Status of High-Gradient R&D

- Structures tested in NLCTA since ISG-9
  FXB-002,H90vg3N,H60vg3N-6C,FXB-003,
  SW20a375,FXB-004,H60vg3S18
- Evolving picture of RF breakdown
- Latest developments in structure design
- Conclusion and Outlook

Next Linear Collider
Test Accelerator

NLC Structure development

SLAC/NLC

C. Adolphsen, G. Bowden, D. Burke, J. Cornuelle, S. Döbert, V. Dolgashev, J. Frisch, E. Garwin, R. Kirby, S. Harvey, K. Jobe, R. Jones, F. Le Pimpec, Z. Li, G. Loew, D. McCormick, R. Miller, C. Nantista, J. Nelson, C.K. Ng, M. Ross, R. Ruth, T. Smith, S. Tantawi, J. Wang and P. Wilson

FNAL/NLC

T. Arkan, C. Boffo, H. Carter, D. Finley, I. Gonin, T. Khabiboulline, G. Romanov, N. Solyak

KEK/JLC

Y. Higashi, T. Higo, N. Toge

Next Linear Collider
Test Accelerator

NLCTA X-band power source

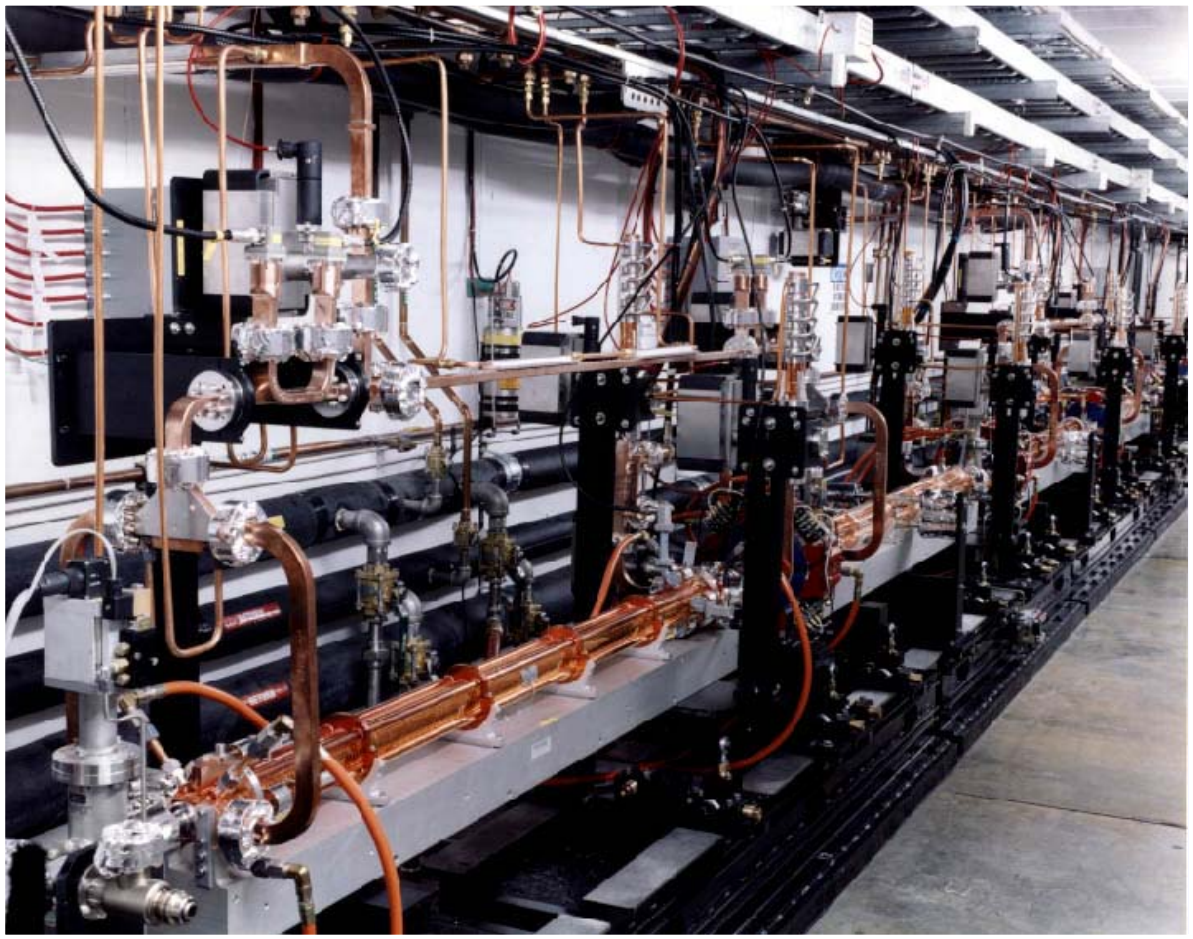
- 2 Test Stations with:

  2x50 MW Klystrons into a SLED system

  2 testing slots each

  150 MW per structure

- 60 MeV electron beam for energy and phase measurements



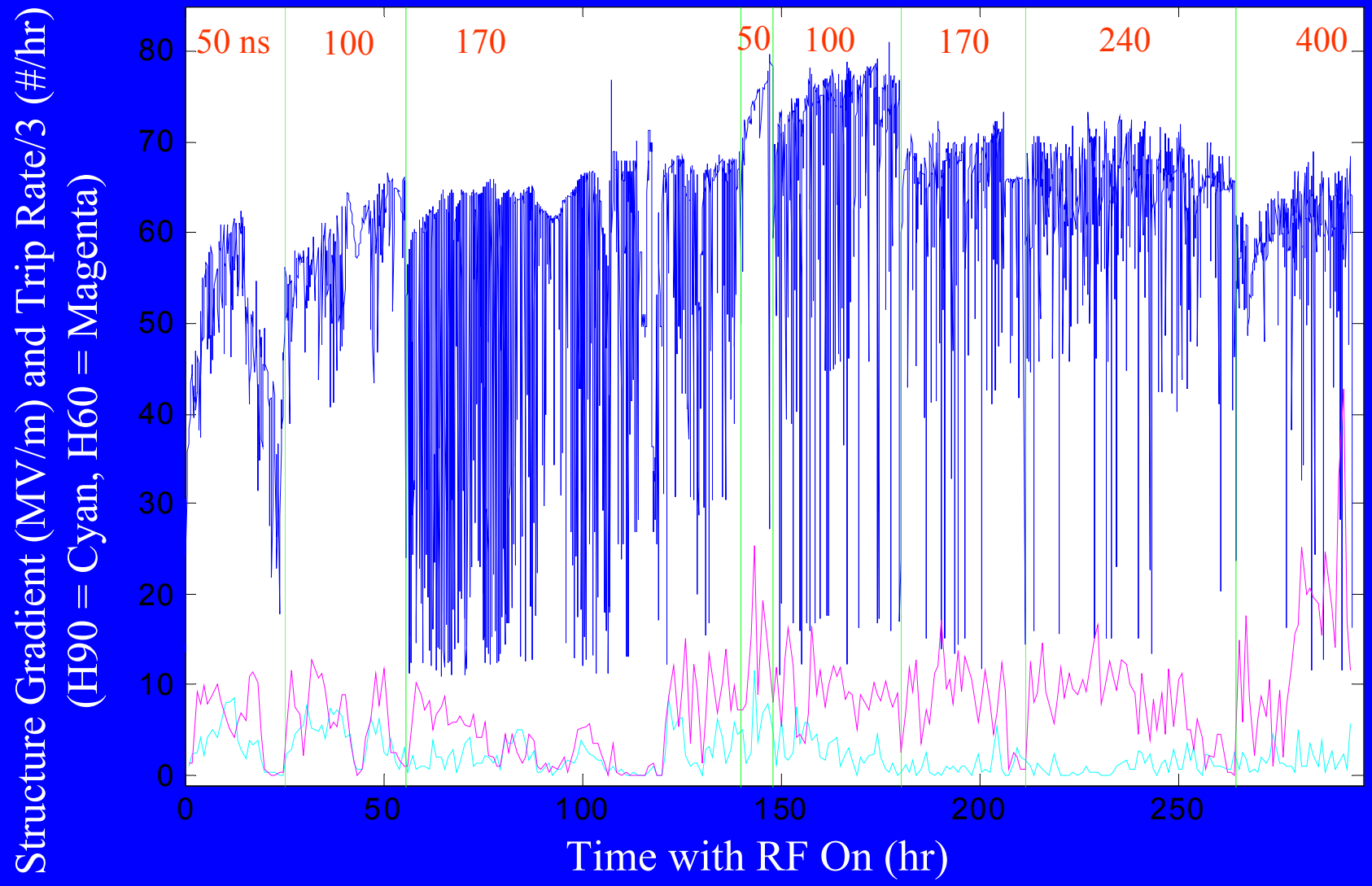
FXB002

First Fermilab structure high power tested

Length:	60 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.2
P_{in} (65 MV/m):	63 MW
Coupler:	rounded
Preparation:	external Ar-brazing, oxidized no vacuum bake

Next Linear Collider
Test Accelerator

FXB002-History



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Next Linear Collider
Test Accelerator

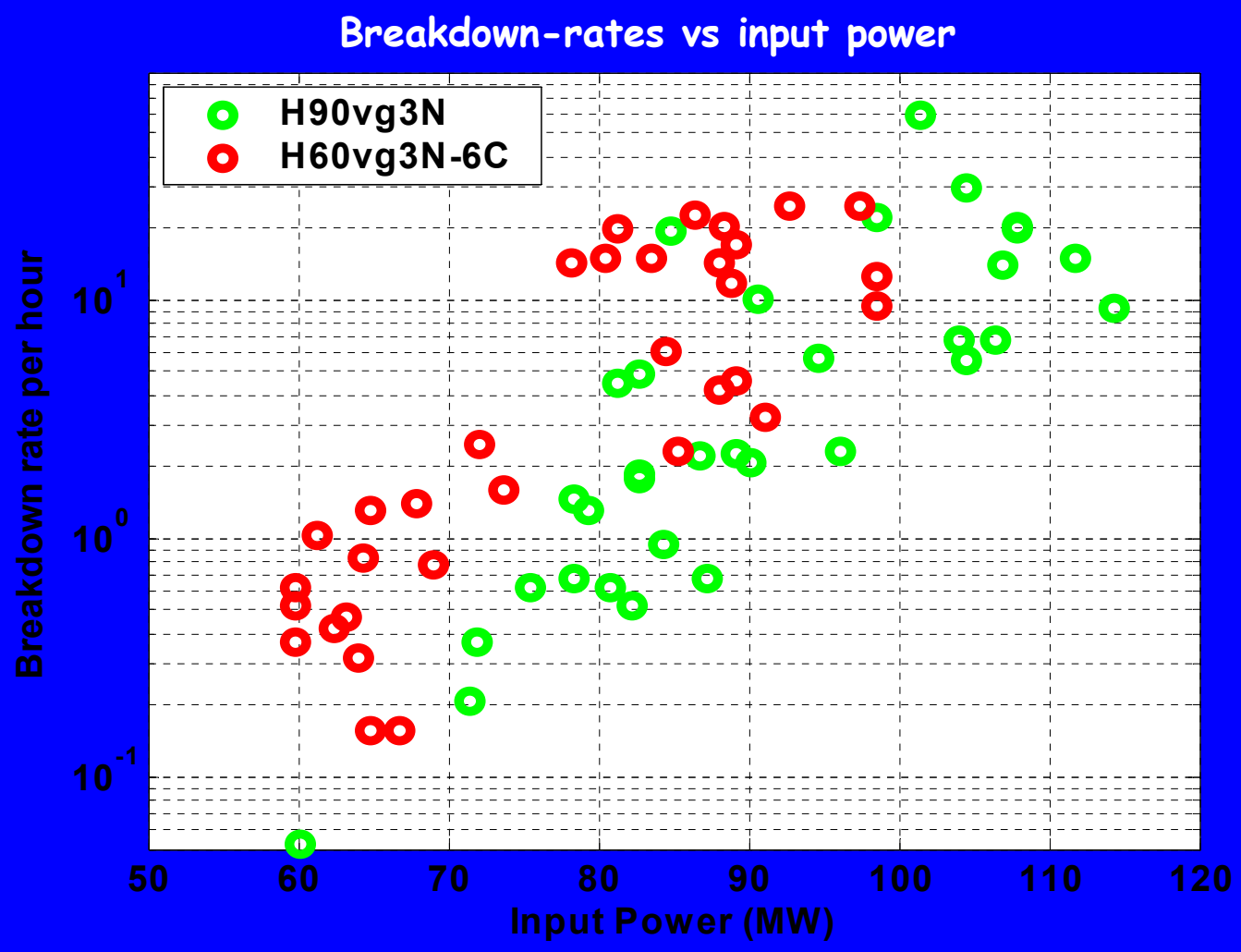
H90vg3N

Paired up with FXB002 afterwards alone

Length:	90 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.4
P_{in} (65 MV/m):	82 MW
Coupler:	rounded, inline taper
Preparation:	H_2-bonding/brazing Vacuum bake

