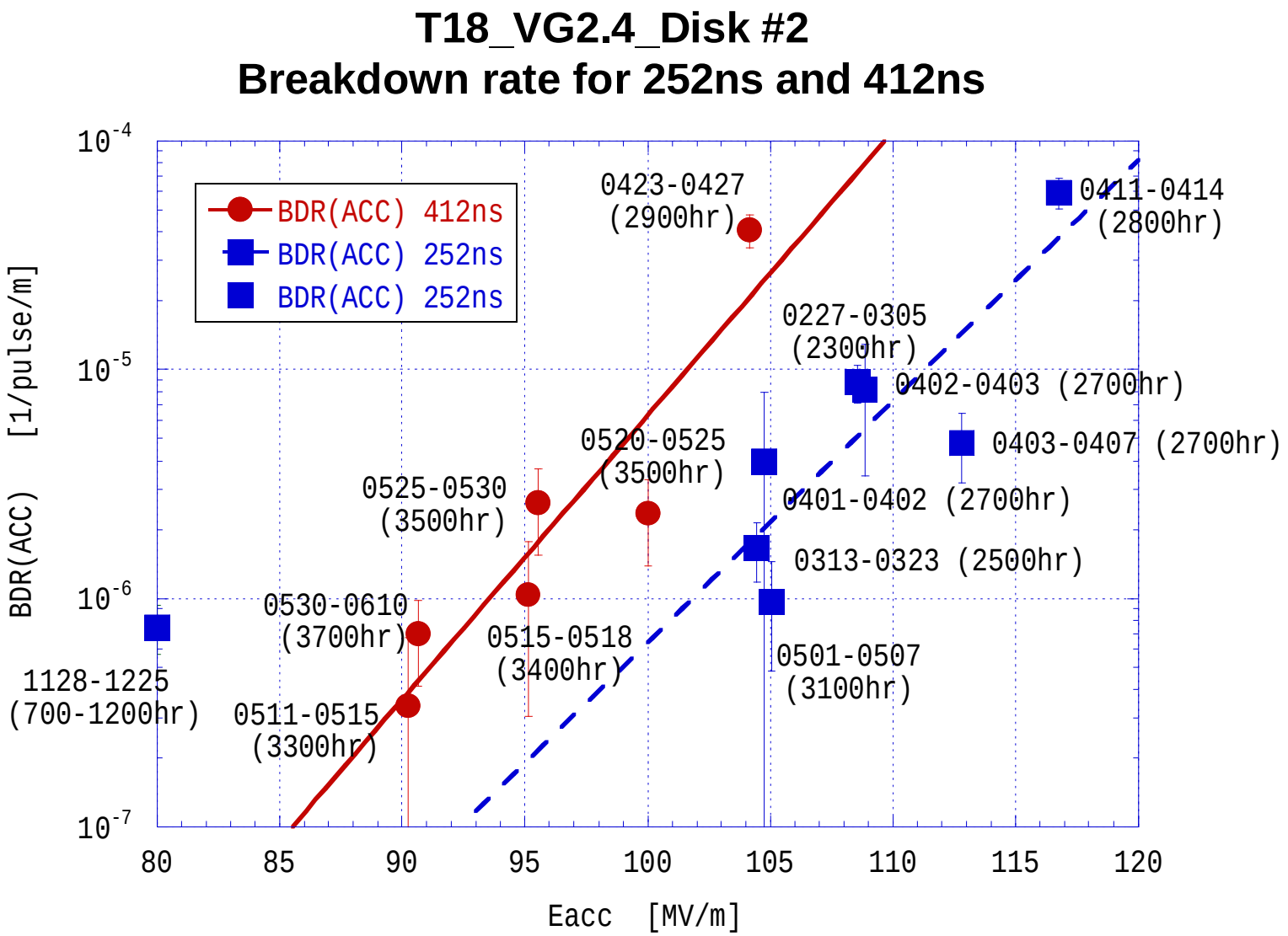
Appearance of breakdowns at 75MW run



Typical processing / steady-state run

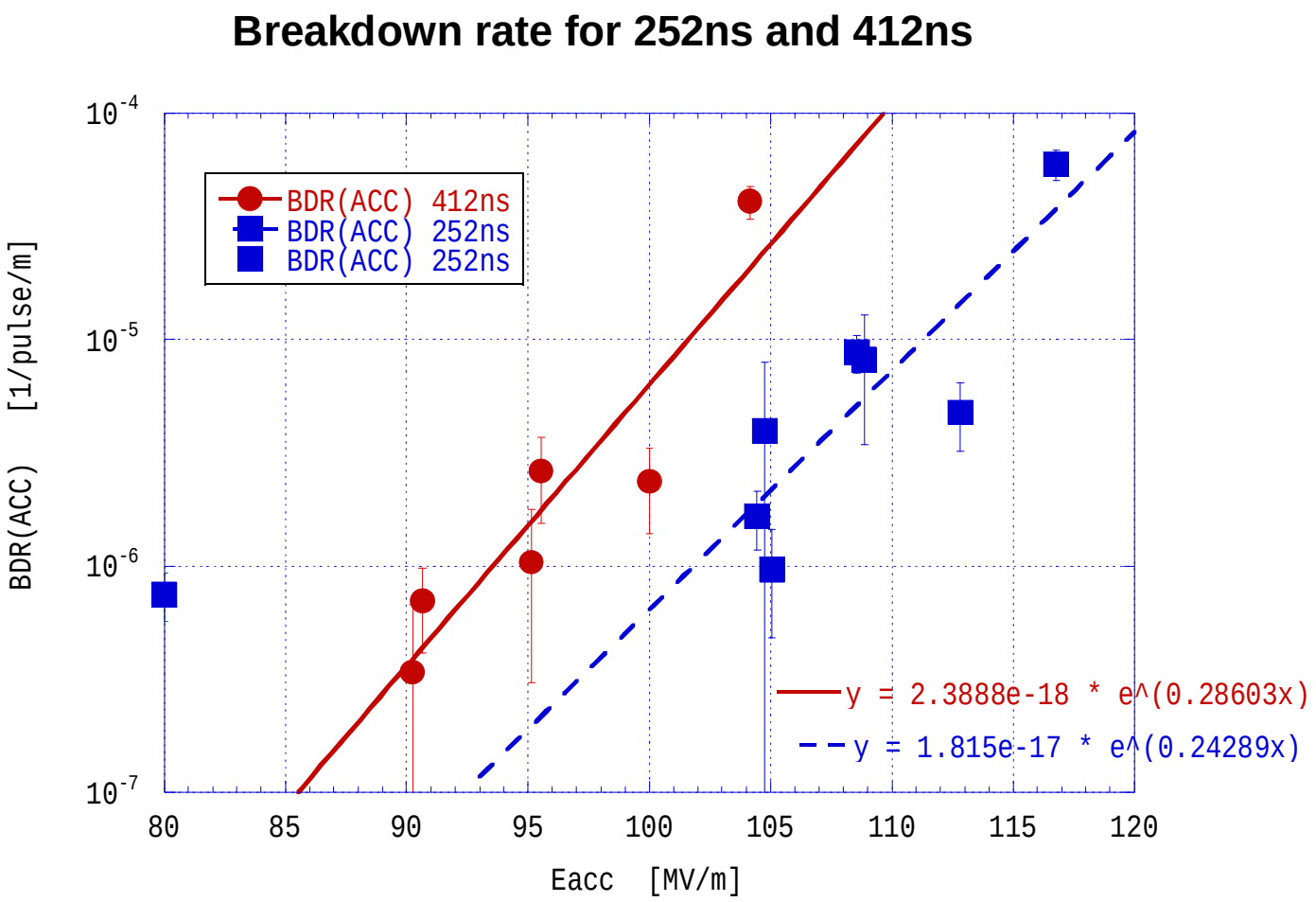
- Breakdowns are
  - mostly followed by a few to several successive breakdowns
  - typically from the very first pulse at even lower power.
- Spurious events exist
  - with flush of current towards upstream occur from time to time

