将来の加速器にむけた高電界加速技術の開発

Research of High Gradient Acceleration Technology for Future Accelerators

平成22年3月２日
日米科学技術協力事業研究計画委員会
ヒアリング

KEK　加速器
肥後寿泰

内容

- 研究の位置づけ
- 2009年の進展
  - 加速管試験
  - 基礎試験
- 2010年度:最終年度での目標
- ・・・・・

本研究課題:
常伝導線形加速器による高電界加速の基礎研究

- 重点項目
  - 高電力RF源の開発
  - 50MV/mを超える実用的加速管の研究開発
  - 高電界加速に関わる放電等の現象の基礎研究
- 体制
  - SLACとKEKとの共同開発と研究
  - 互いの研究資産、人材などの交流、相互の比較試験
- 最終年度
  - リニアコライダーに向けた提案をする

今最も重要と考える研究テーマ

- 電界放出電子･プラズマ･放電･アーク･････
  - 放電に至るメカニズムの理解
  - 放電頻度の抑制
  - 放電の影響の抑制
- 加速管
  - 設計
  - 材料
  - 製作
  - インストールまでの工程

リニアコライダーにとって重要な判断

- 強減衰構造は高電界と共存できるか？
  - 現CLIC　開口部→Hs大→pulse heating
  - これが放電特性に支配的かの見極めが重要
  - 現在試験進行中（TD18, TD24 .vs. T18, T24）
  - 2010は、こちらに集中して試験すすめる

- 弱減衰・離調型構造は設計できるか？
  - GLC/NLC型をバックアッププランとしてもつ
  - HOM設計可能か？
  - 100MV/m級の実証必要
  - 強減衰の特性を見て進める

2009年度の研究の方針

- 2008-2010年の3年計画で申請
- 50~100 MV/mのできるだけ高い勾配で安定に運転できるレベルを見極める。
- CLIC加速管をひな形として評価する。
- 2004年までに開発してきたSLAC/KEKの加速管製作技術に立脚する。
- 複数のラボ（現状：KEK＋SLAC）での高電界特性の相互比較を行う。
- 委員会からのコメント: 「基礎的かつ継続的な研究により重点を置くことが望まれる」

2009年度の研究の進展

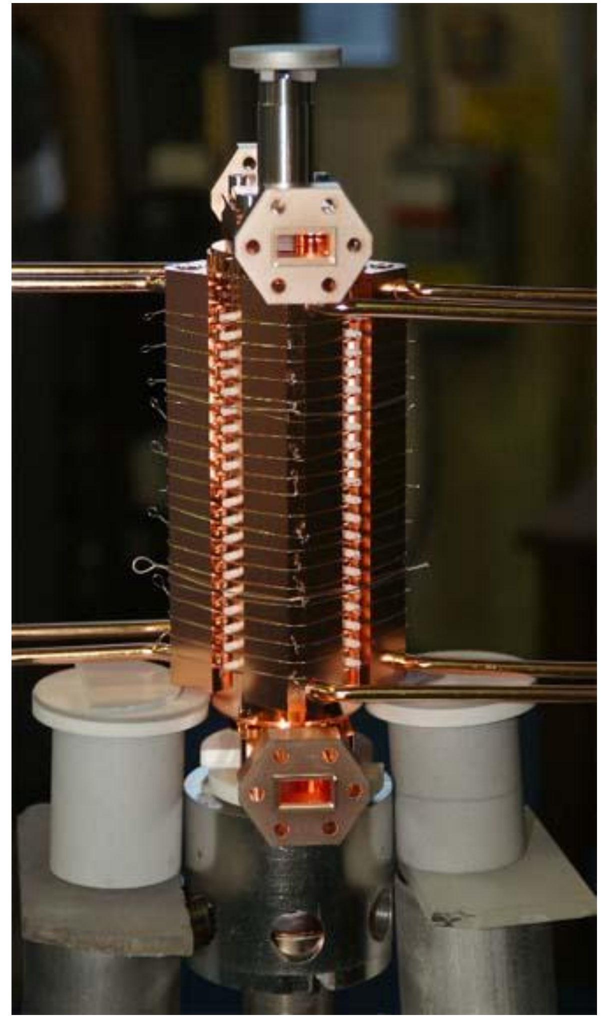
- 試験加速管の製作
  - T18、TD18、C10、CD10、T24、TD24
  - SLAC/KEK共同製作
- 加速管高電界試験
  - SLAC（NLCTA)　T18#1＆#3、TD18#3
  - KEK（Nextef)　T18#2、TD18#2
  - 試験結果の比較の定量化
- 試験構造の製作と試験
  - SLAC（KlyLab）：Single-cell加速管での放電レート測定試験
  - SLAC（KlyLab）：銅や銅合金へのパルス加熱試験
  - KEK（KT1）：狭導波管試験
  - KEKのスタンド立ち上げの努力

Test structure fabrication

- Work partition as usual
  - KEK cell and coupler fabrication
  - SLAC cleaning, bonding and baking
  - KEK+SLAC high power test
- In JFY2009
  - Made second pair of un-damped T18 structures
  - Made first pair of damped TD18 structures
  - Made a pair of C10 and CD10 cell parts

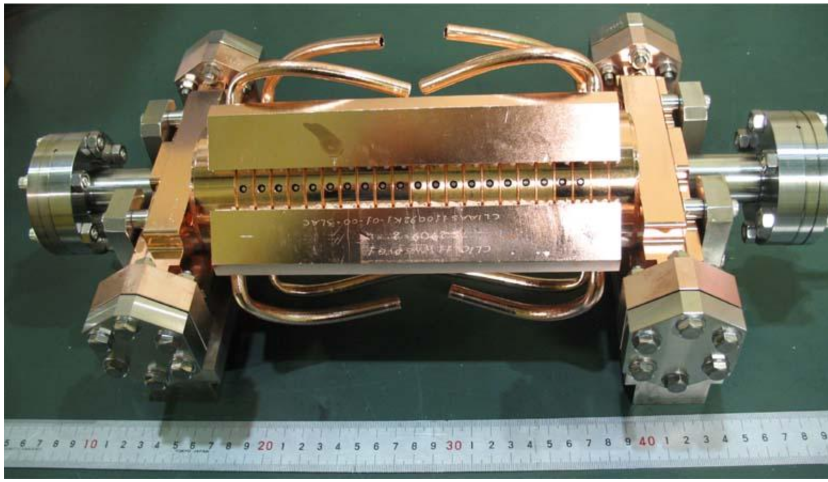
Fabrication of damped structures

KEK fabricated all parts.



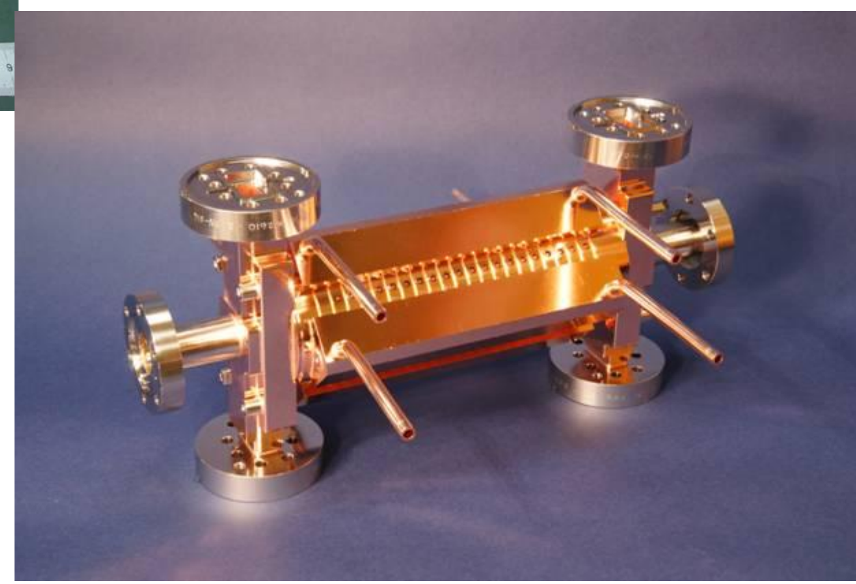
SLAC made assembly.