Next Linear Collider
Test Accelerator

H90vg3N



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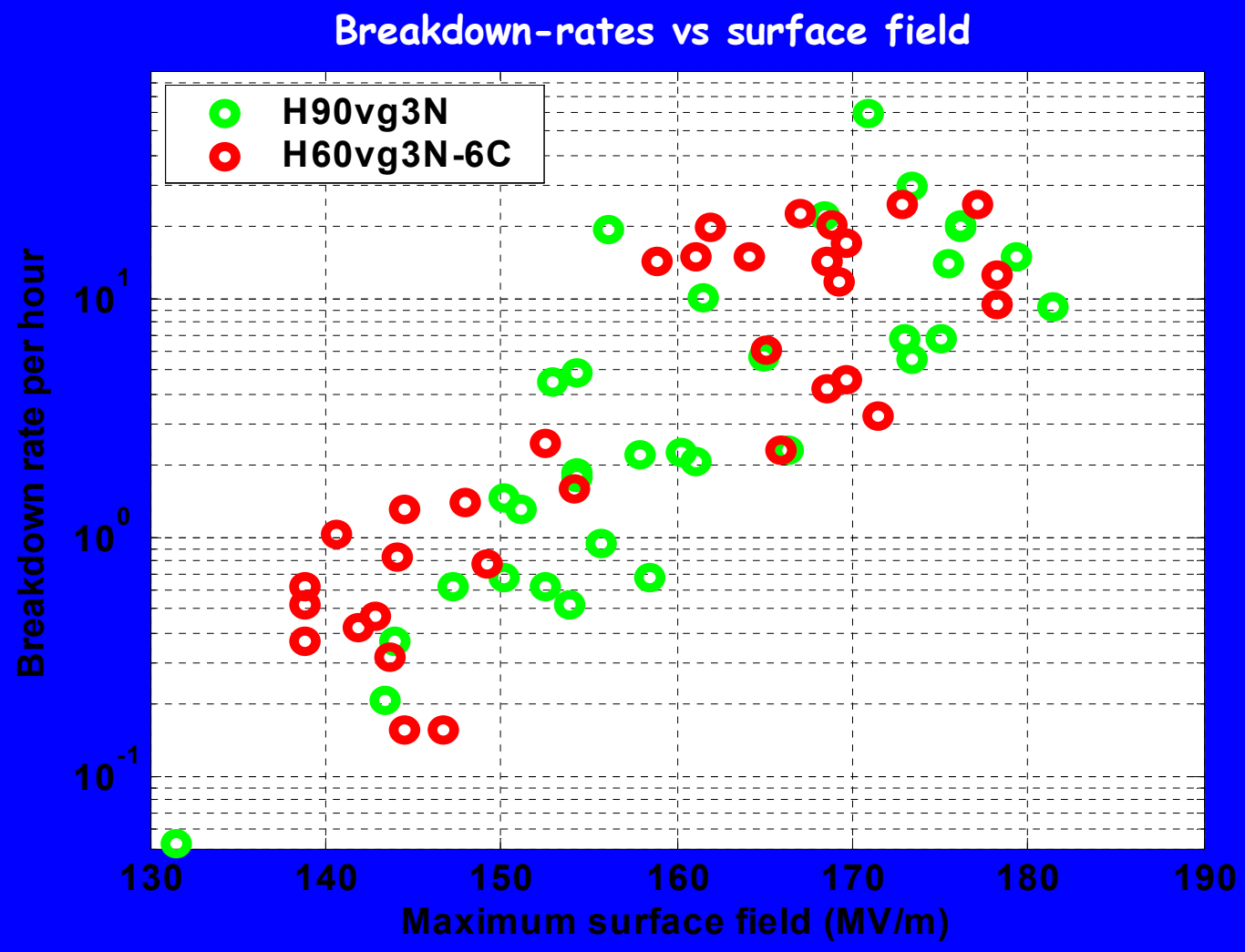
Next Linear Collider
Test Accelerator

H90vg3N



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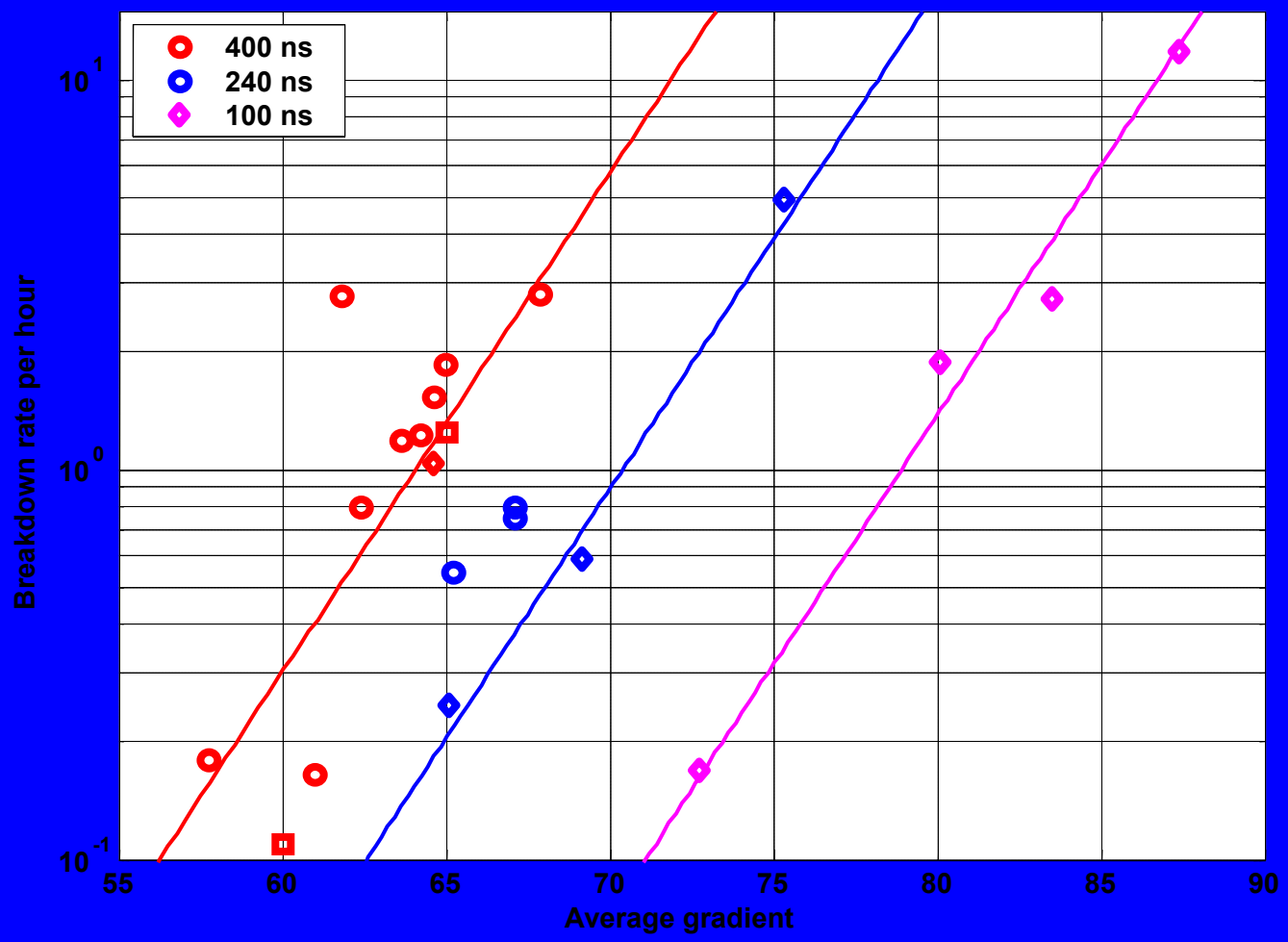
Next Linear Collider
Test Accelerator

H90vg3N

Breakdown-rates vs pulse length



Slope:

8 MV/m

per decade

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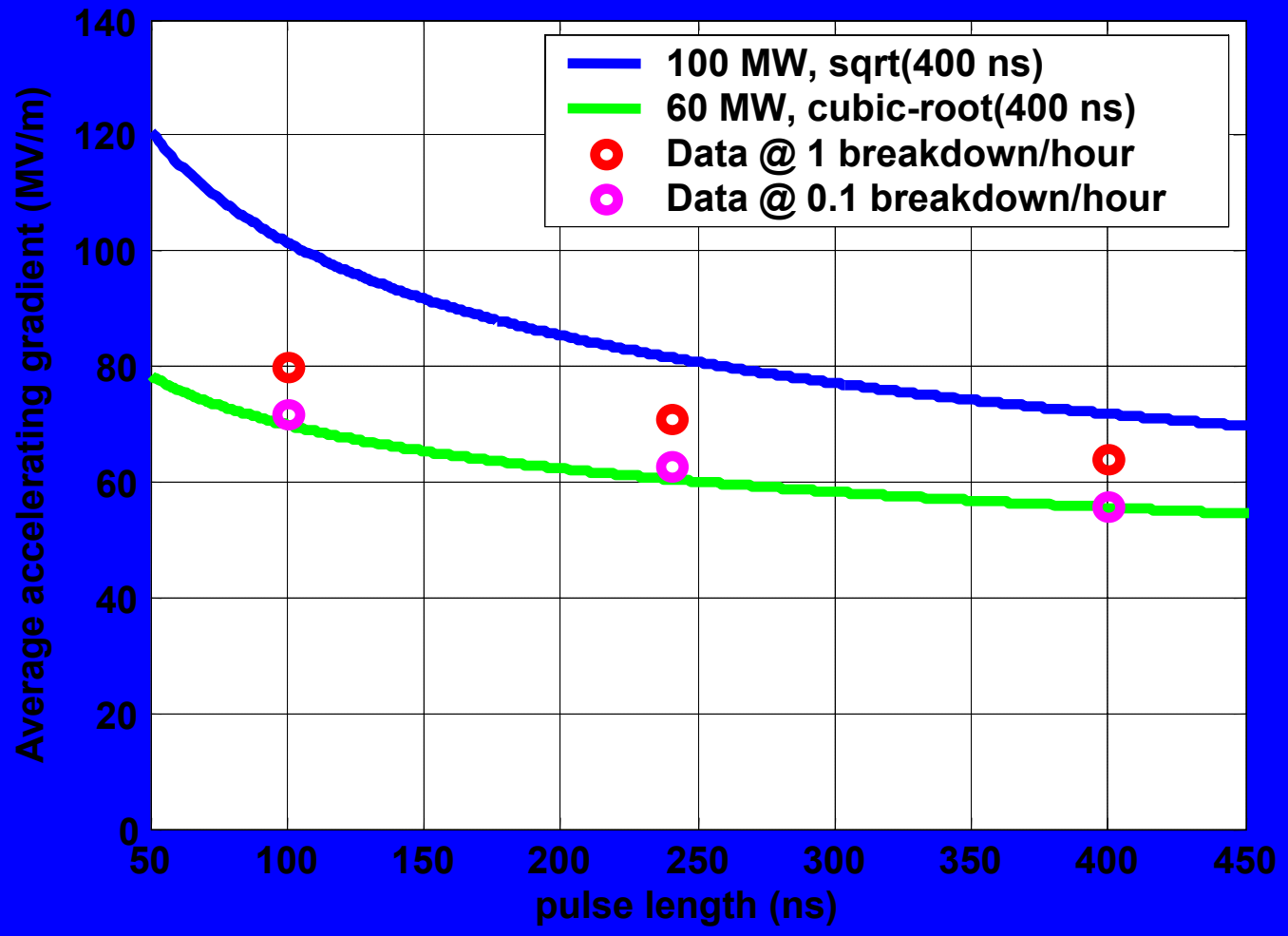
Next Linear Collider
Test Accelerator

H90vg3N

Pulse length dependence



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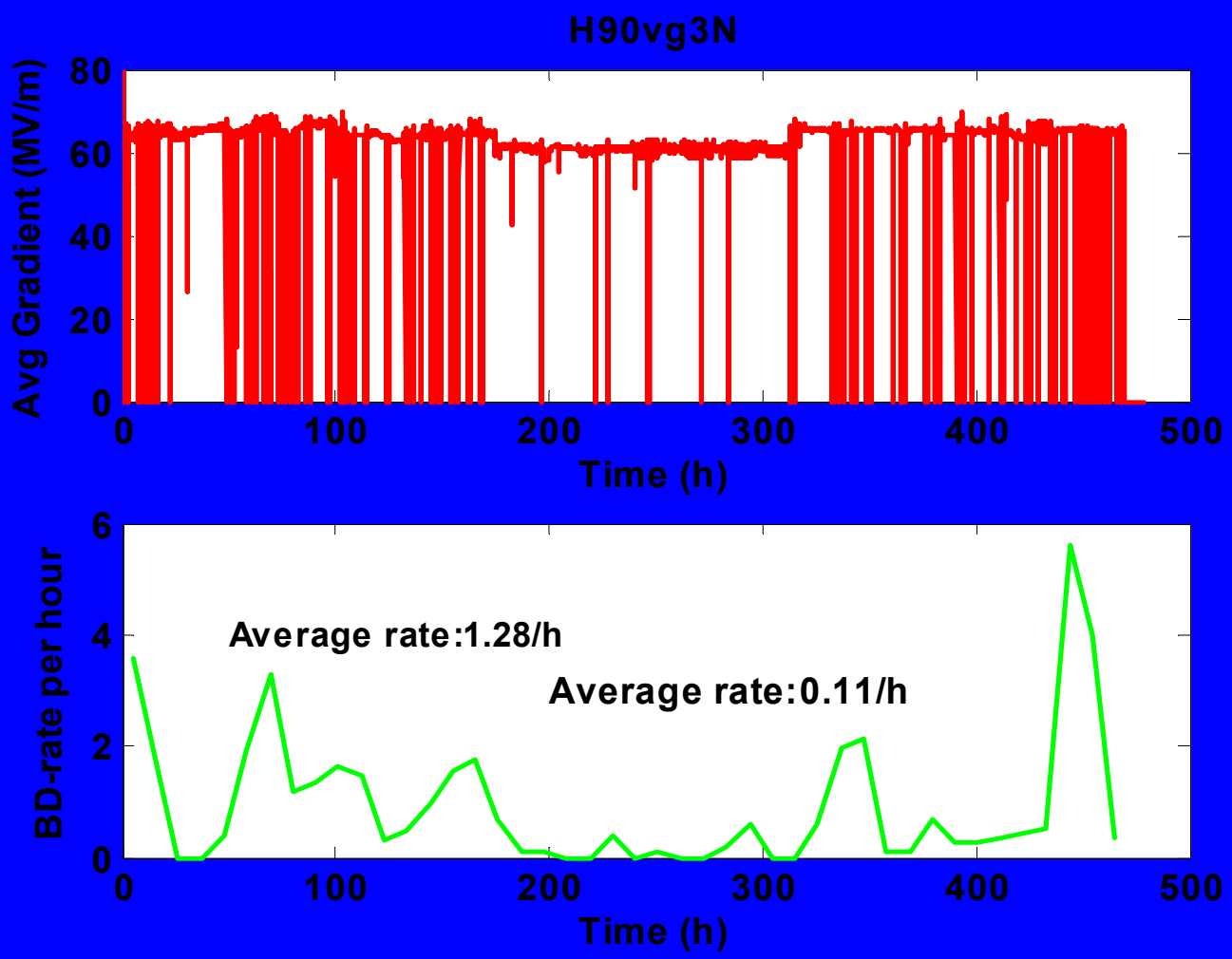
Next Linear Collider
Test Accelerator