Breakdown rate evaluation



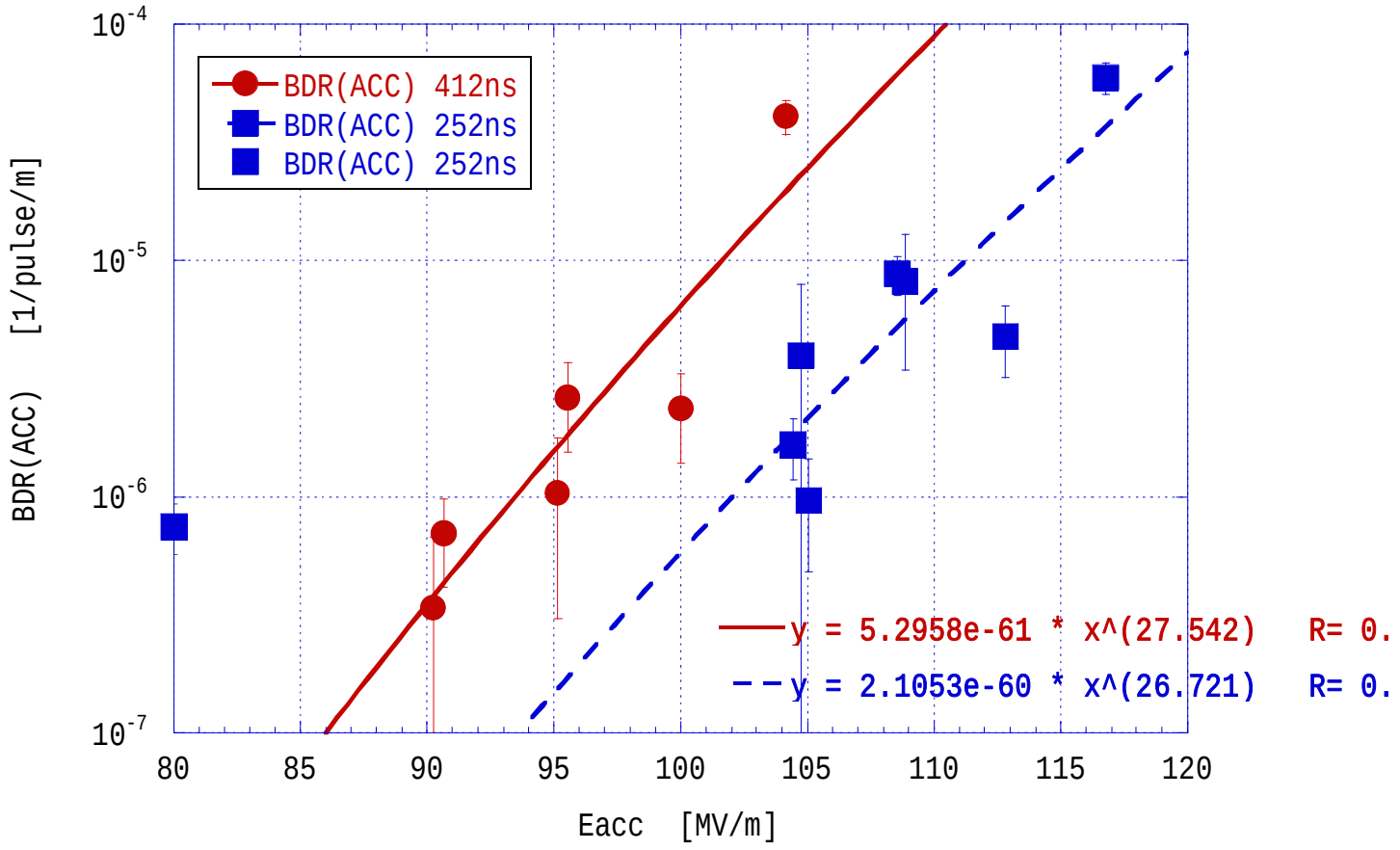
It is not so clear from this experiment that the breakdown rate decreases as function of "processing."

Breakdown rate versus Eacc



Exponential fit.