TD18_VG2.4_Disk #2 & #3



#2 being tested at KEK Nextef

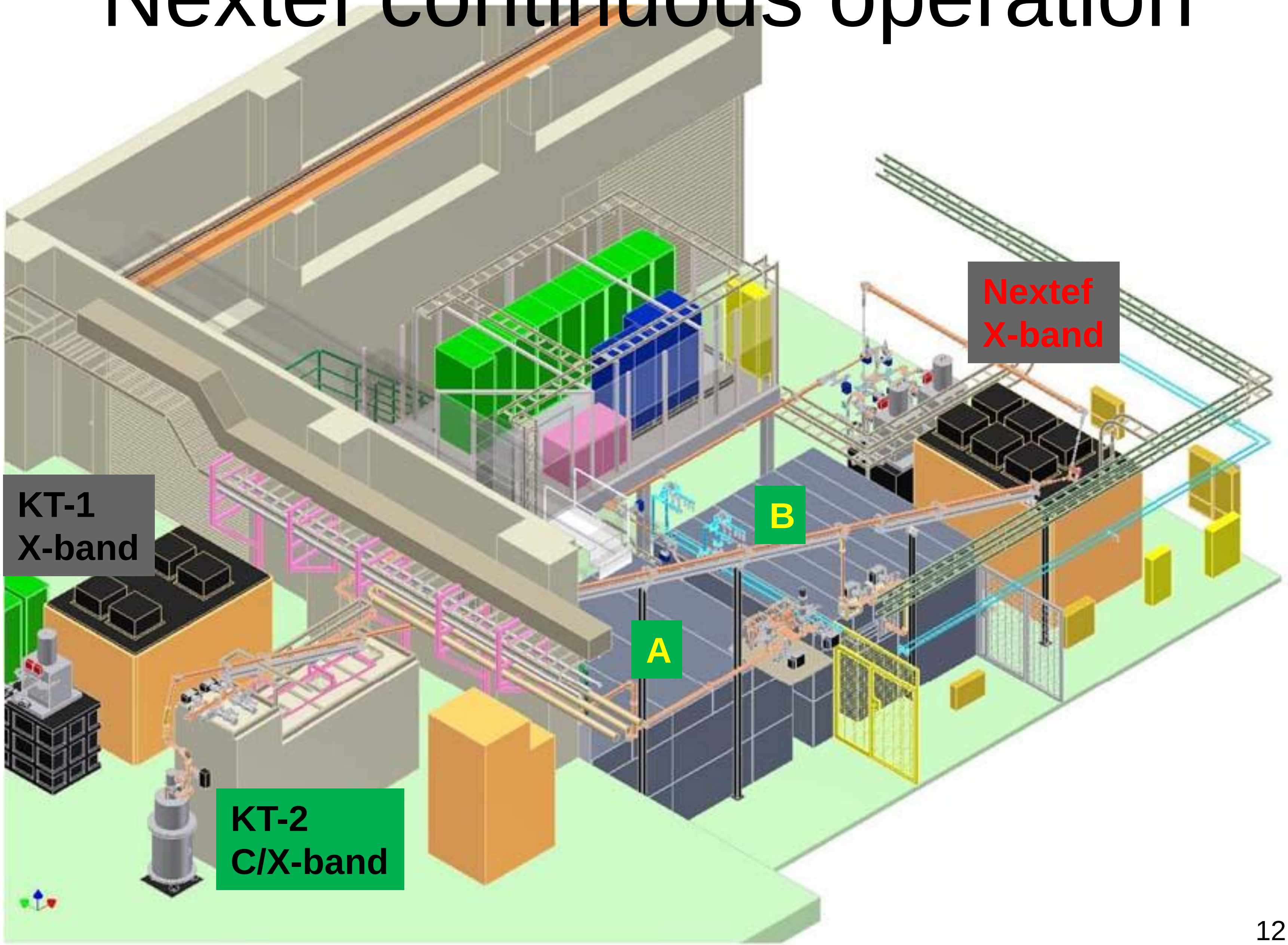
#3 being tested at SLAC NLCTA



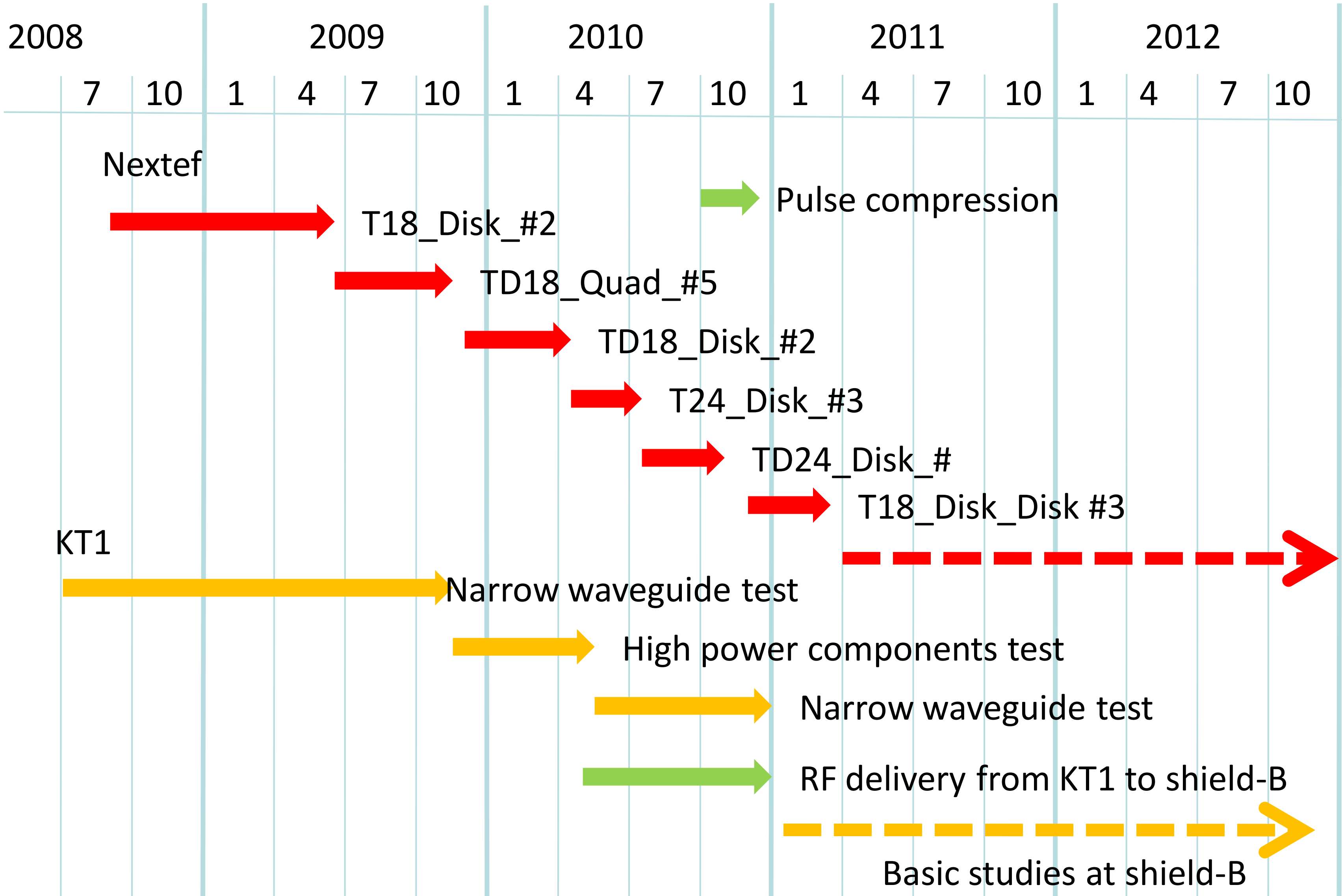
High power test

- Independent tests in 2009
  - Independent but for comparison
  - Nextef of KEK and NLCTA of SLAC
  - KEK tested T18_#2 and started TD18_#2
  - SLAC made test of T18_#1 and #3 and started test of TD18_#2
- Basic studies
  - Pulse heating test
  - Single-cell high gradient study

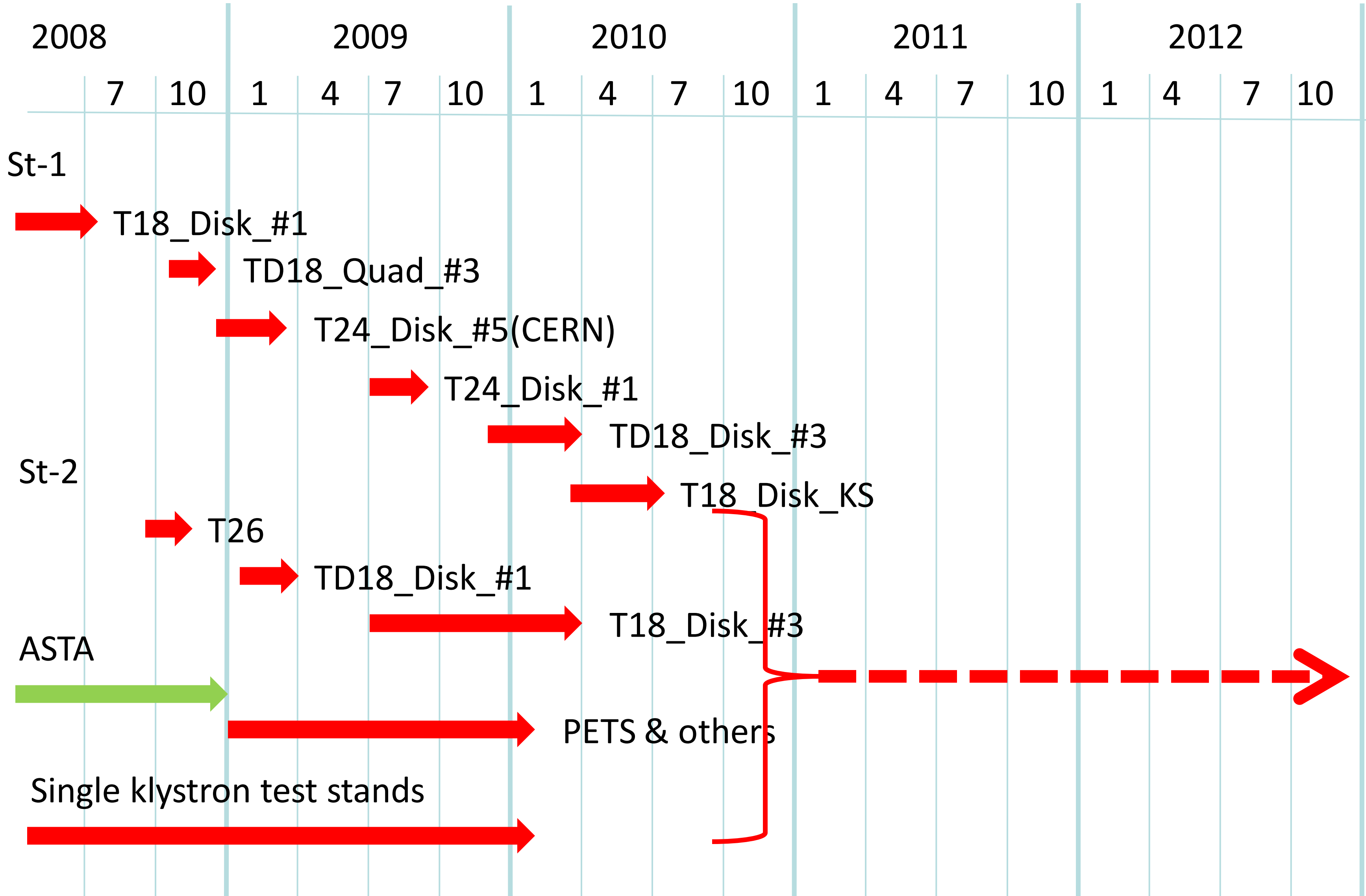