Running at 65 MV/m - H90vg3N



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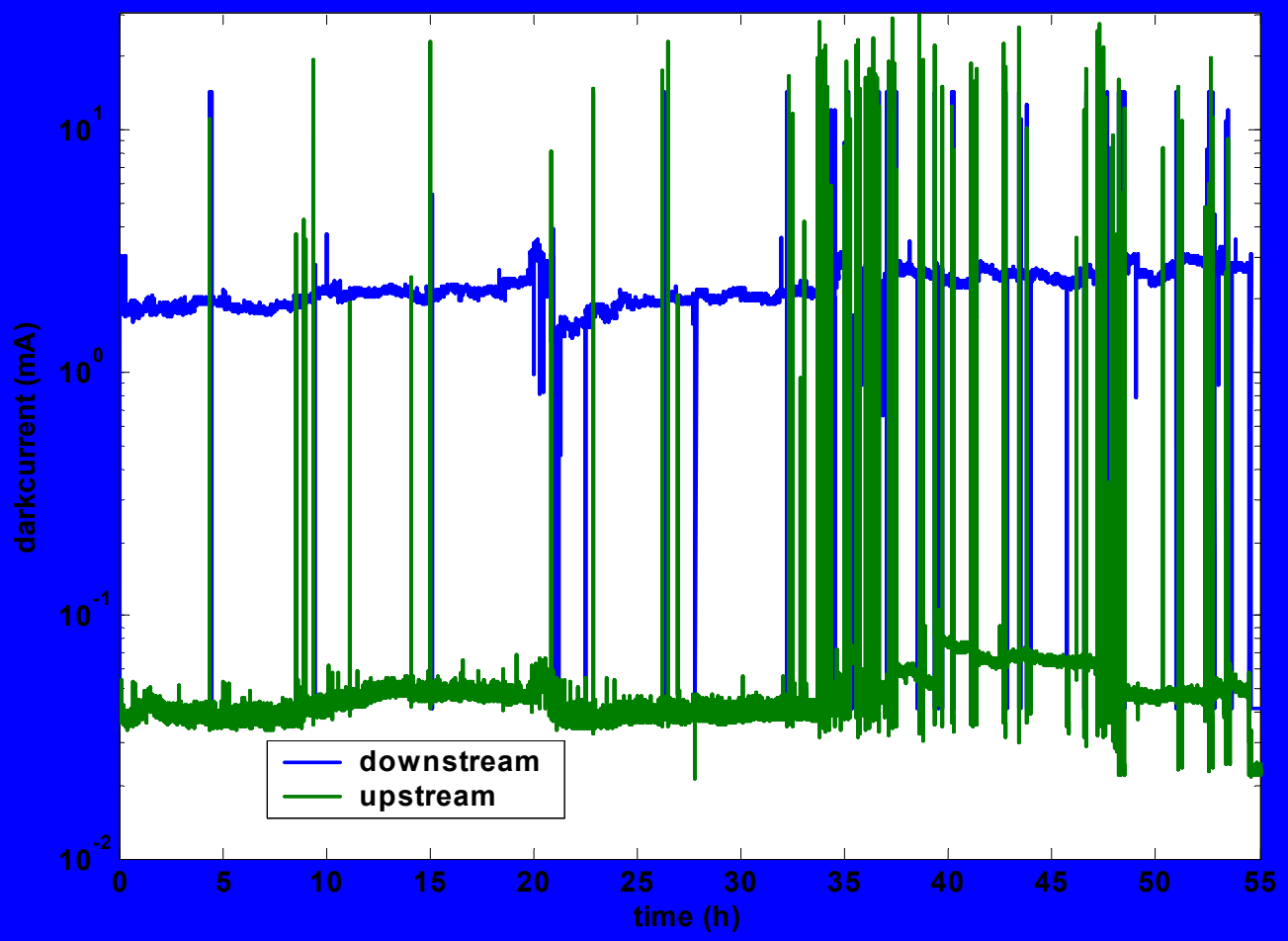
Next Linear Collider
Test Accelerator

Dark currents - H90vg3N

Surface field: 156 MV/m (Eacc = 65 MV/m)



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Next Linear Collider
Test Accelerator

H60vg3N-6C

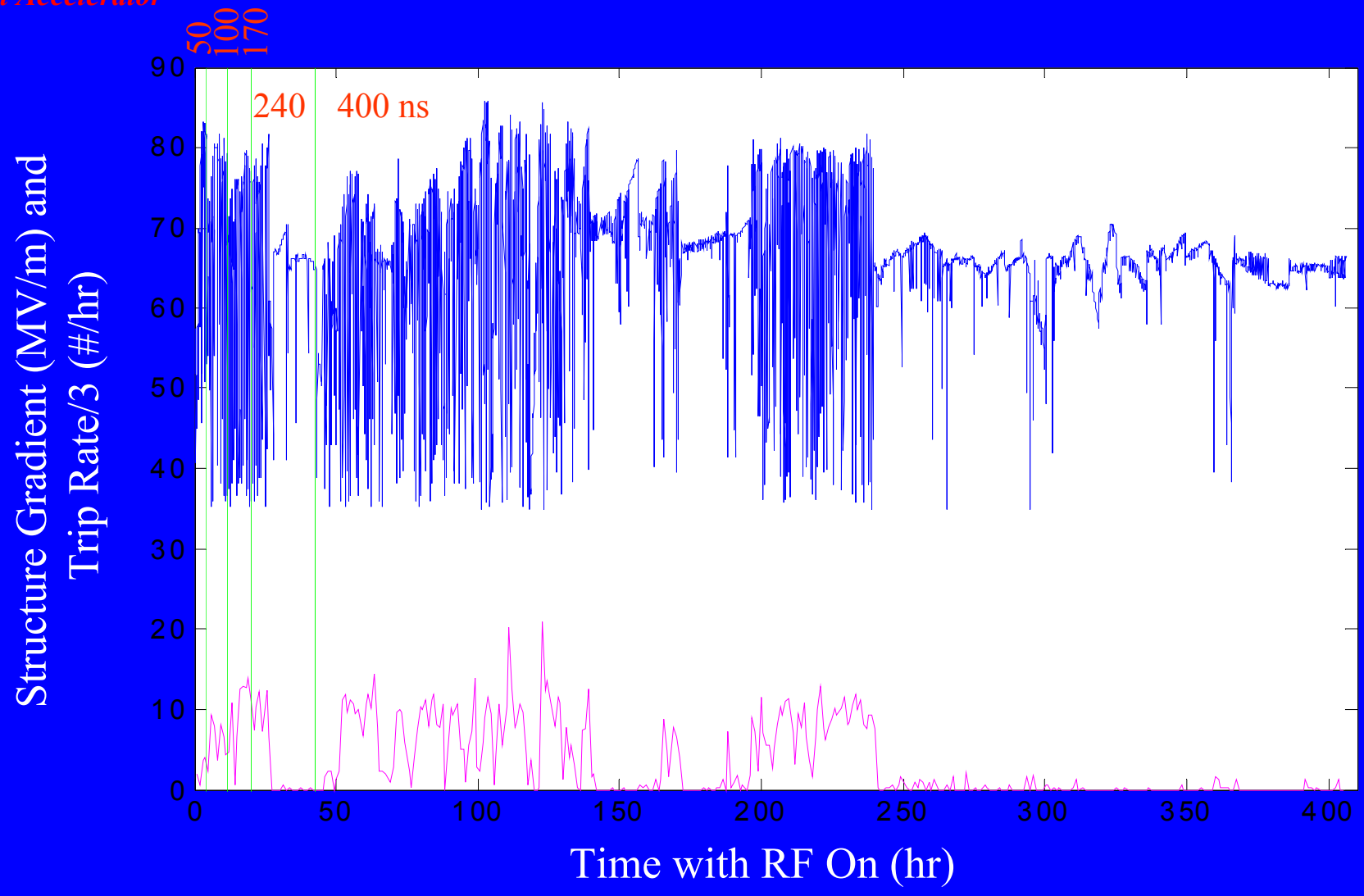
6 slotted cells brazed in the middle

Best H-structure so far !

Length:	60 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.2
Pin (65 MV/m):	63 MW
Coupler:	rounded, inline taper
Preparation:	H_2-bonding/brazing Vacuum bake