Breakdown rate for 252ns and 412ns

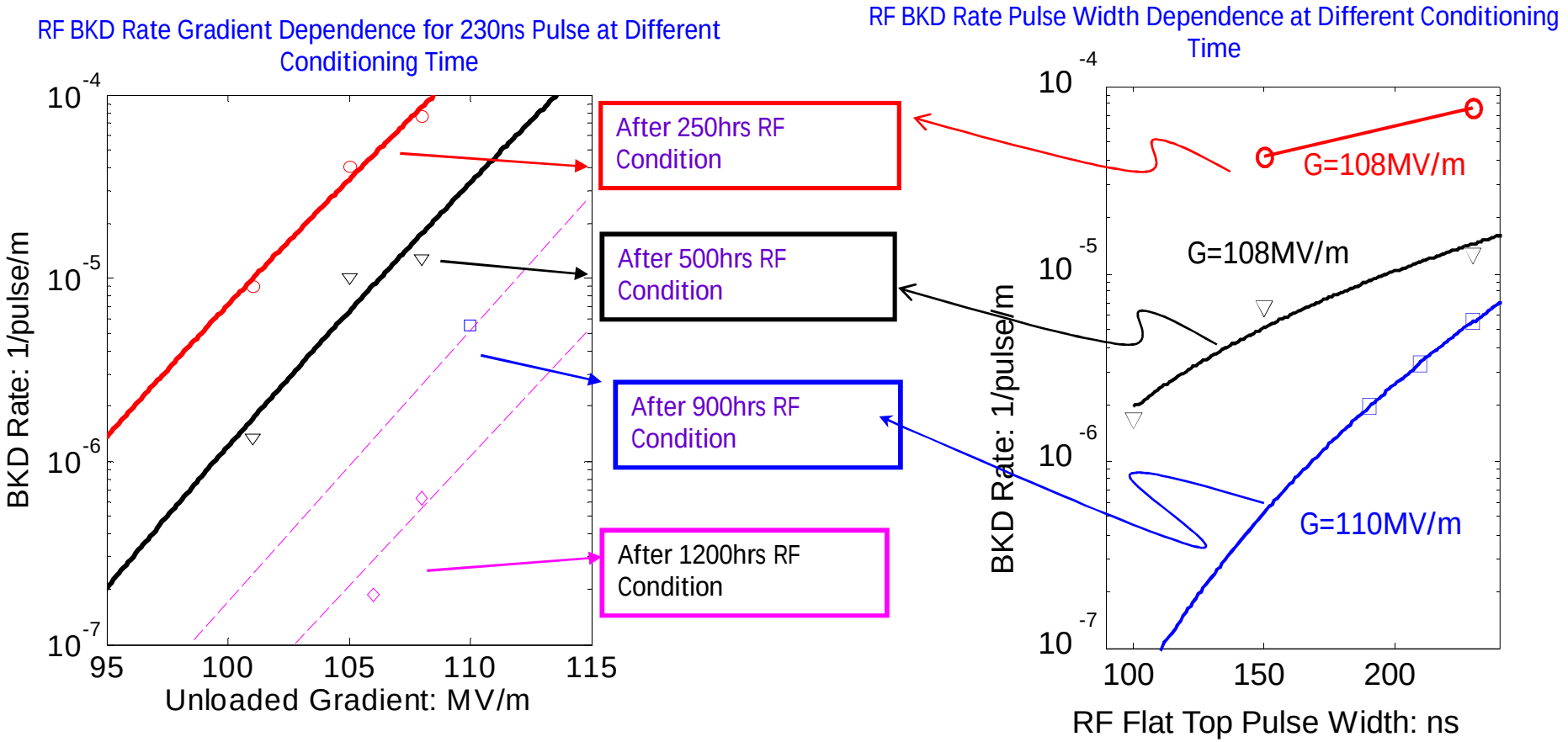


Power fit.

Cannot discuss functional form due to large scatter.

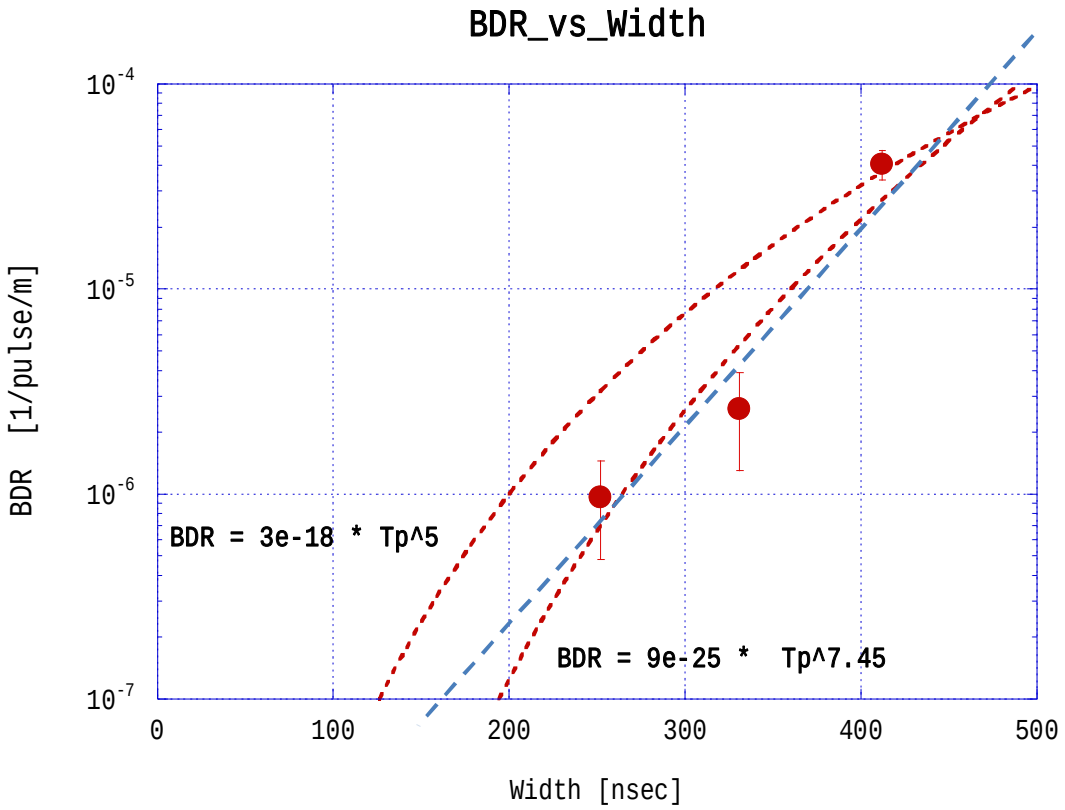
R. Ruth at X-band workshop at CI, UK, Dec. 2009

RF Processing of the T18 Structure



This performance *maybe* good enough for 100MV/m structure for a warm collider, however, it does not yet contain all necessary features such as wake field damping. Future traveling wave structure designs will also have better efficiencies

Breakdown rate versus width



Not enough to discuss functional form.
But it is evident that the longer pulse makes breakdown rate large with much more than linear dependence.