Nextef continuous operation



KEK Nextef & KT1



SLAC NLCTA st-1 + st-2

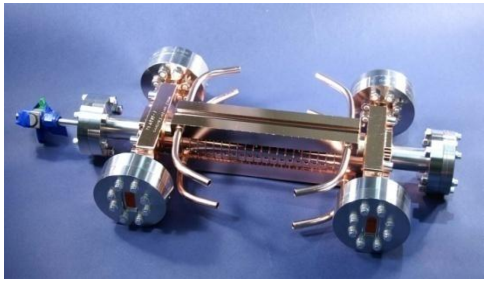


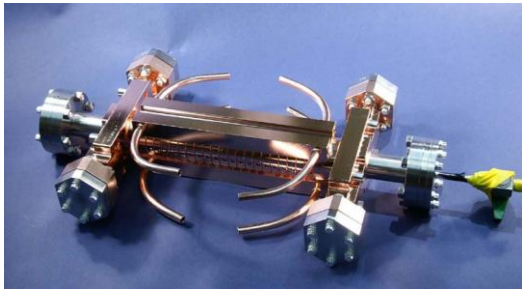
Test results on un-damped structures and damped structures

- T18 (undamped)
  - Comparison between KEK and SLAC
  - Basically the same characteristics
- TD18 (damped)
  - Started at both laboratories
  - Considerable difference in processing speed
  - Need to compare in such as criteria of trip
  - Or need to identify the origin of the difference of the structures