Next Linear Collider
Test Accelerator

Processing history – H60vg3N-6C

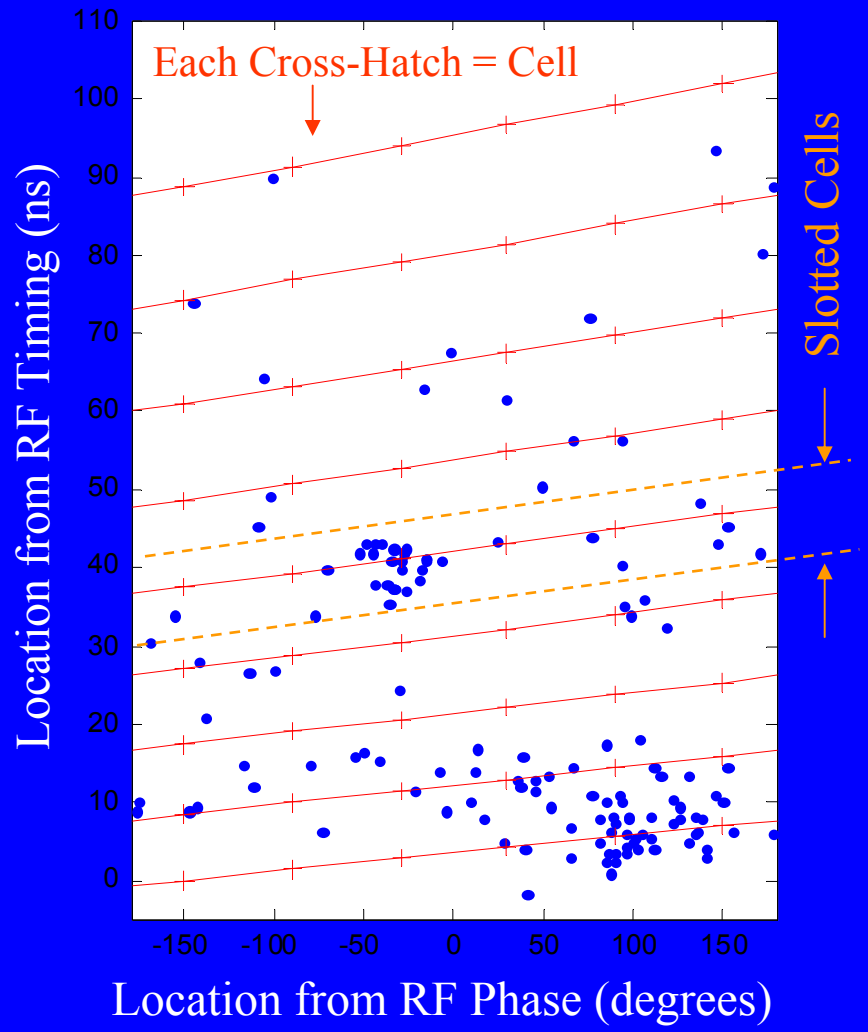


Next Linear Collider Test Accelerator

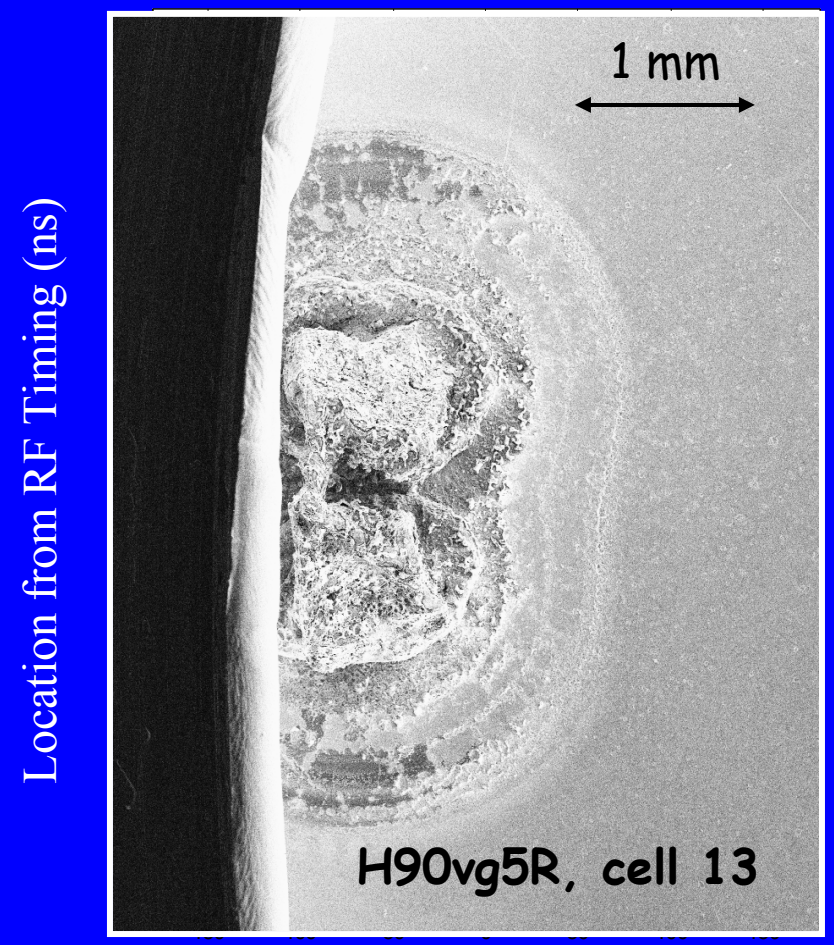
Clustering in space - H60vg3N-6C

Hot spots: dirt or defects ?

H60vg3N-6C



H90vg3N



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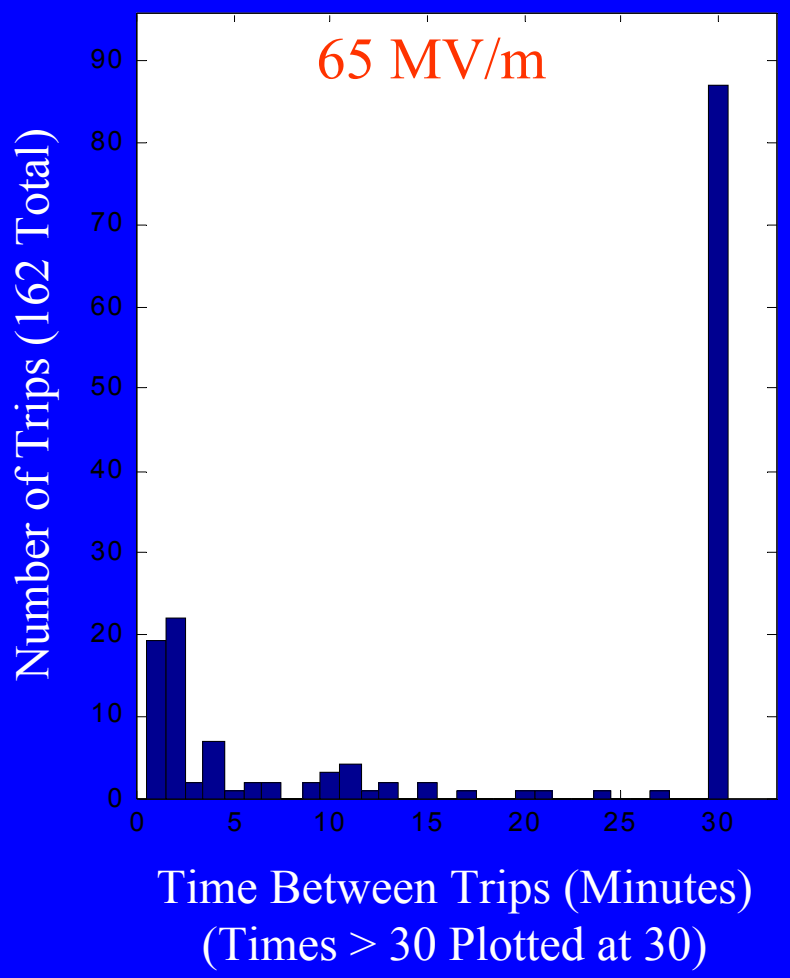
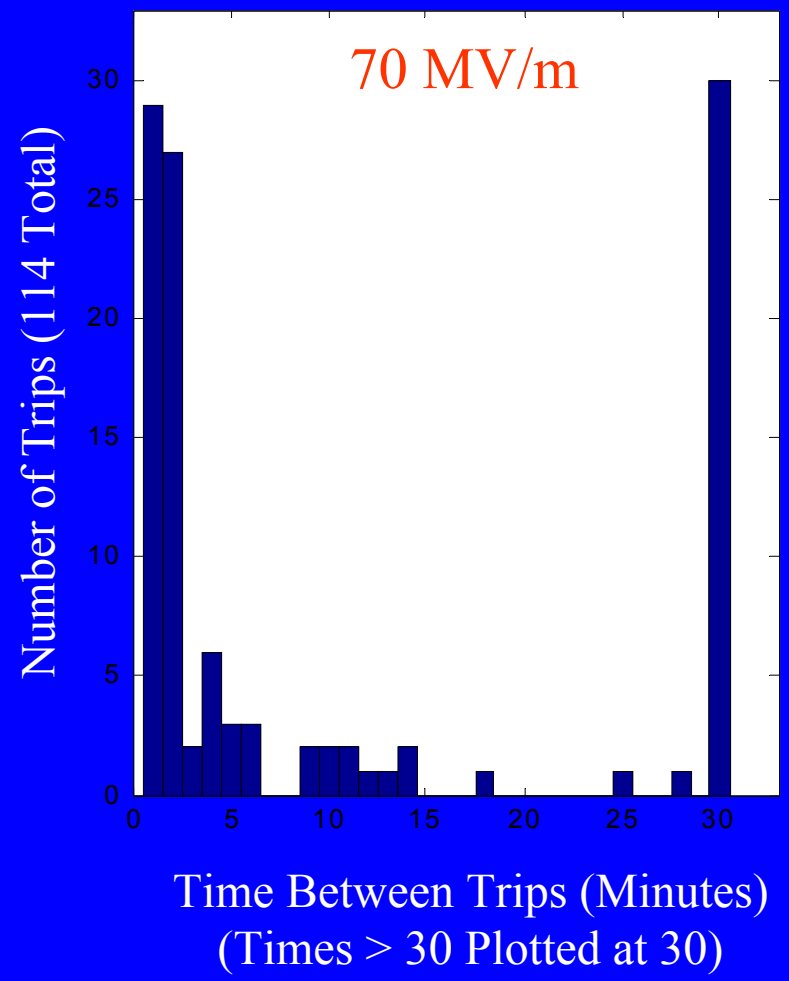
Next Linear Collider
Test Accelerator

Clustering in time - H60vg3N-6C

Spit fests: damage or processing ?





Next Linear Collider
Test Accelerator

One month at 65 MV/m - H60vg3N-6C

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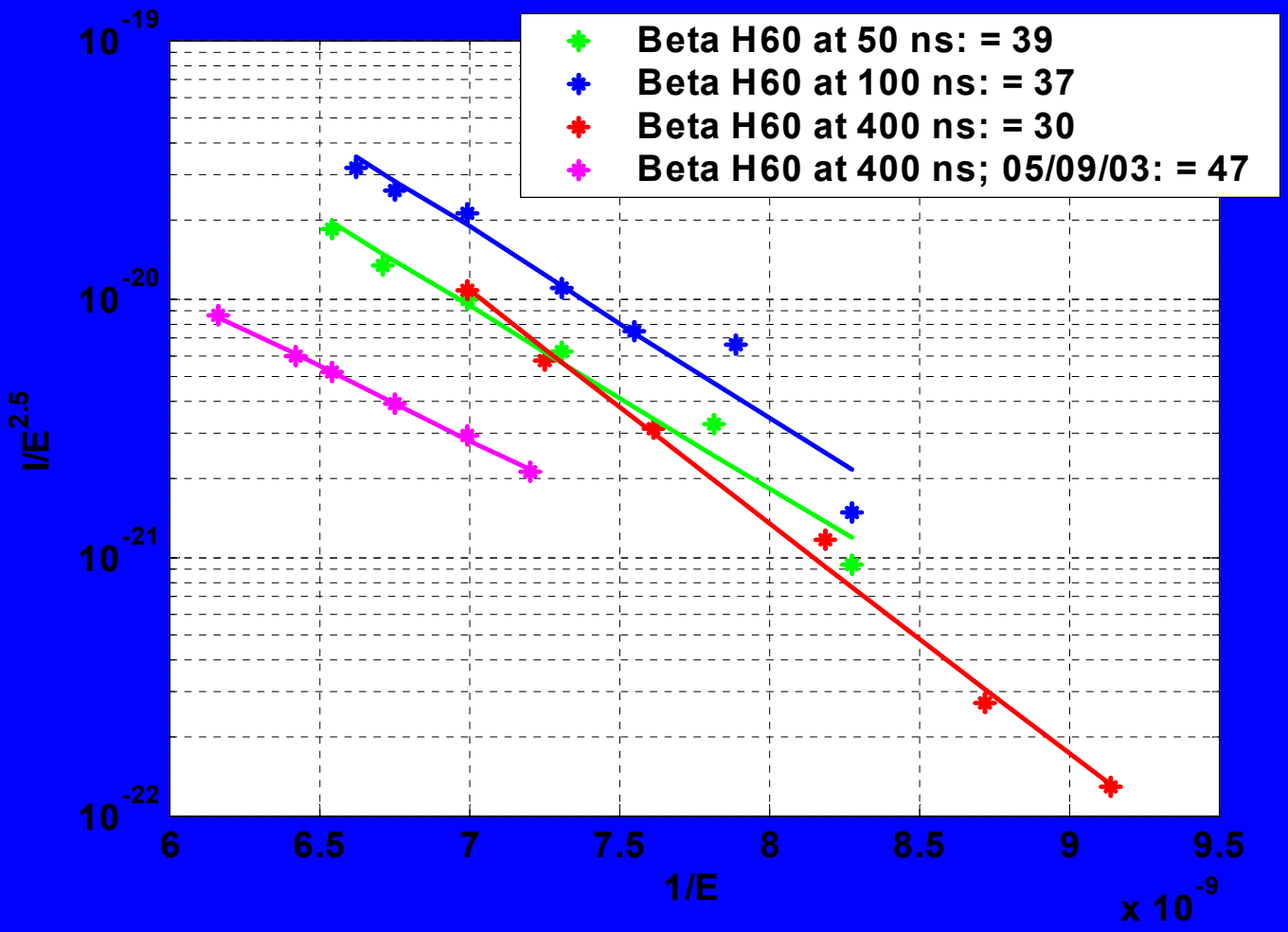
Next Linear Collider
Test Accelerator

Dark currents - H60vg3N-6C

Fowler-Nordheim-Plots



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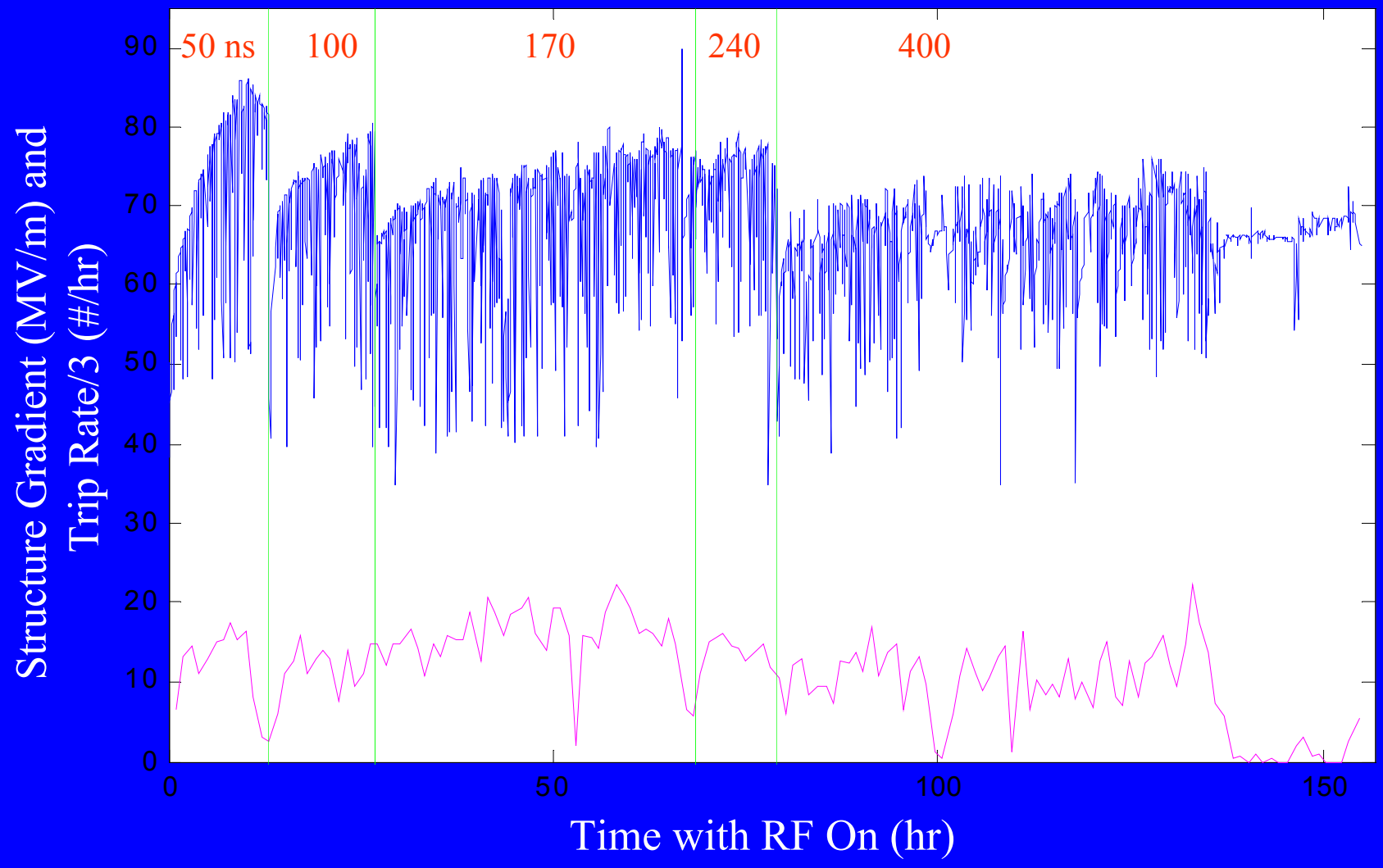
FXB003