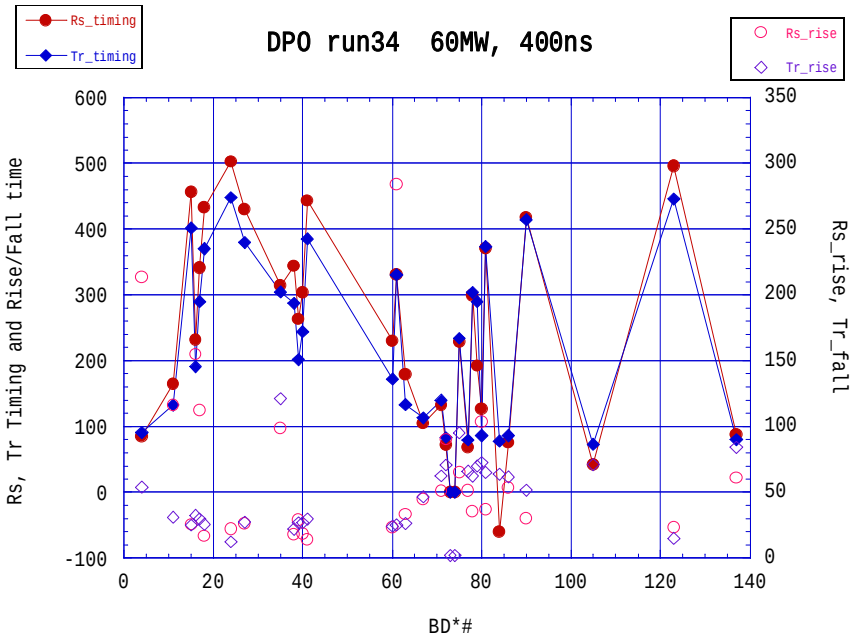
Summary of breakdown rate

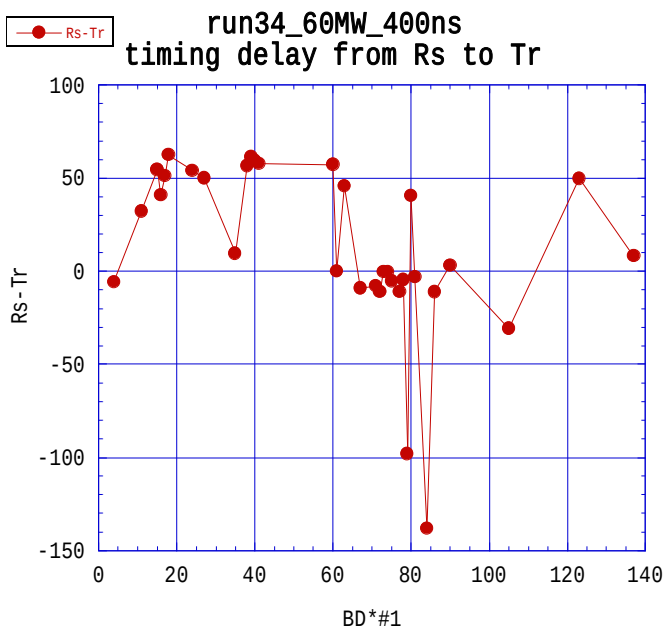
- Exponential slope as Eacc
  - Data scattering band around a slope is by an order of magnitude
  - Slope = an order of magnitude by 10 MeV/m
  - Not enough to discuss about the functional form
- Breakdown rate evolution
  - Reduction of BDR was not seen in last 2000 hours

Breakdown position and timing

- Still trying to analyze in detail.
- At present, mainly refer to Steffen's previous analysis
  - More frequent at downstream

Analysis still on the way
137 examples of run24: 60MW, 400ns

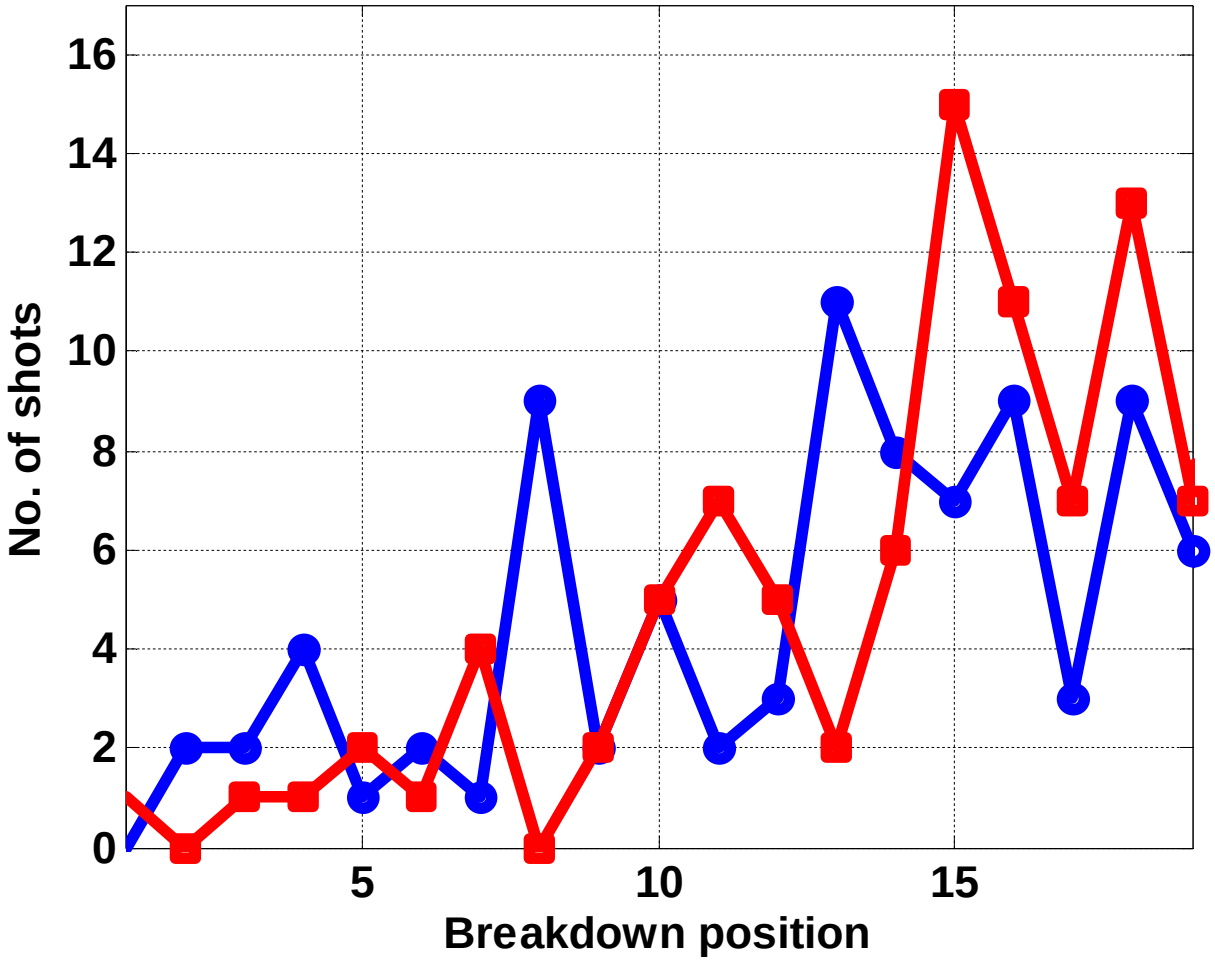




Timing of Rs rise and Tr fall show correlation.
Two cases: those at the same time and those at 50ns later.
Position and time of the breakdown should be deduced from Rs and Tr.
FC current burst timing and amount should be integrated in the analysis.
Breakdowns from the very first pulse are missing; should be included in the analysis.