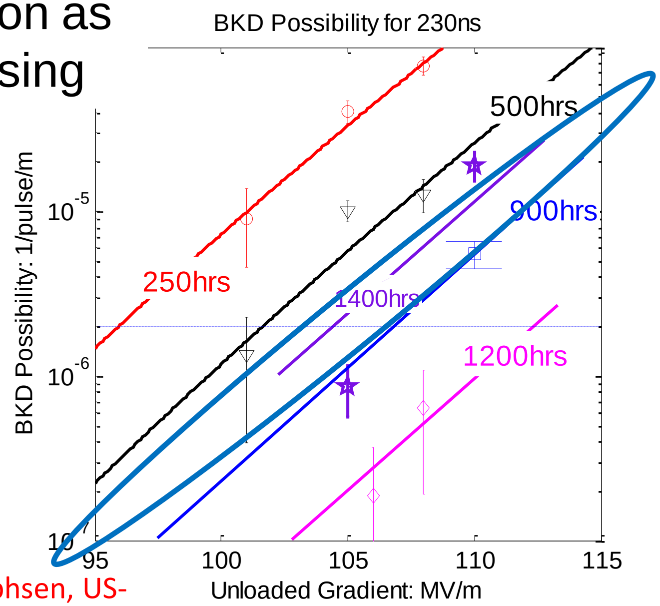
Comparison of breakdown rate

#2 tested at KEK
#1 tested at SLAC



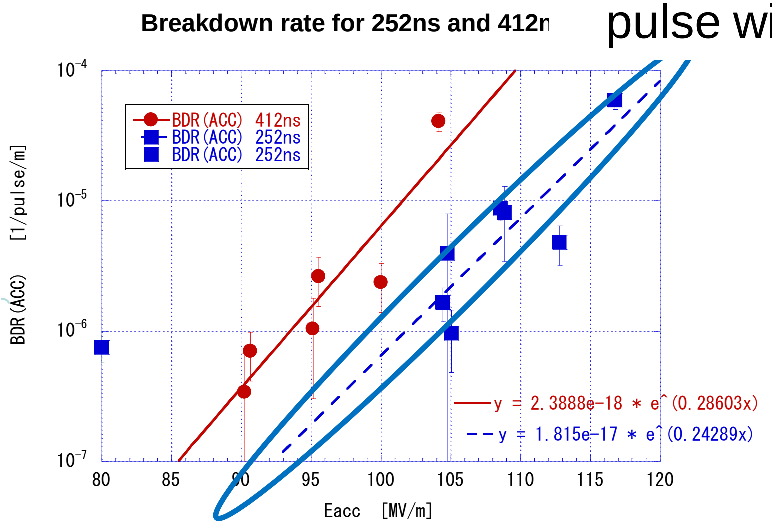


Evolution as processing



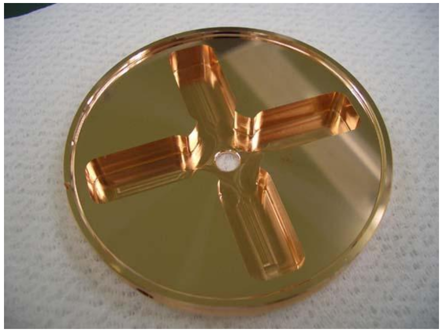
C. Adolphsen, US-HG@ANL, 2009

Different pulse width

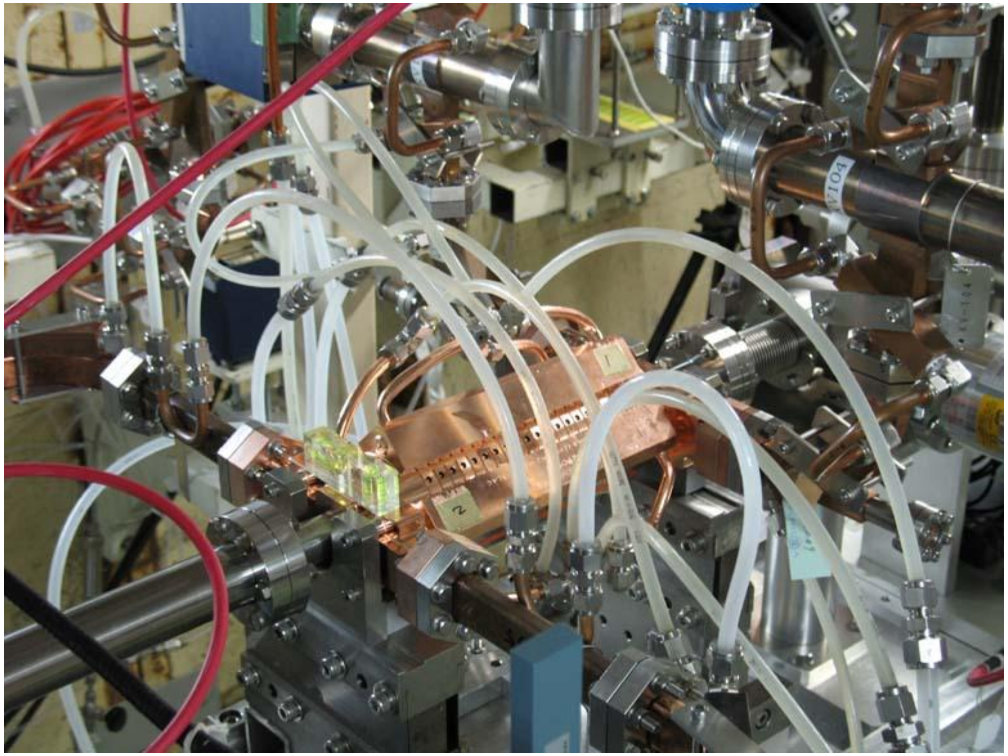


Similar breakdown rates were obtained for the first pair.
The next pair will be compared later.