Congratulation ! No.2 worked

Length:	60 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.2
Pin (65 MV/m):	63 MW
Coupler:	rounded
Preparation:	Ar-brazing, short H_2-bake + Vacuum bake

Next Linear Collider
Test Accelerator

Processing history - FXB003



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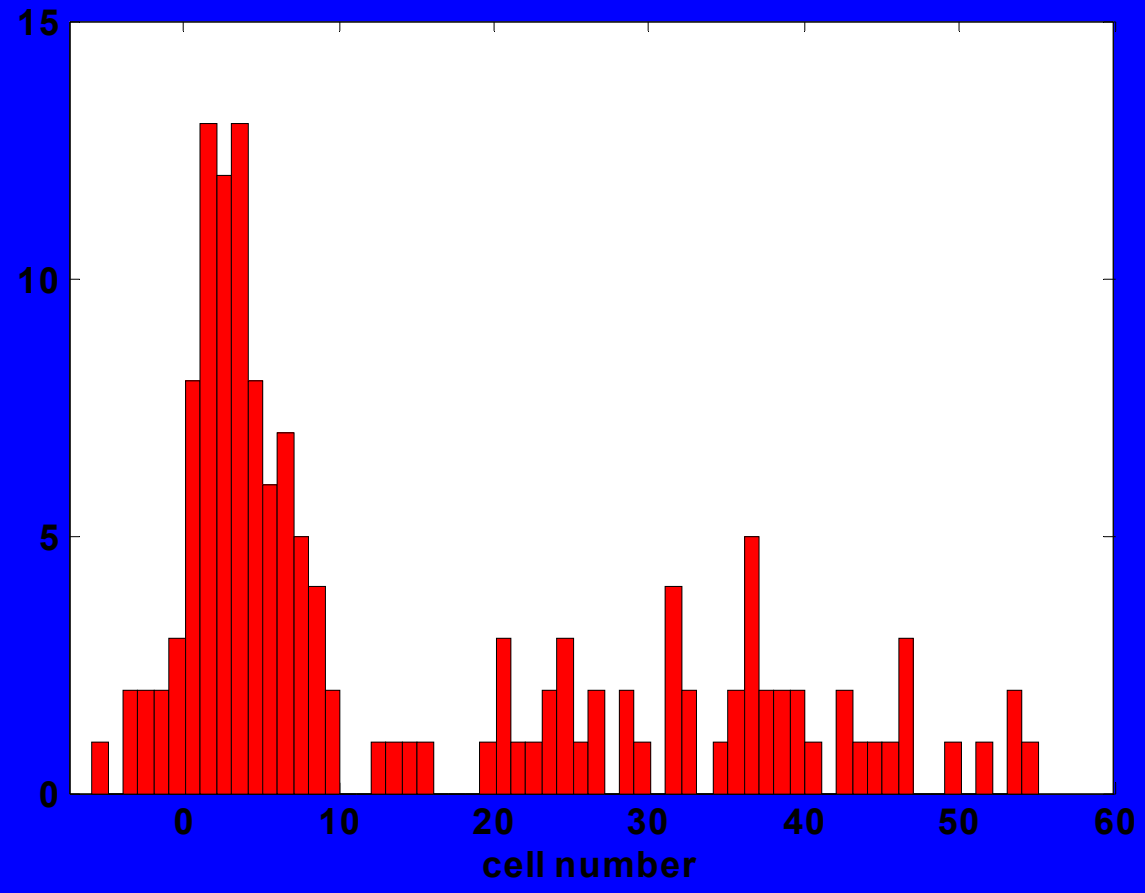
Next Linear Collider
Test Accelerator

Breakdown locations - FXB003

65 MV/m run

No clear hot spots

But typical front bias



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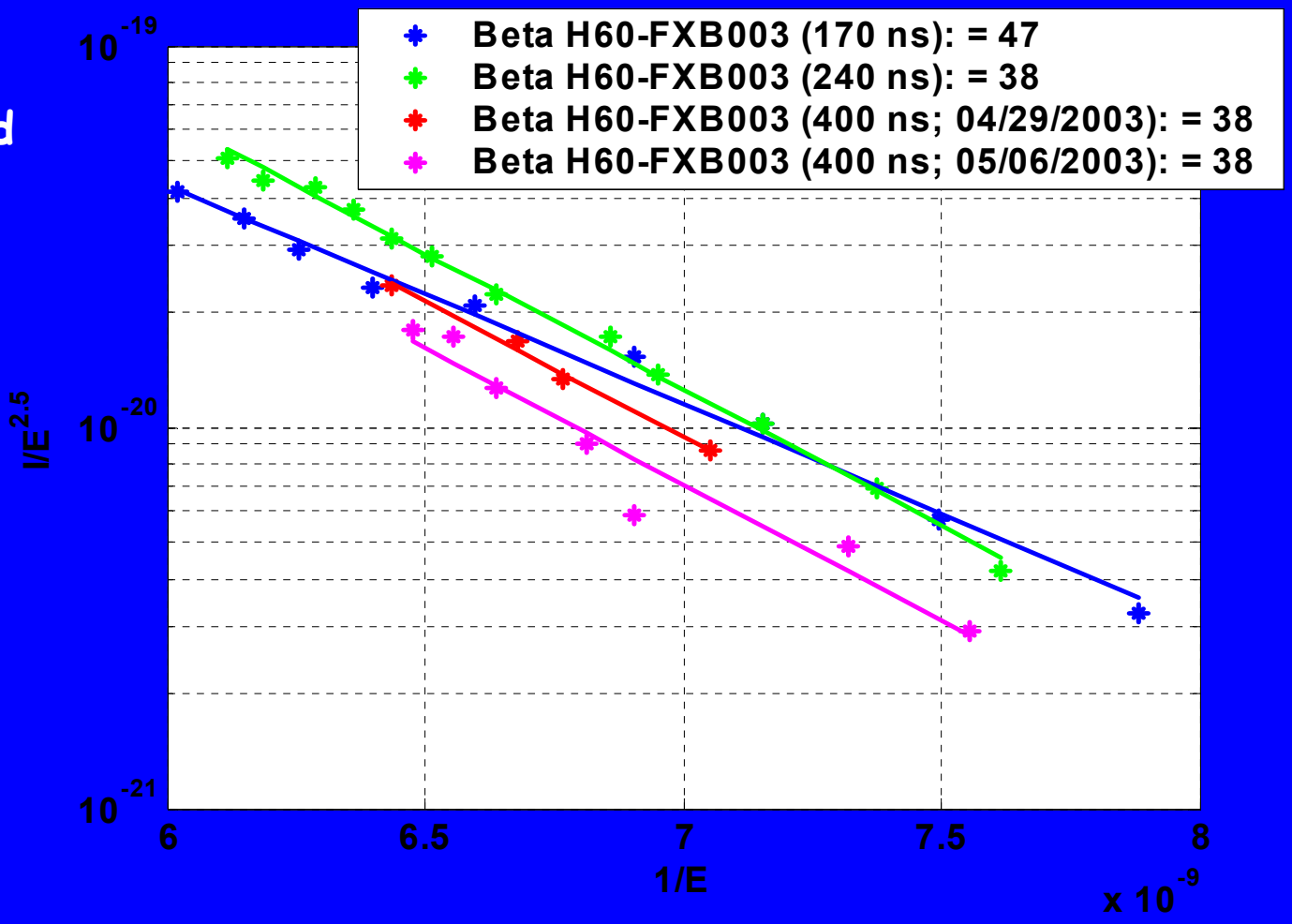
Next Linear Collider
Test Accelerator