Steffen 090227

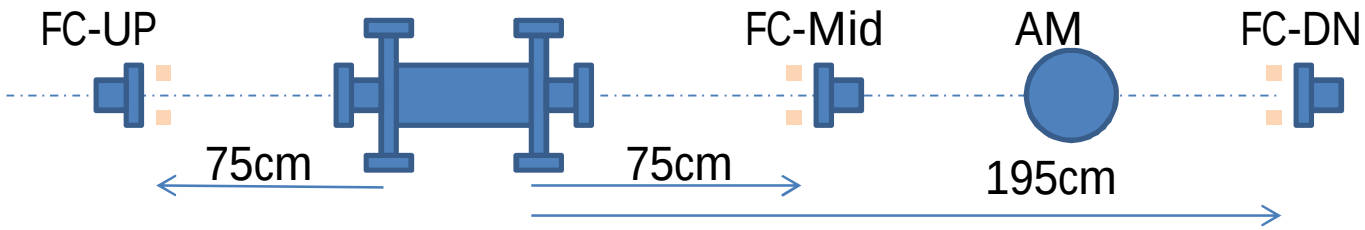
Breakdown position for 205 ns data



Red real cell timing, blue linear cell timing, 205 ns data

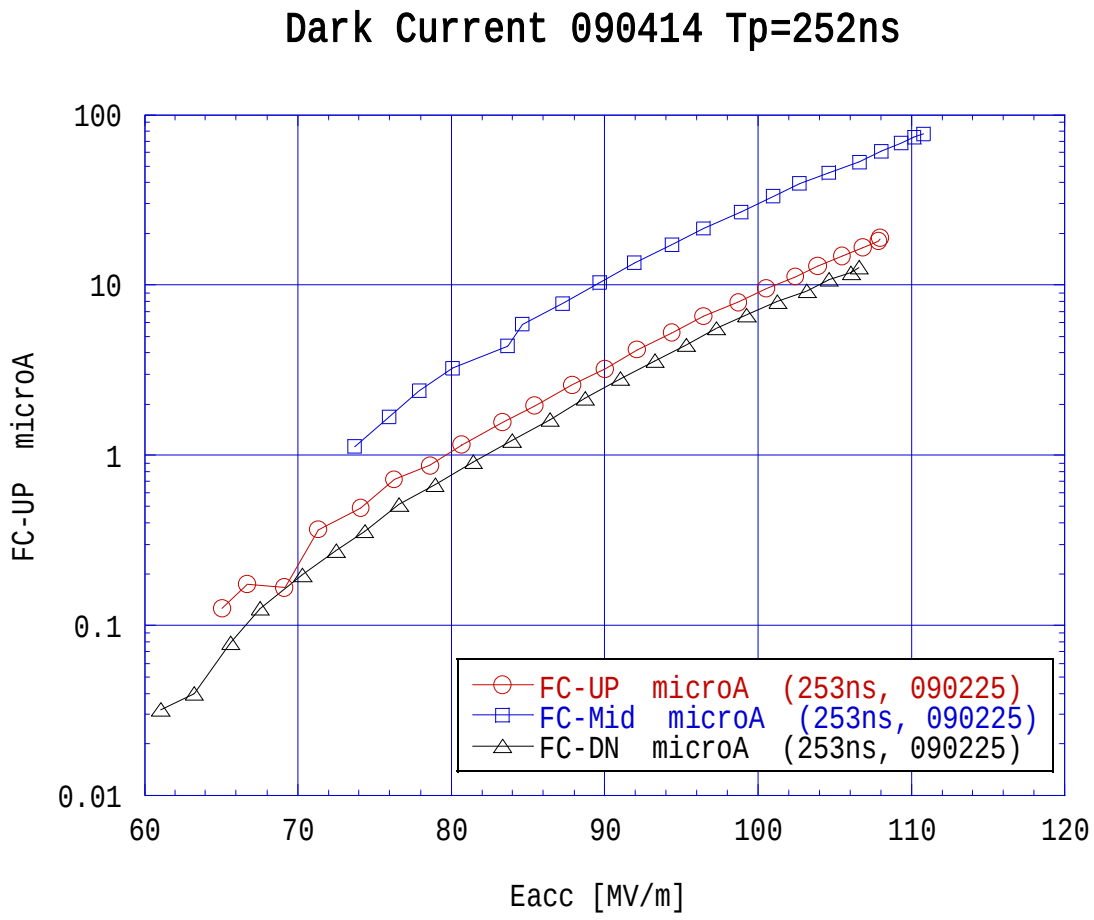
Dark current measurement

- Setup



- Amount and beta value of dark current versus processing time
- Spectrum at RF-ON 2000hrs and 4000hrs