On-going test of damped structures

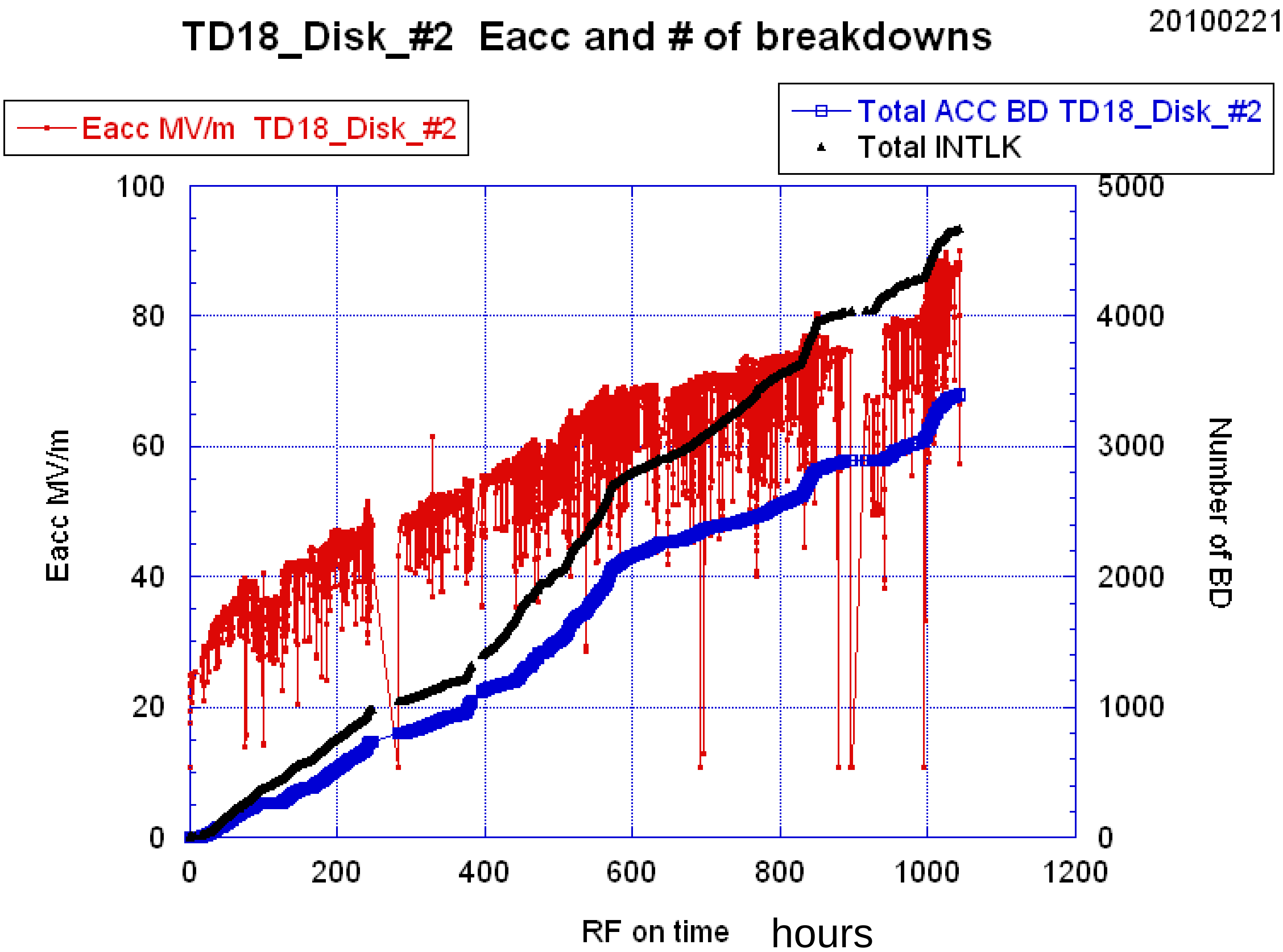


Damped cell

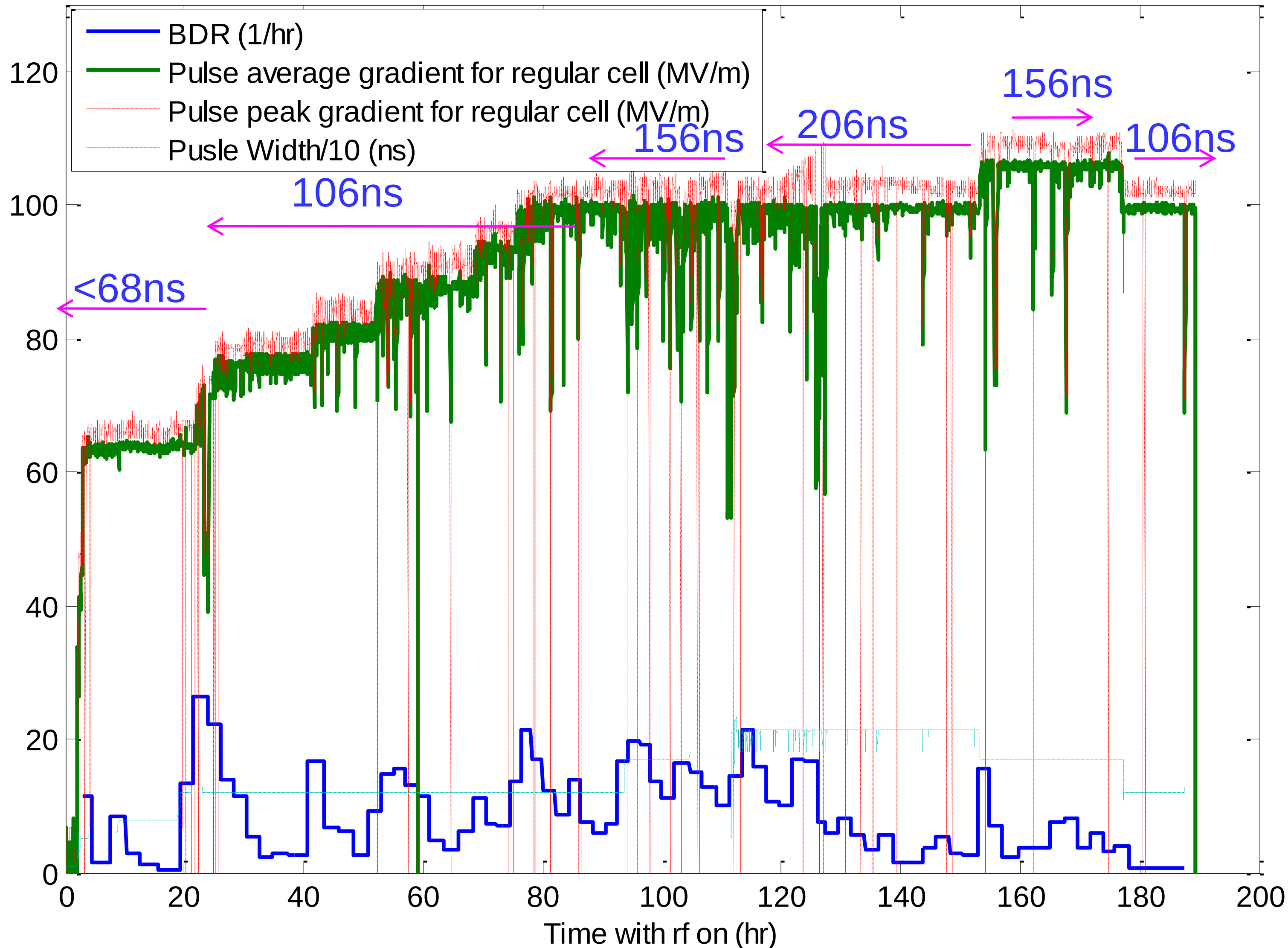


Ongoing test at KEK Nextef

TD18_#2(KEK) processing



High Power Test begin at 12/03/2009 15:00



BKD Rate ~ 0.3/hr at 12/14/2009

From F. Wang, SLAC, Dec. '09

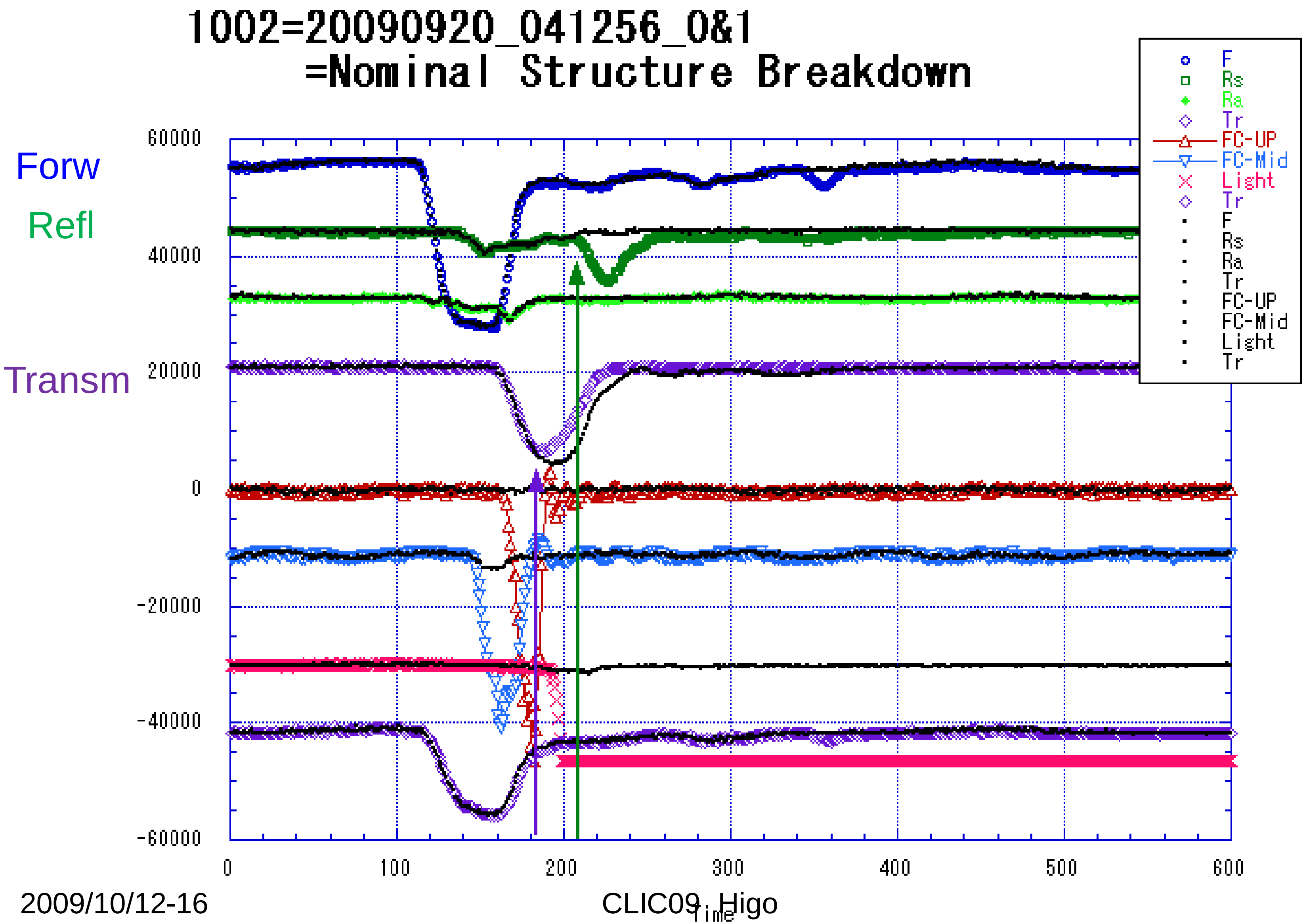
Comparison

- Discussion on trip criteria was started
  - SLAC: missing energy
  - KEK: Current burst