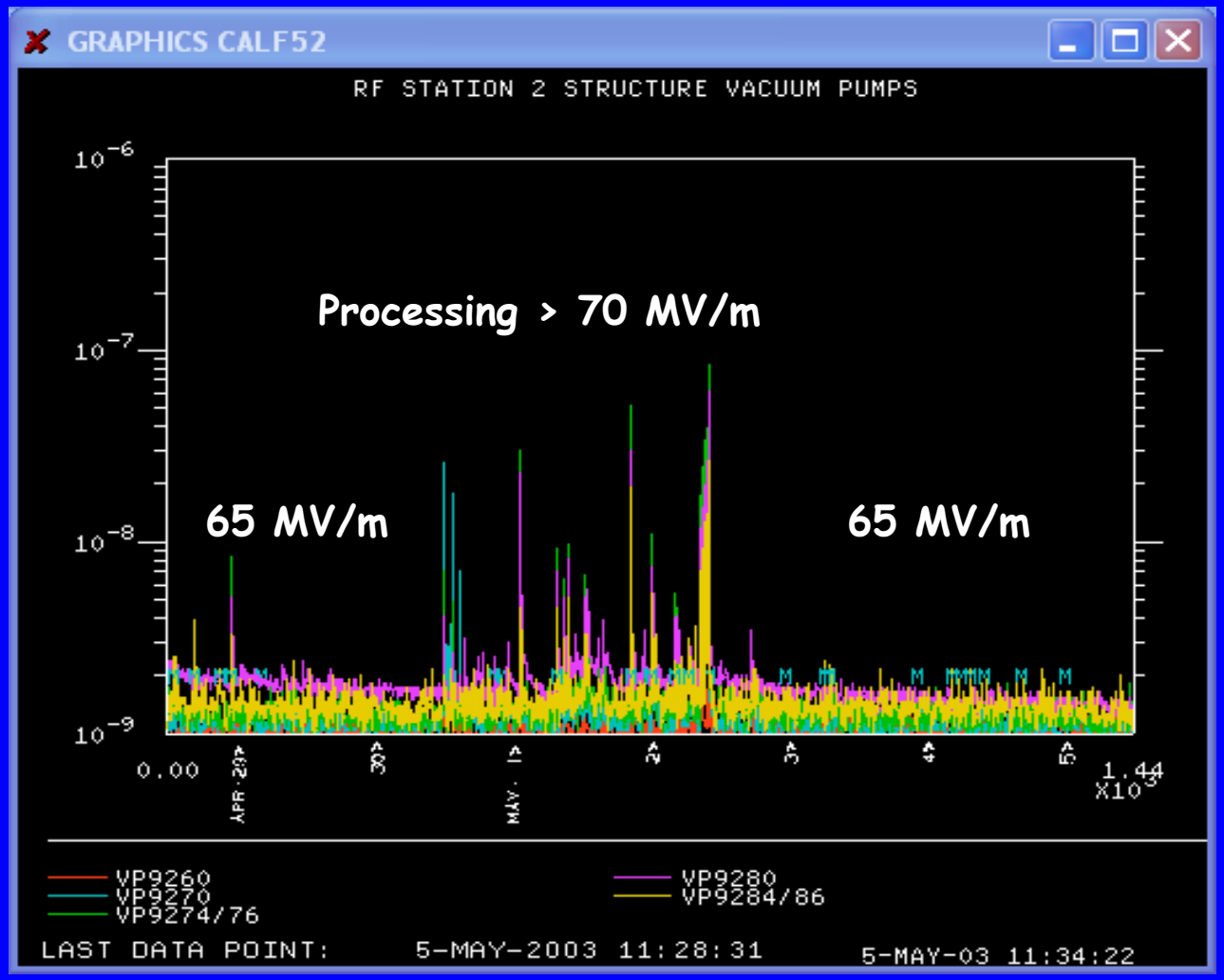
Dark currents - FXB003

- Normal machined
- Beta similar to H60vg3N-6C



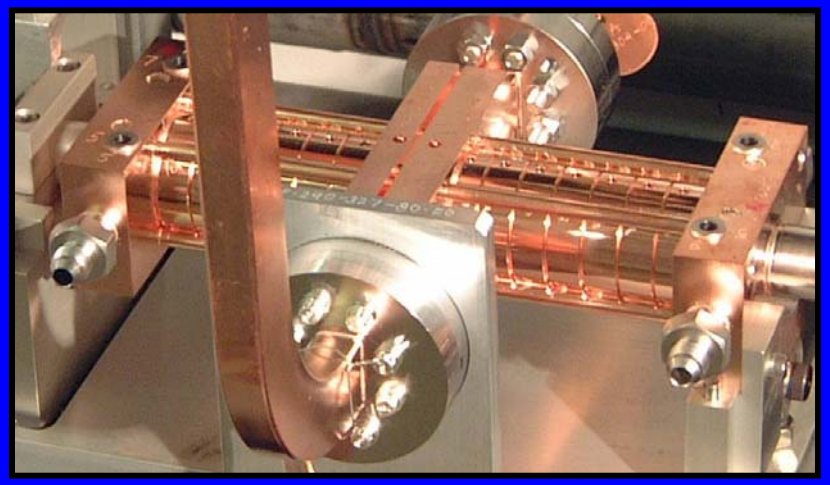
Next Linear Collider
Test Accelerator

Vacuum activity - FXB003



Next Linear Collider
Test Accelerator

SW20a375



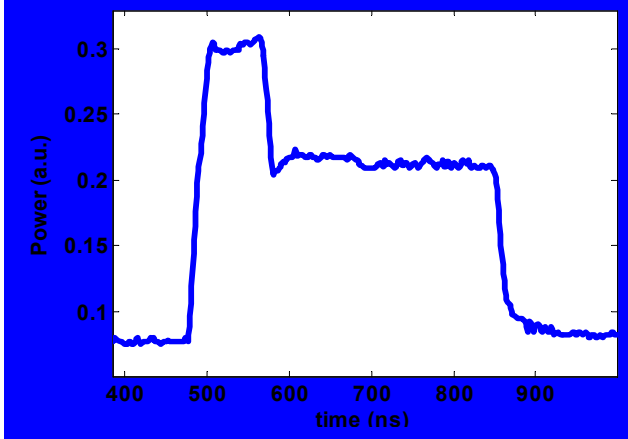
Standing wave structures

Length:	2x20 cm
Phase advance:	180 deg
Es/Eacc:	2.05
P_{in} (55 MV/m):	9 MW
Coupler:	rounded
Preparation:	H_2-bonding/brazing Vacuum bake

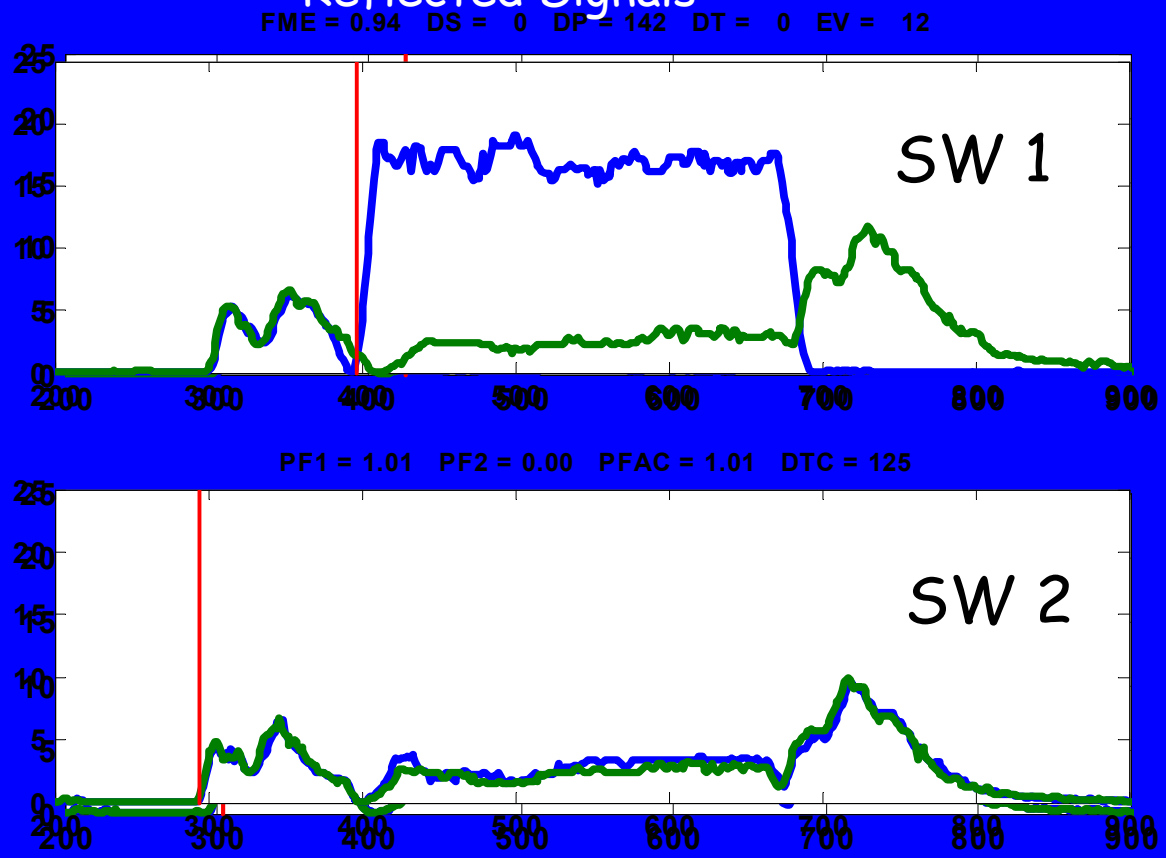
Next Linear Collider
Test Accelerator

Examples - SW20a375

Input RF pulse

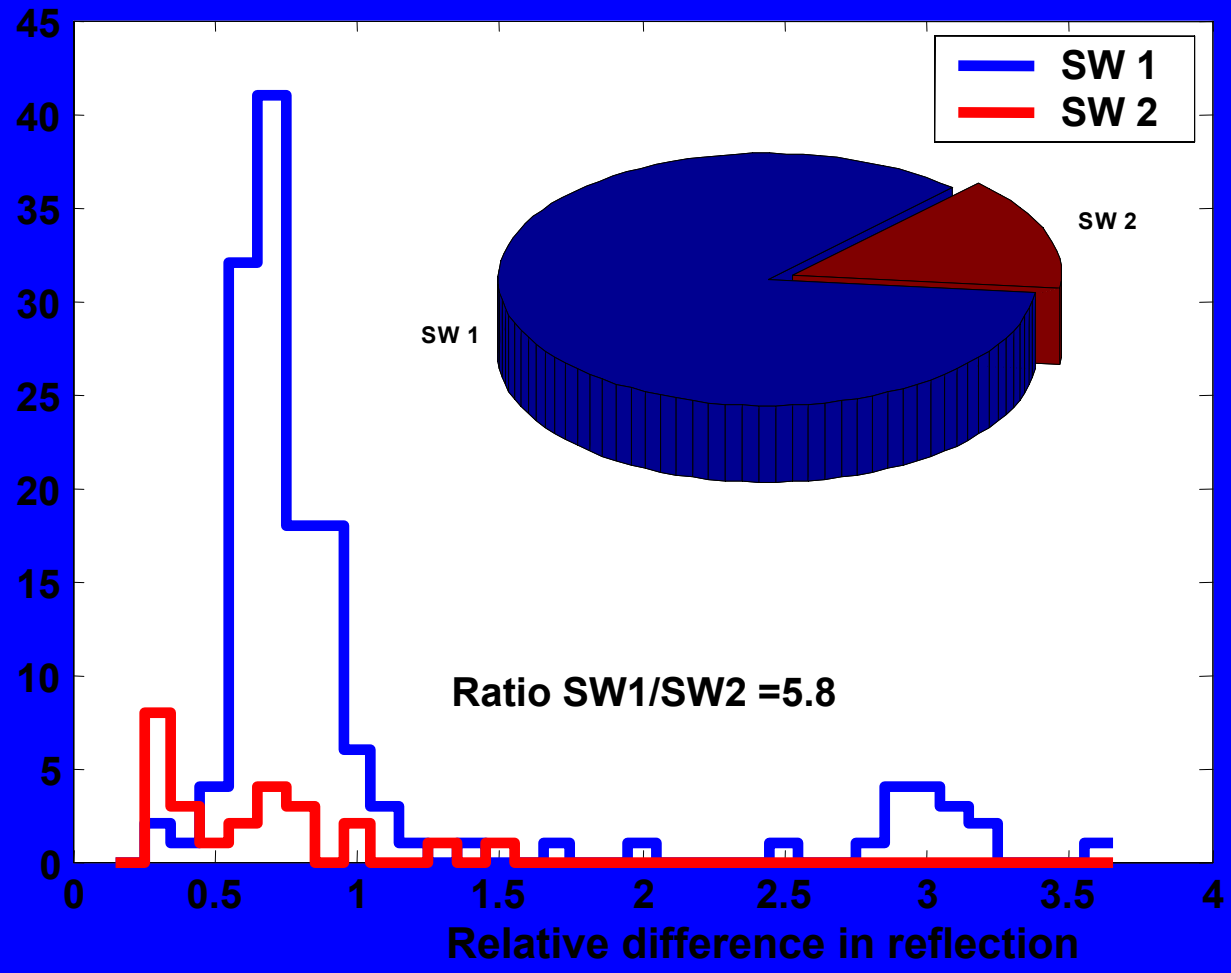


Reflected Signals



Next Linear Collider
Test Accelerator

SW20a375



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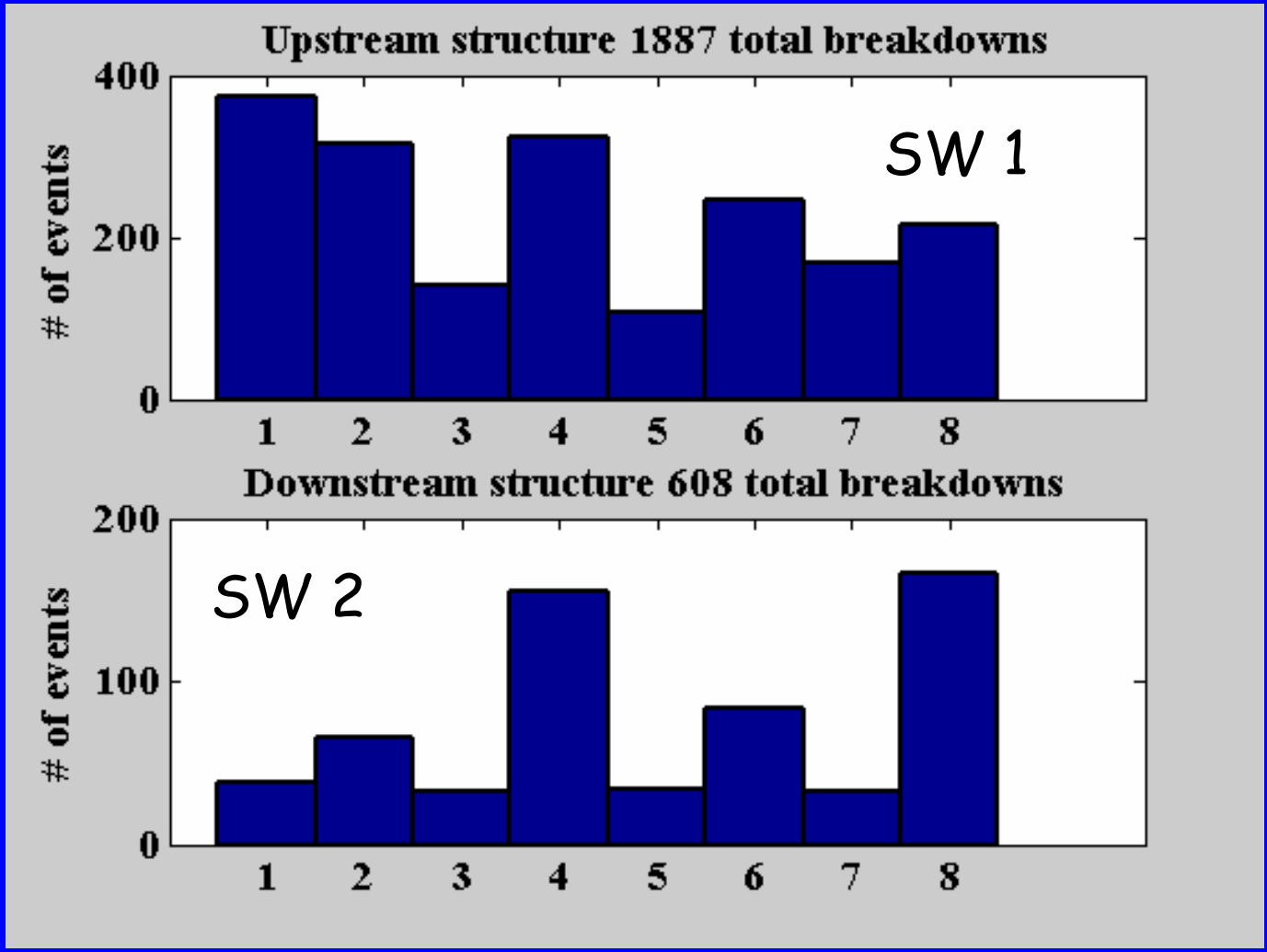
Next Linear Collider
Test Accelerator