Amount of dark current

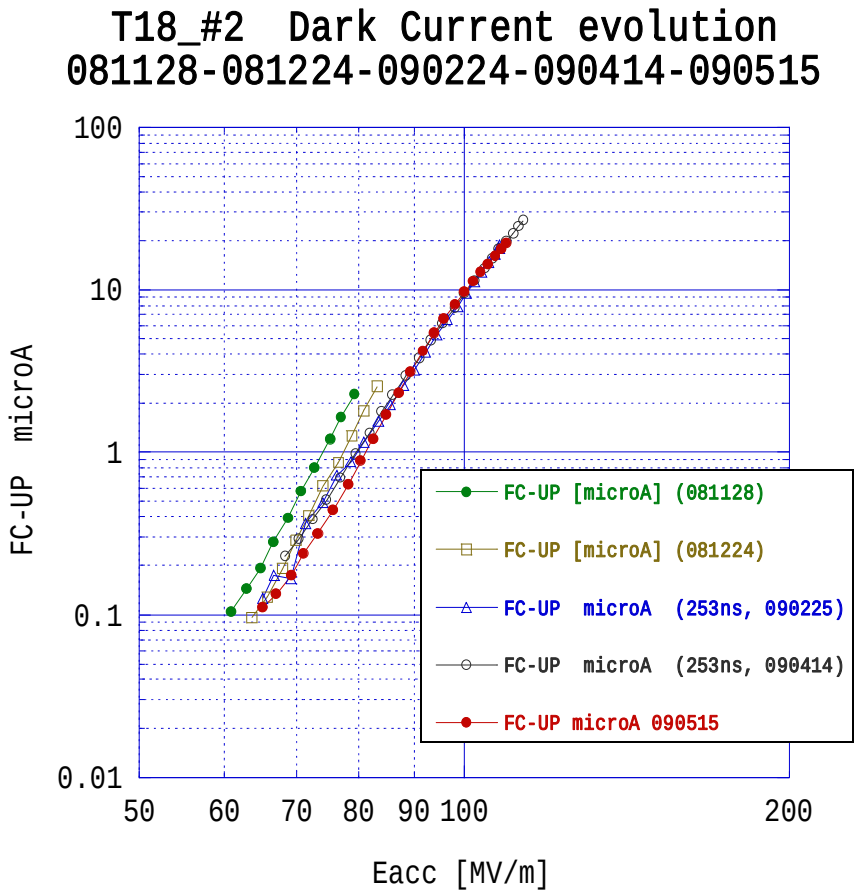


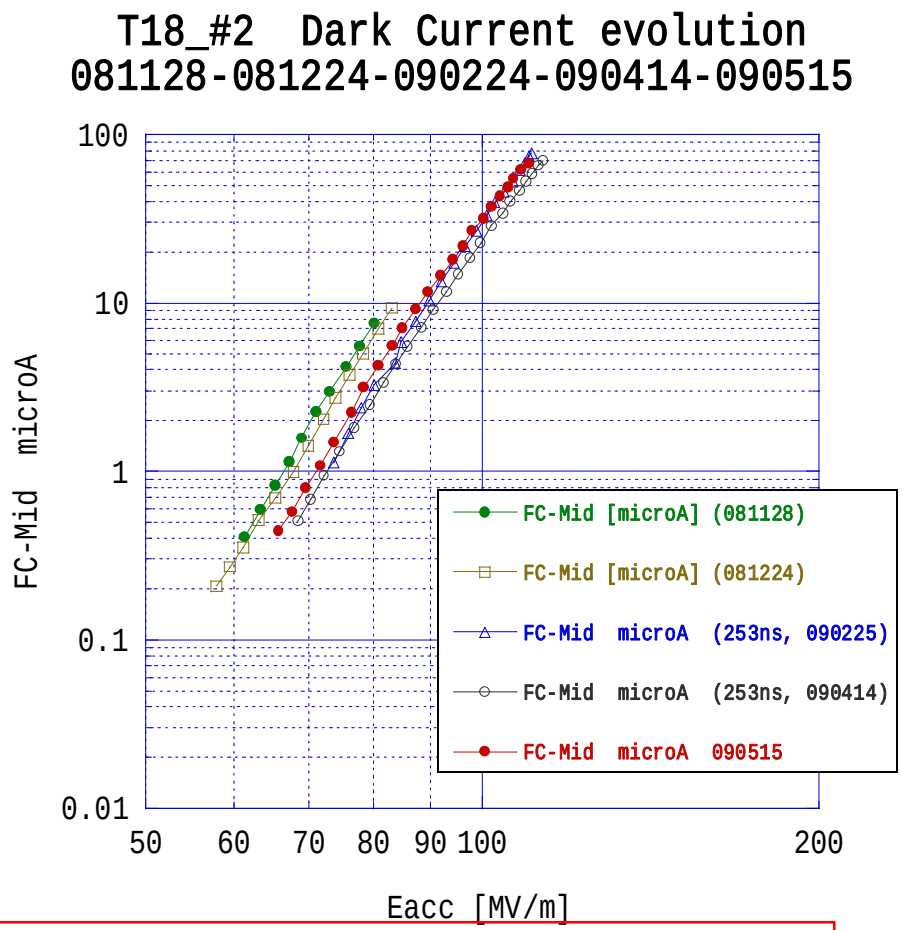
FC-Mid = 30μA @100MV/m

FC-UP ~ FC-Mid/3

FC-DN ~ FC-Mid/4

Dark current evolution 252nsec



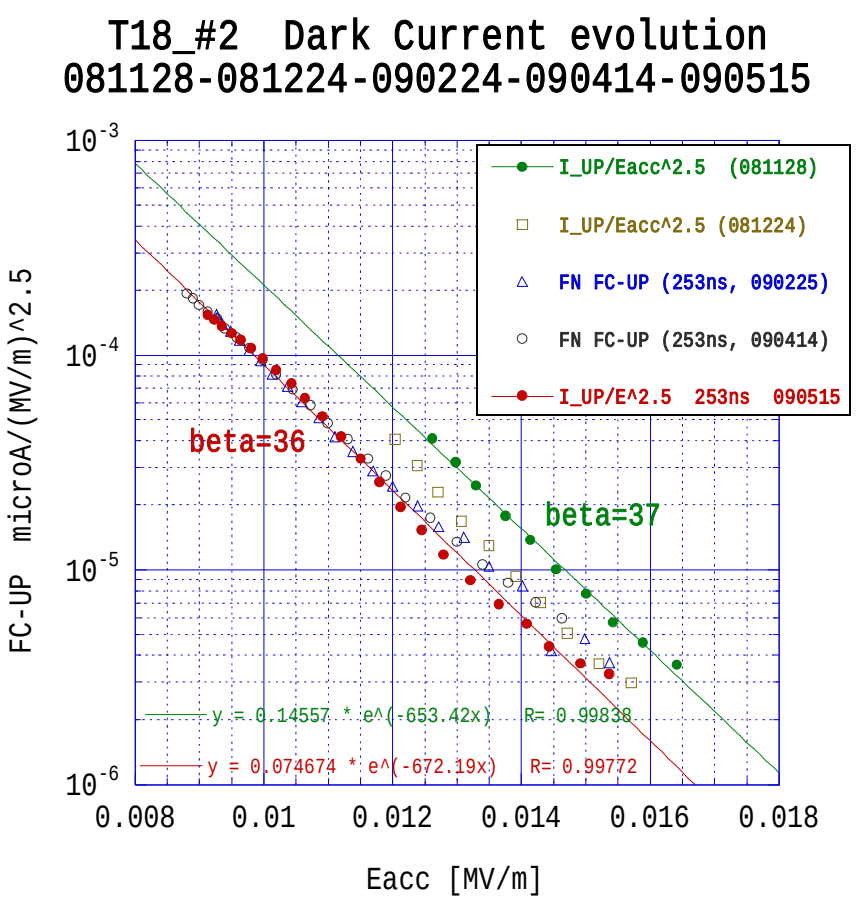


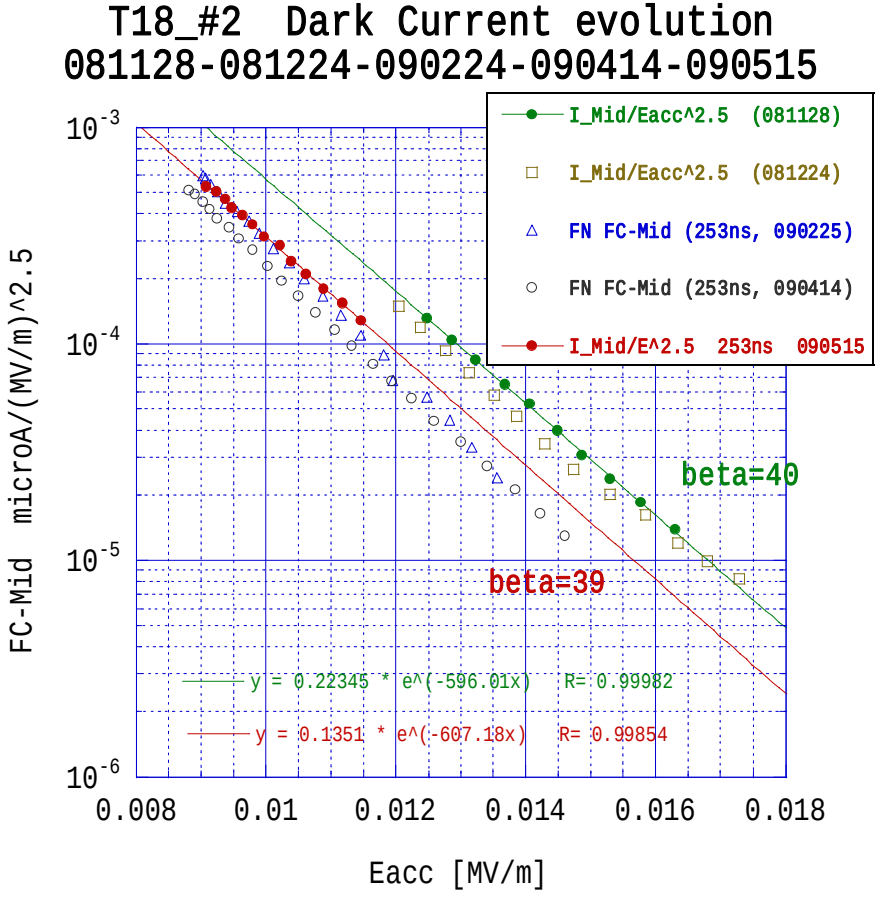
Measured at RF ON 700 – 1200 – 2100 – 3000 – 3400 hours

Decreased by a factor 2 between processing with max Eacc 80 → 110MV/m,

but no more suppression in the following steady-state run for more than 1000 hours

Dark current evolution 252nsec





Measured at RF ON 700 – 1200 – 2100 – 3000 – 3400 hours

No big change in shape nor slope (beta).