- Effort to identify difference between structures
  - Shipping from US to Japan
  - RF load downstream
  - Any others under discussion for detail

Efforts for understanding

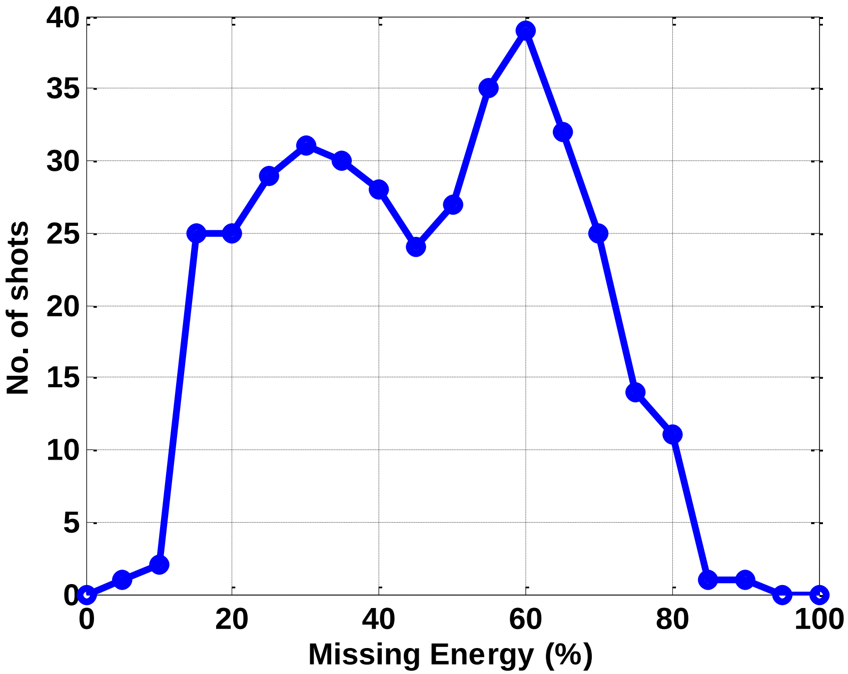
- Breakdown location
  - Need better method? (KEK) – phase info.
- Dark current and spectrum
  - Data(KEK) vs simulation(SLAC)
- Missing energy and RF pulse analysis
  - Careful comparison is needed
- Any other to improve evaluation