Acoustic sensors - SW20a375



Next Linear Collider
Test Accelerator

H60vg3S18/FXB004

First fully slotted structure

Length:	60 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.2
P_{in} (65 MV/m):	66 MW
Coupler:	mode launcher
Preparation:	H_2-bonding/brazing

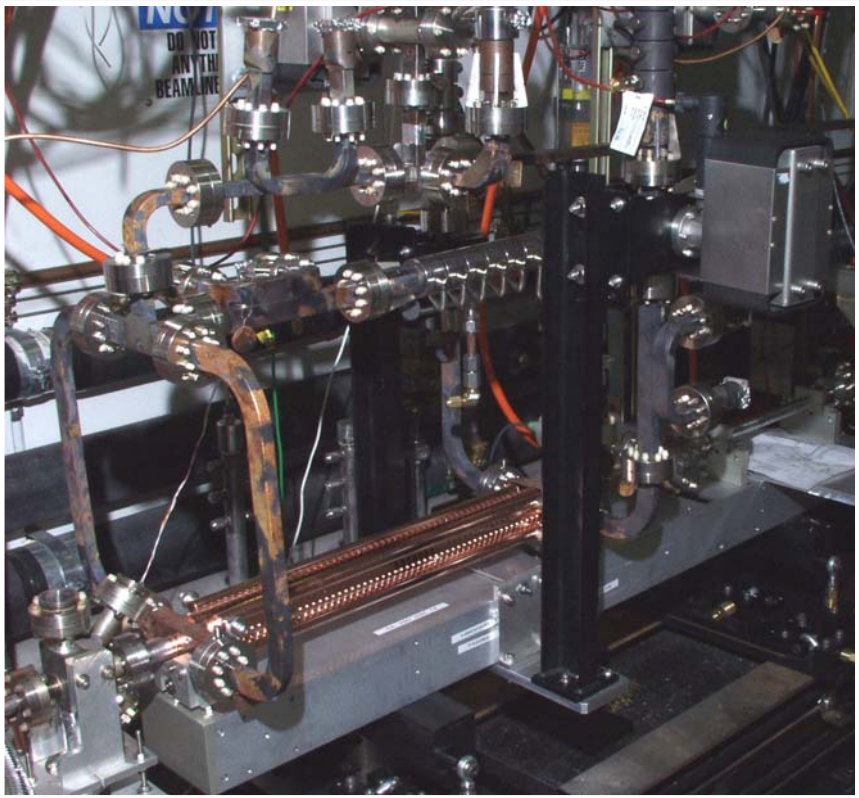
Structure without Hydrogen

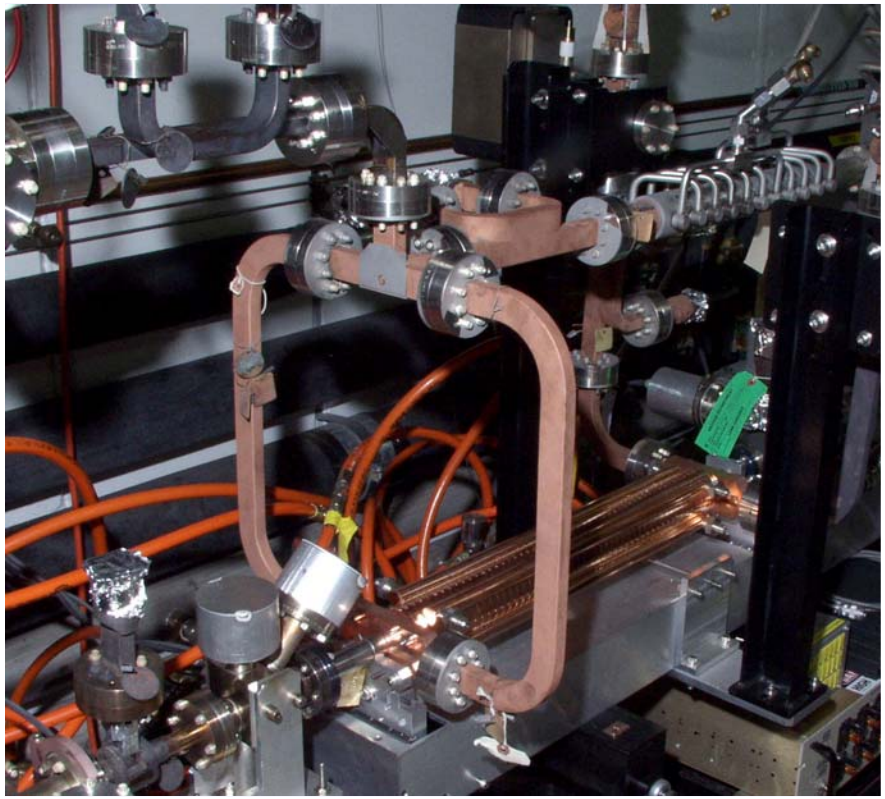
Length:	60 cm
Phase advance:	150 deg
Group velocity:	3 %
Es/Eacc:	2.2
P_{in} (65 MV/m):	63 MW
Coupler:	waveguide coupler
Preparation:	Ar-brazing

Next Linear Collider
Test Accelerator

H60vg3S18/FXB004

Processing started June 11th

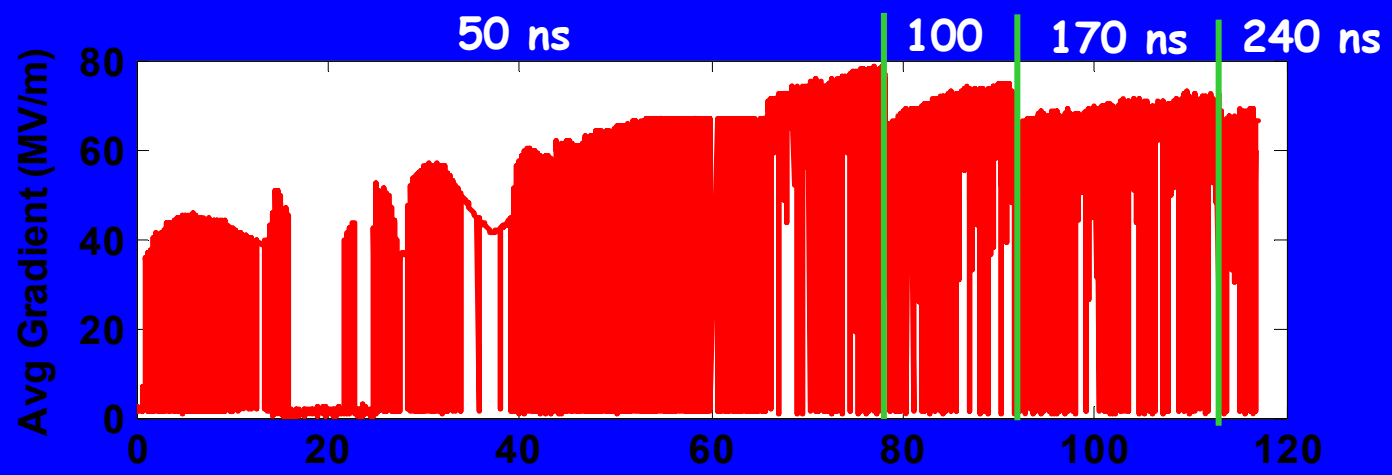


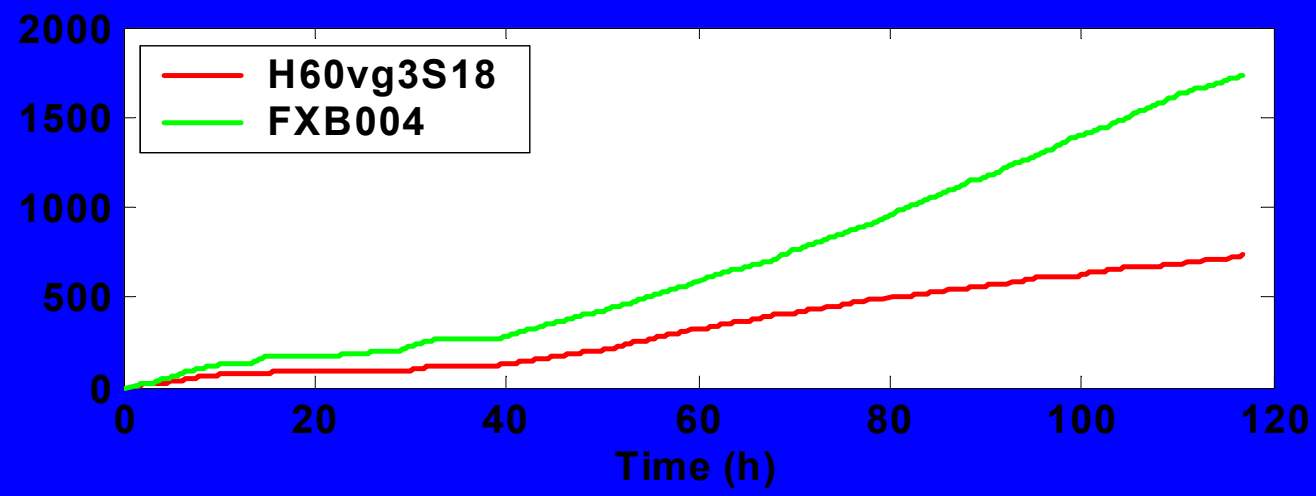


Next Linear Collider
Test Accelerator

H60vg3S18/FXB004

Initial conditioning





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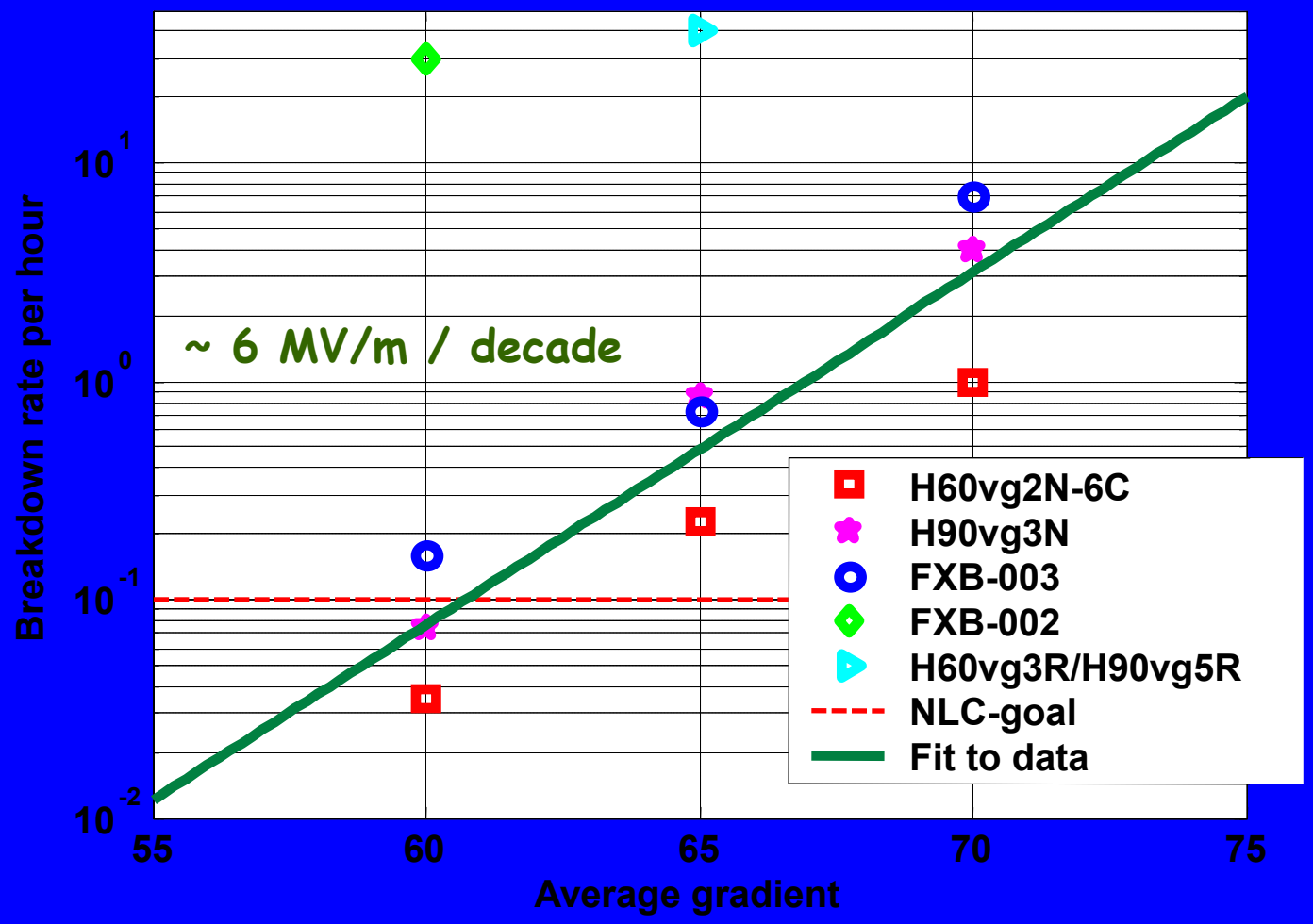
Next Linear Collider
Test Accelerator