Deduction of the field enhancement factor

Fitting of modified F-N curve

$$\frac{I}{E^{2.5}} \propto e^{-\frac{6.53\times10^{9}\,\phi^{1.5}}{\beta\,E_s\,(V/m)}} = e^{-\frac{\alpha}{E_{acc}\,(MV/m)}}$$

Assuming Es/Eacc=2

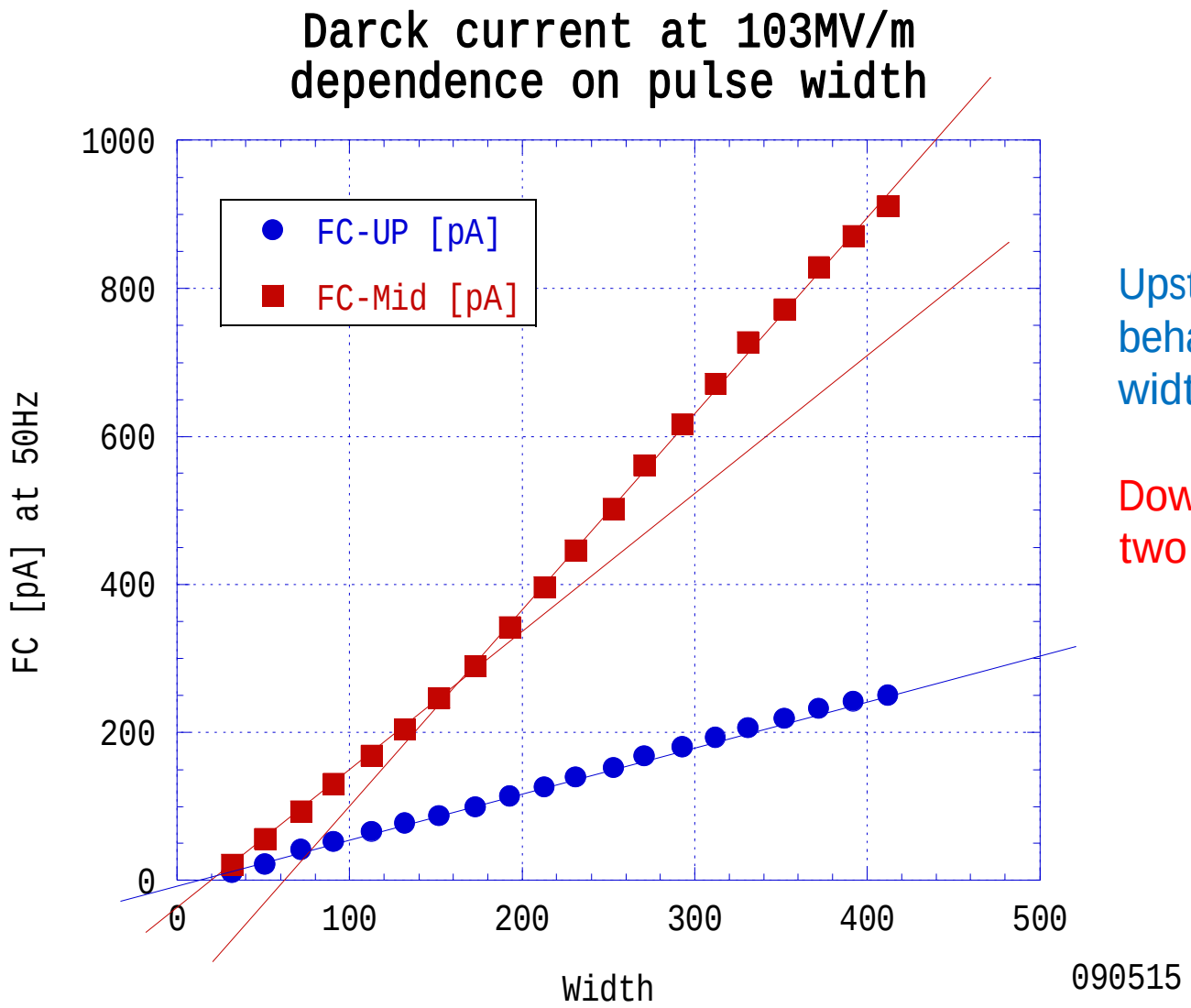
actually T18_VG2.4_Disk

Es/<Eacc>~2.62 max

ϕ(Cu)=4.52eV

$$\beta = \frac{6530\,\phi^{1.5}}{\alpha\,(E_s / E_{acc})} = \frac{23951}{\alpha}$$

Width dependence



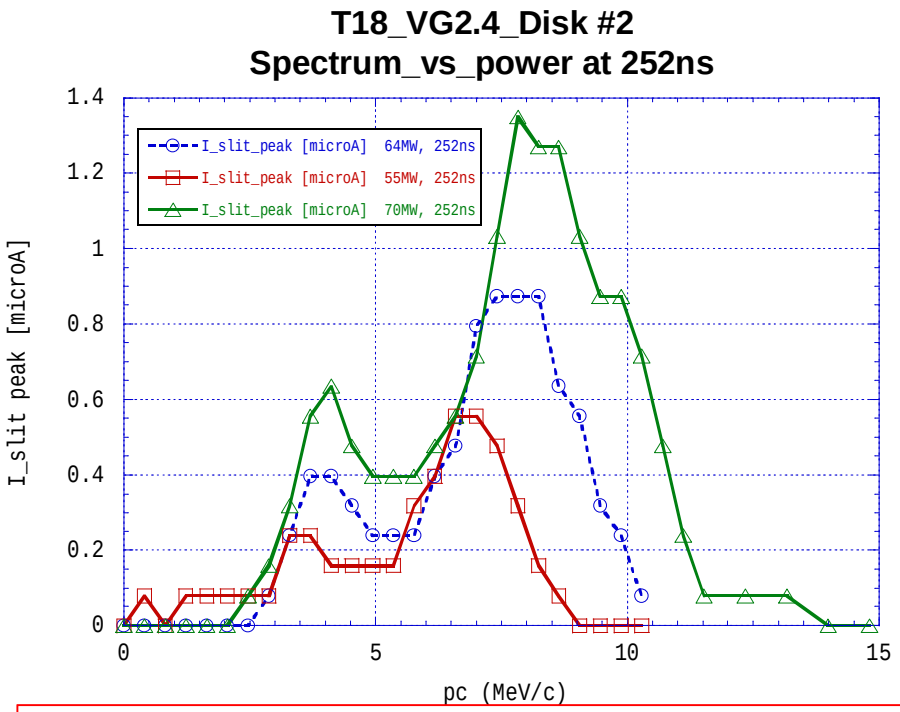
Upstream current behaves as linear on width

Downstream current has two components.