Breakdown pulse analysis   Quad#5



090227 Steffen (CERN):

T18_#2 Missing Energy from breakdown events at 252 ns

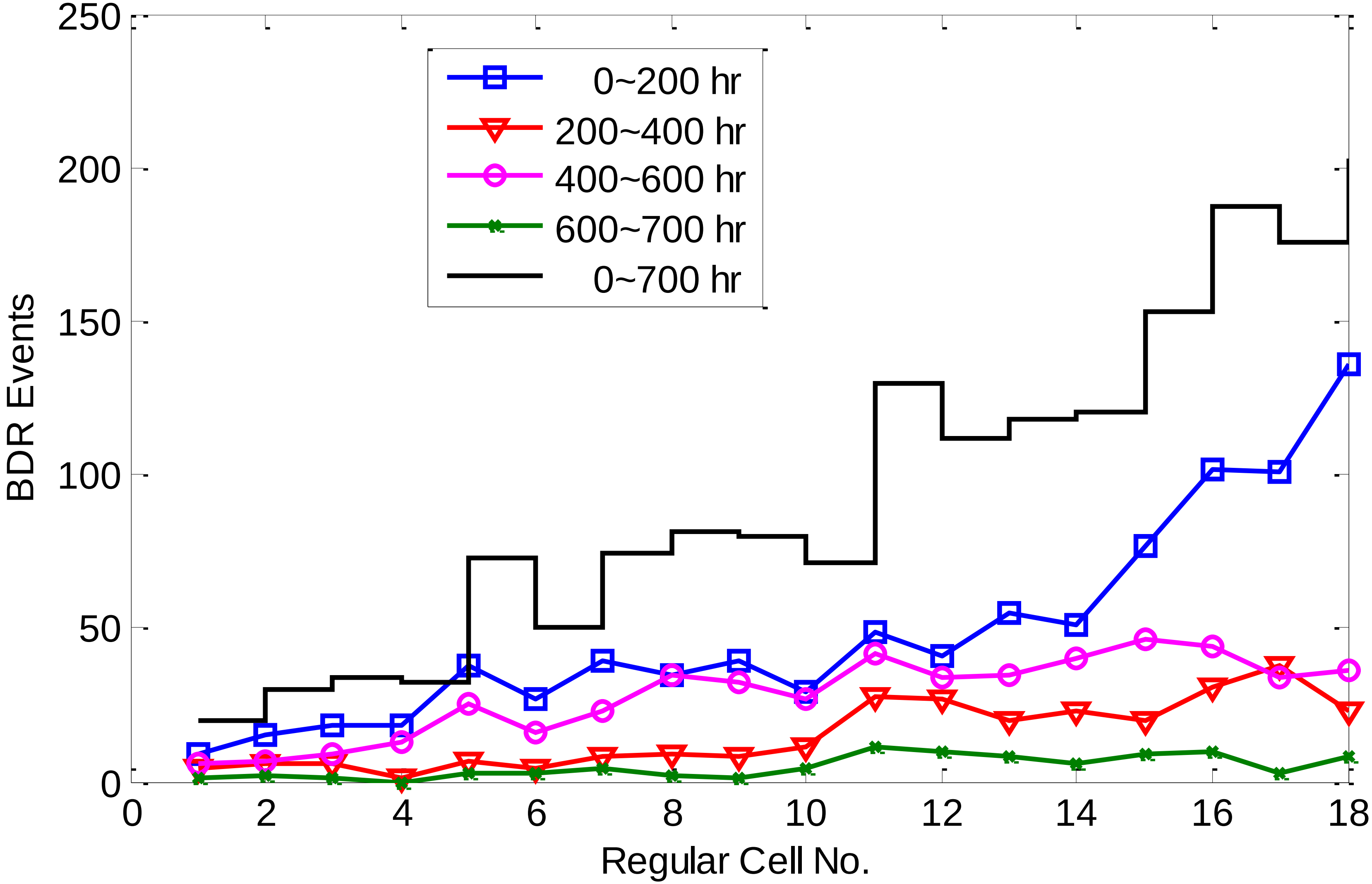


Missing energy
= Forward
- Reflected
- Transmitted

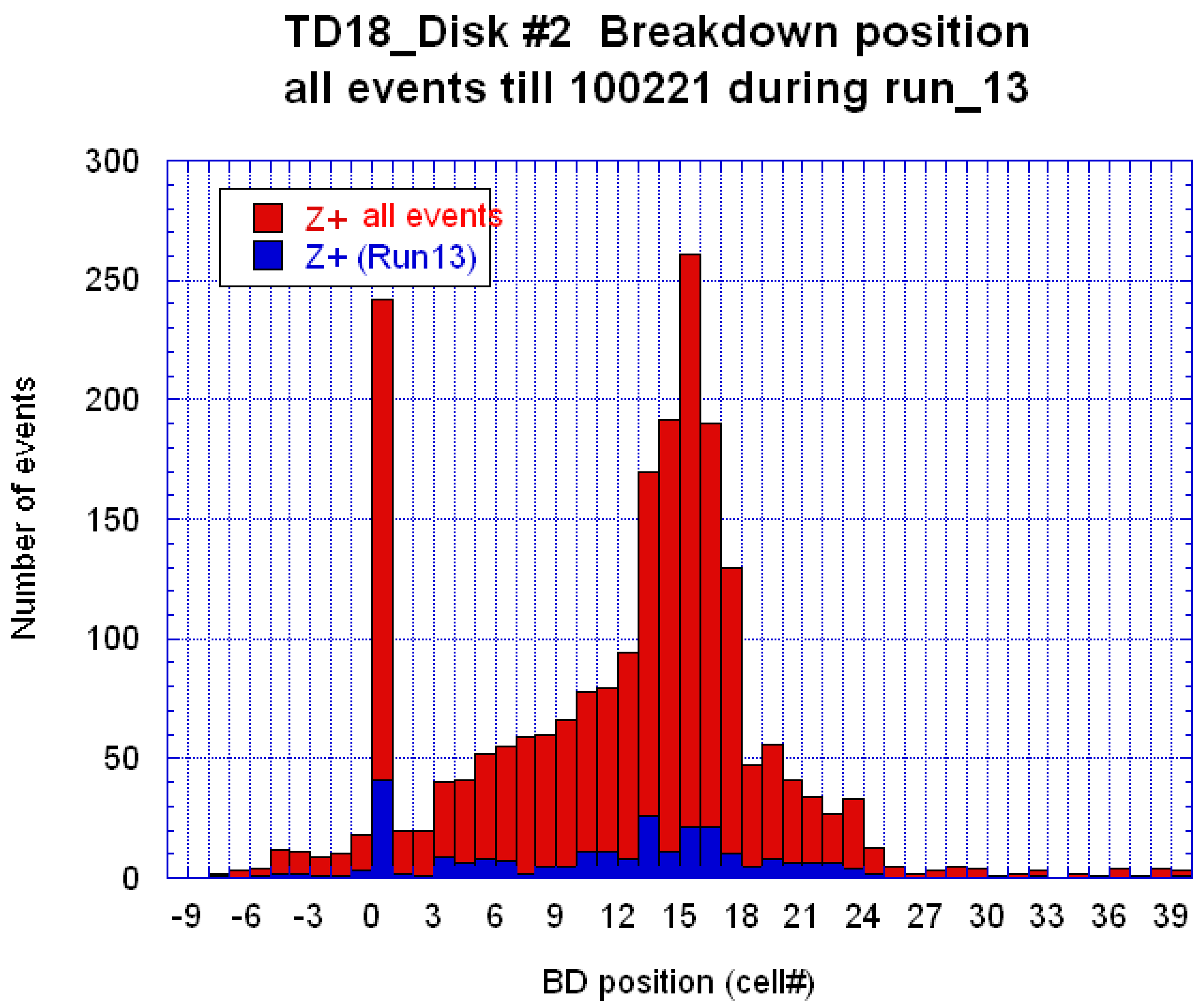
Energy deposit
→ degradation?
→ surface change
→ long term stability over ten years

Still need to be analyzed in a sophisticated manner.

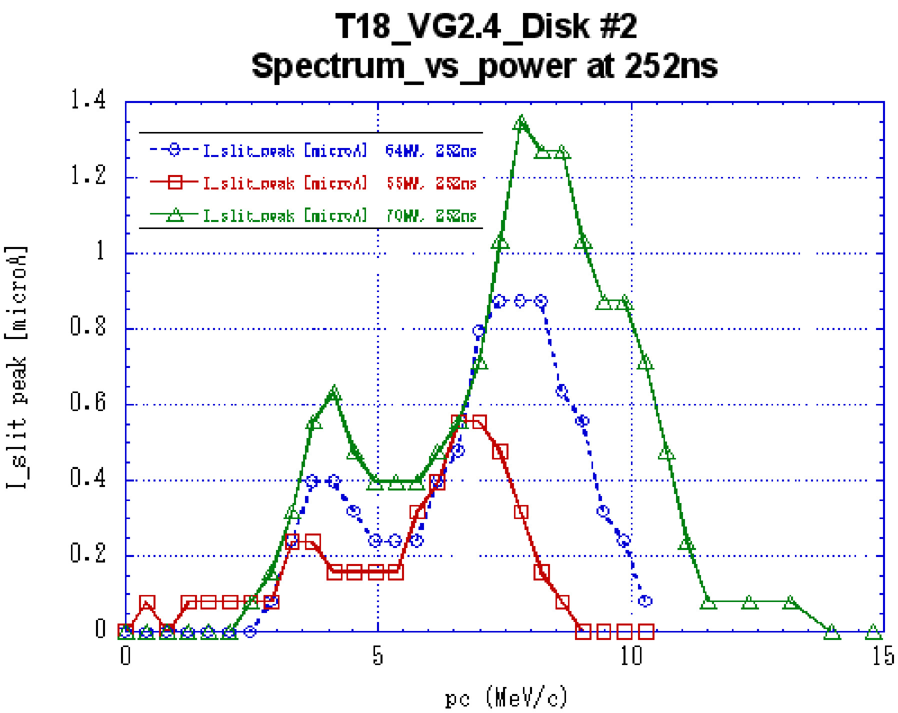
Breakdown distribution at different stage

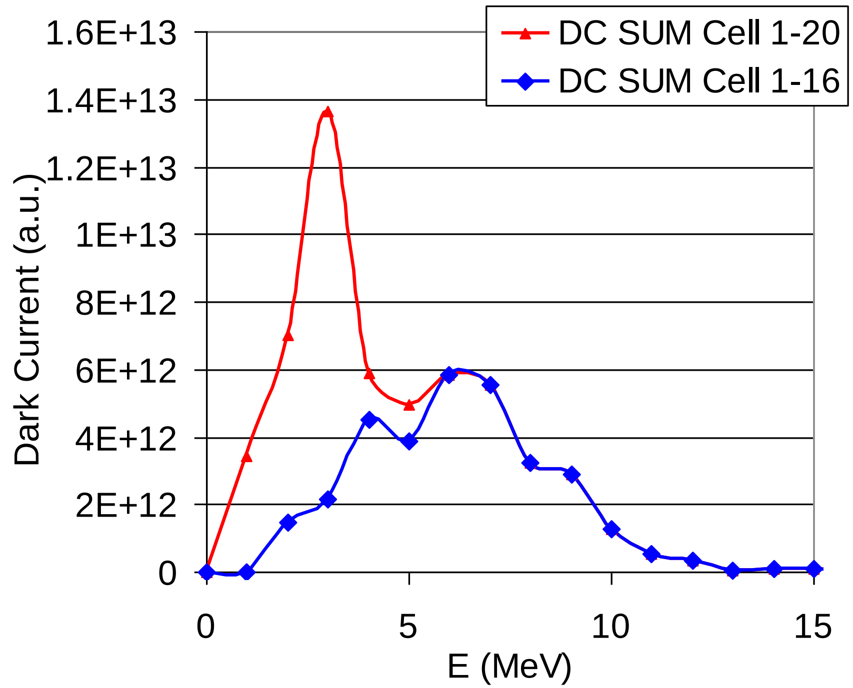


20100221


TD18_Disk #2 Breakdown position
all events till 100221 during run_13
Z+ all events
Z+ (Run13)
Number of events
BD position (cell#)
300
250
200
150
100
50
0
-9
-6
-3
0
3
6
9
12
15
18
21
24
27
30
33
36
39