H-type-performance BD-rate



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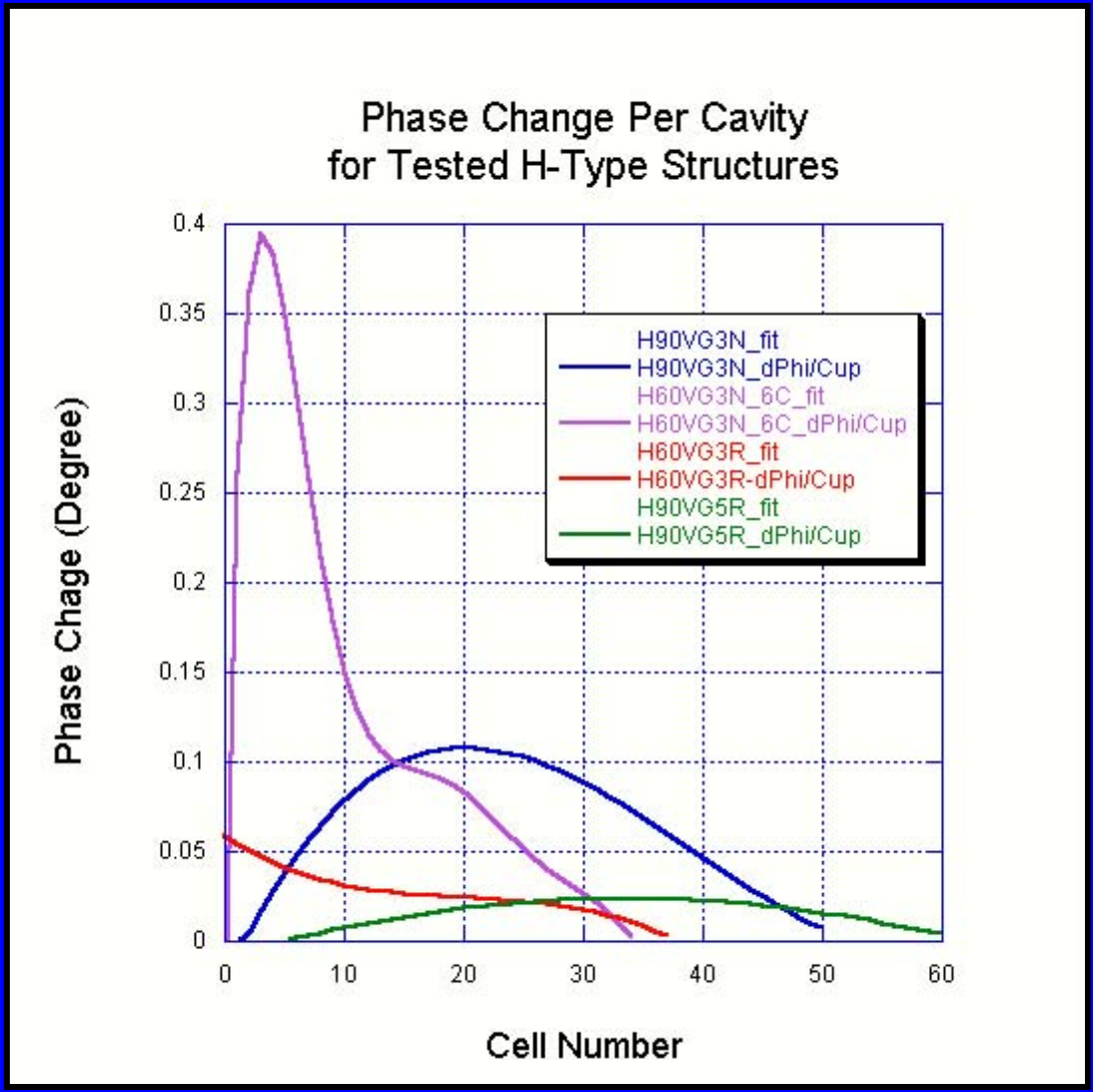
Next Linear Collider
Test Accelerator

H-type-performance Damage

Preliminary results !

- Inline taper helps
- Damage appears correlated to surface field distribution

Hot topic in working group



Next Linear Collider
Test Accelerator

Evolving picture of RF-breakdown

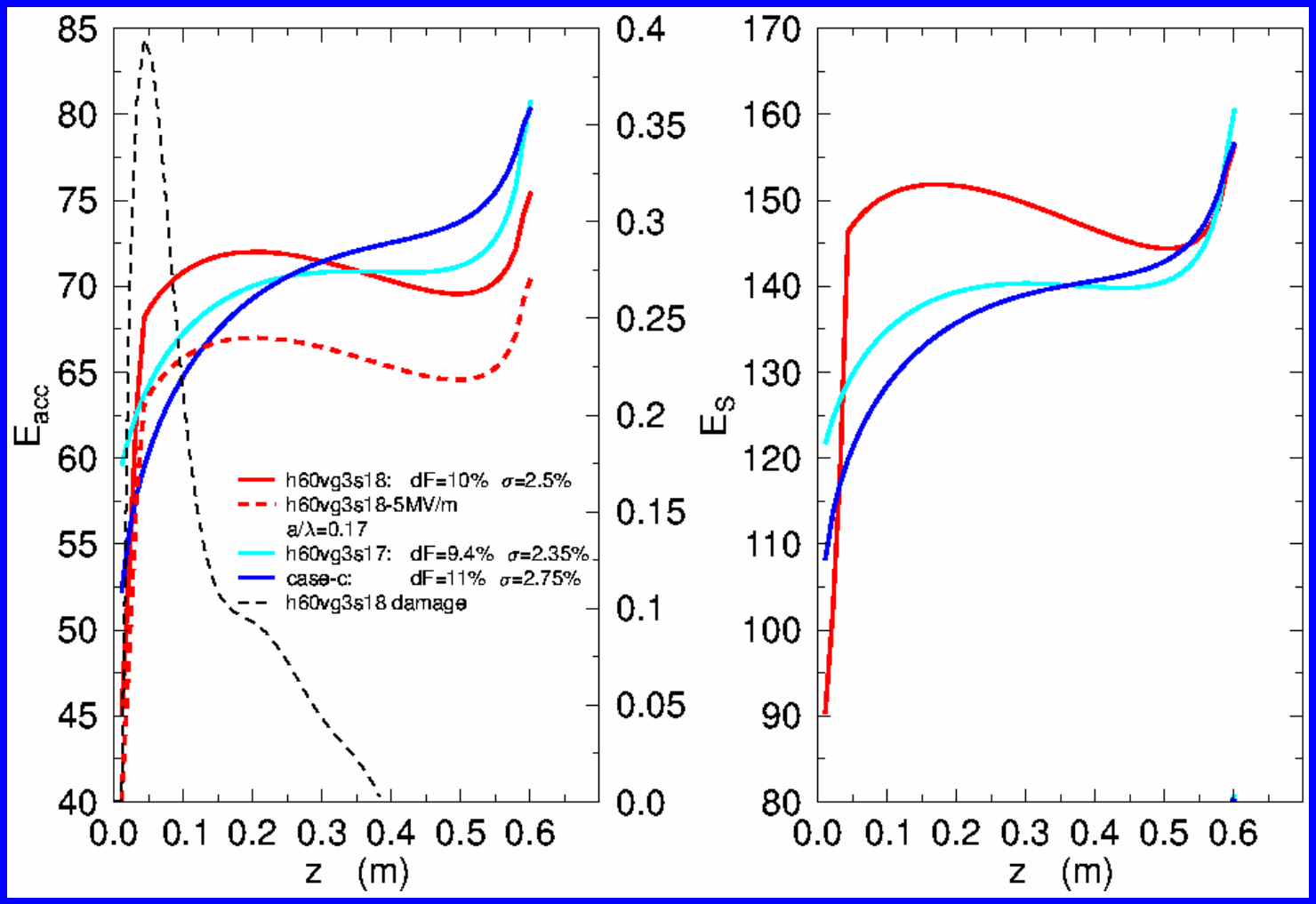
Breakdown probability and damage threshold depends on:

- pulse length ($\tau^{-1/3}$)
- surface field (exp)
- input power (exp)
- RF- surface ($\sim A_s$)
- Material parameters ($T_m^{0.77}\ C_p^{0.53}\ D_m^{\ 0.29}$)
- clean fabrication and handling helps

Next Linear Collider
Test Accelerator

New generation of H-structures

Optimization strategy or Zenghai's tricks



Next Linear Collider
Test Accelerator

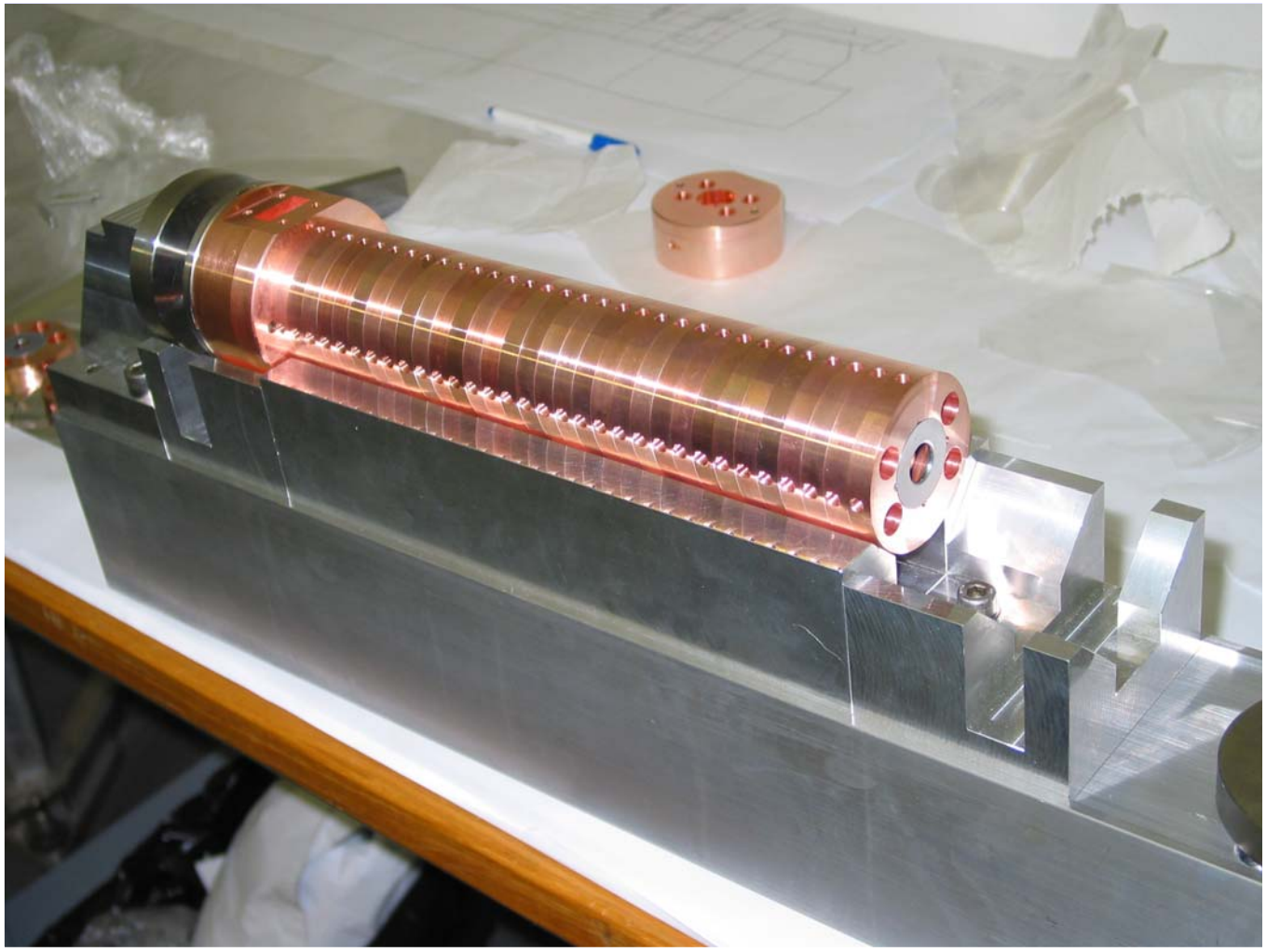
CERN- Mo/W - structures

Clamped constant impedance structure with Mo-irises

Length:	30 cm
Phase advance:	120 deg
Group velocity:	4.65 %
Es/Eacc:	2.2
P_{in} (65 MV/m):	90 MW
Coupler:	mode launcher
Preparation:	Clamping, no bake

Next Linear Collider
Test Accelerator

CERN- Mo/W - structures



Some Questions

- What is a hotspot and how to avoid
- Why is it breaking down in the front
- Exact dependence of BD-rate = $f(P, Es, As, v_g, \tau)$
- Understand and characterize damage
- When does it occur
- Which preparation is really necessary
- …

Next Linear Collider
Test Accelerator

Conclusion and Outlook

Great results but not yet good enough

60 MV/m with NLC criteria demonstrated

65 MV/m is still somewhat marginal but very close

(beam loading and power ramp helps)

Slots appear to be OK

<u>Road to 65 MV/m:</u>

H60vg4S17: higher shunt impedance,
lower surface fields

Standing wave and new materials (Moly, Tungsten)

NLCTA
Next Linear Collider Test Accelerator

Near future schedule

	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
Station1:Acc1	SW	CERN MO		FXB-05		CERN W		8-Pack Powering		
Station1:Acc2				H60vg3R17						
Station2:Acc1	H60vg3NS18			FXB-06				8x60 cm NLC-ready structures		
Station2:Acc2	FXB-04		H75vg4NS18							

H60vg4S17-1,2,3,4
FXC001,2,3,4,..