Dark current spectra in June

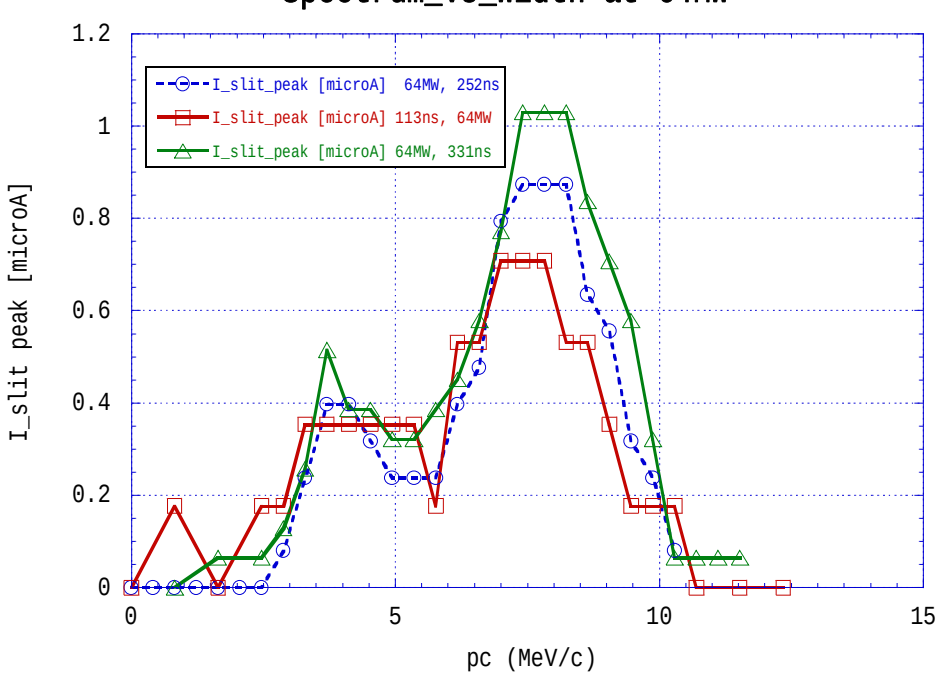
09

Dependence on power



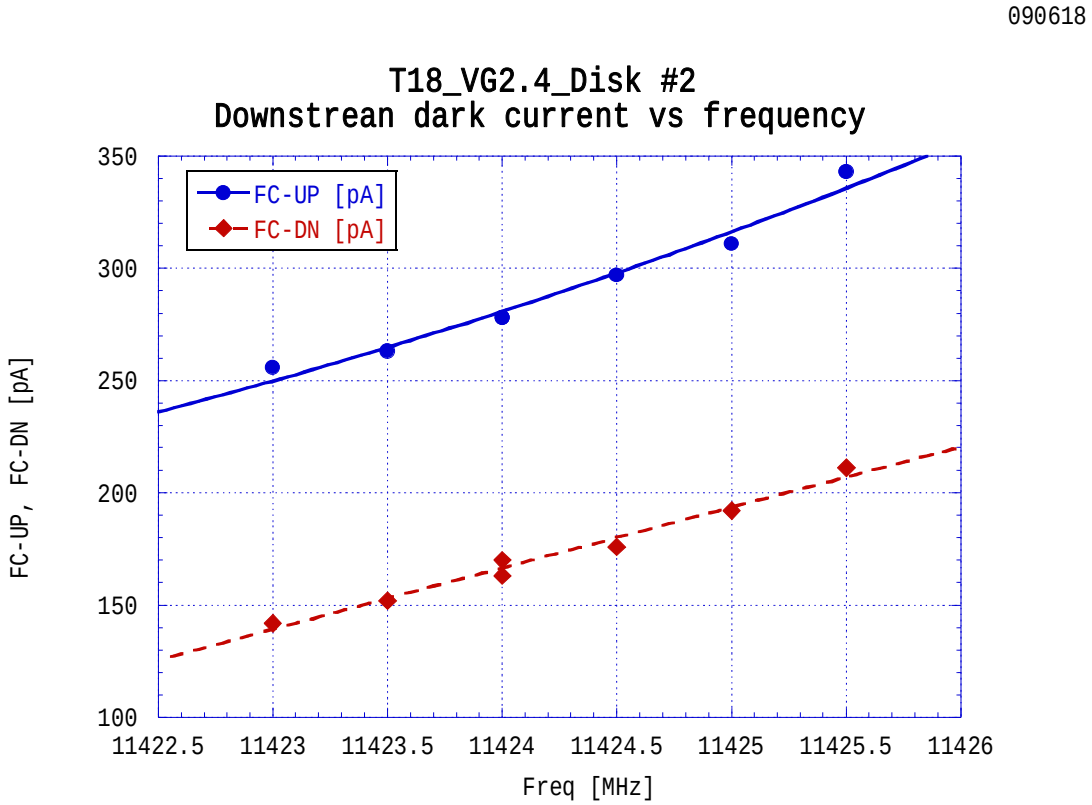
Dependence on width

090618



Actual field of analyzer magnet was checked.
The formula used up to now pc[MeV/m] = 1.646 x I [A] = 8.23xRef. Volt. [V] was confirmed.
Two peaks appear and higher for higher momentum one.
Less than ½ of full acceleration.
Little exists below 2.5MeV/m.

Dark current versus operation frequency



Increase as operation frequency increases.
Easy to be captured for both!?

Dark current behaviour

- Amount
  - to upstream << to downstream
  - Divergent: 1/4 from Mid to DN
  - Linear vs pulse width
- Reduction of dark current
  - By a factor 2~3 during first 2000 hrs
  - No reduction after 2000 hrs
- Beta value
  - Stayed almost constant from 700hrs to 3300 hrs
  - Not processed?
- Spectrum
  - Two peaks below half of full acceleration

Conclusion

- Established a basic procedure of processing and evaluation
  - Can proceed a series of structure tests
  - Better to further develop a system in such as
    - Phase measurement, missing energy evaluation, etc.
- Breakdown rate was evaluated.
  - Gross comparison with that of SLAC is consistent with each other.
  - In order to precisely compare, power estimation and identification of breakdowns should be better.
- Dark current
  - Decreased during initial processing but stayed constant during a long-term run without higher field nor longer pulse processing.
  - Energy is at most a half of full acceleration and little exists below a few MeV/c.
- Breakdown pulse analysis
  - Breakdown pulses are still to be analyzed carefully.