Dark Current Spectrum Comparison





Measured dark current energy spectrum at downstream (need to scale by 1/(pc)

Spectrum from Track3P simulation, 97MV/m gradient.

"Certain" collimation of beampipe on dark current is considered in simulation data. More detailed analysis needed.

July 2009, R. Siemann Workshpp at SLAC, Z. Li simulation

Basic studies with simple configuration

- Single-cell extreme gradient(SLAC)
- Pulse heating by TE01(SLAC)
- Narrow waveguide high gradient (KEK)

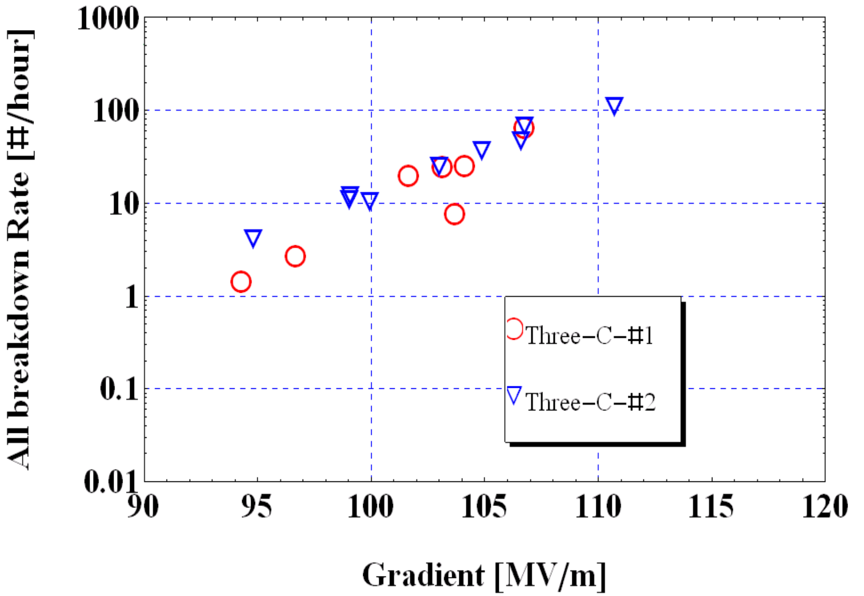
- We, especially KEK, want to study
  - Material,
    - Purity (7N) or inclusion (CuAg)
  - Crystal structure
    - Single crystal, Large grain

Effort to prepare test sample in a sophisticated manner by KEK

Yasuo Higashi, KEK

Single-cell SW high gradient test at SLAC

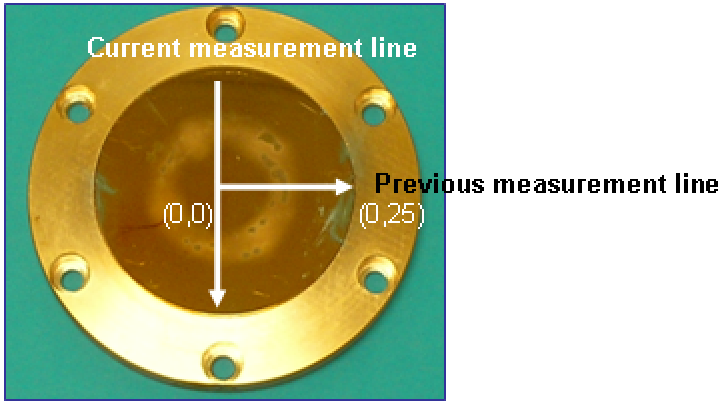
ultra clean condition vs
normal surface processing conditions.

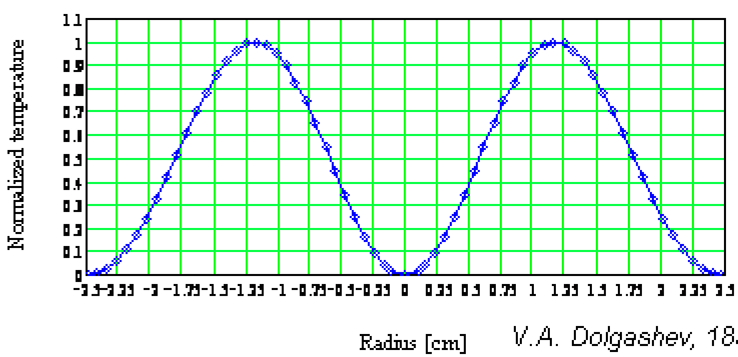


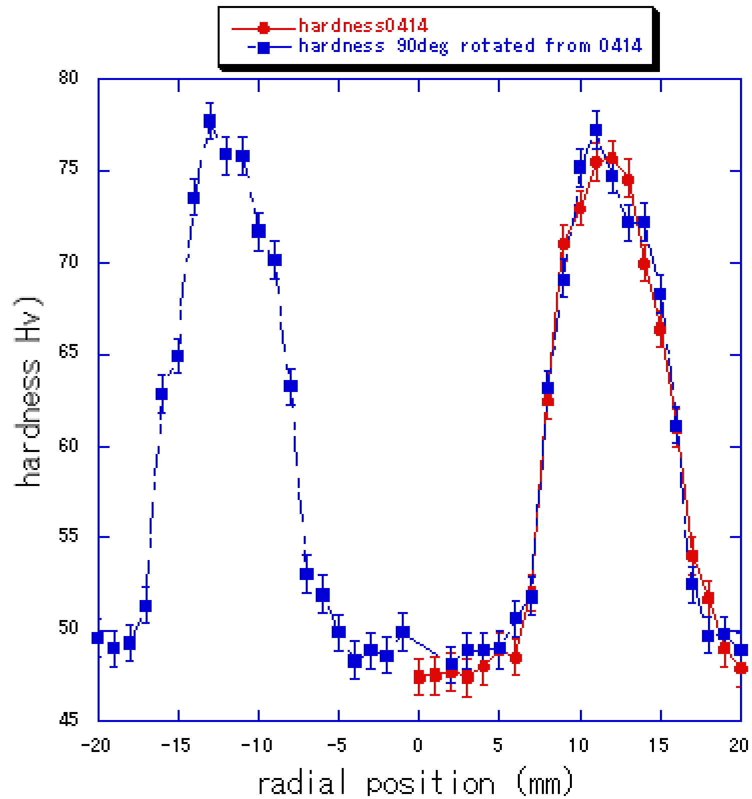
The near perfect surface processing affected only the processing time.
The second structure processed to maximum gradient in few minutes vs few hours for the normally processed structure.

But we are curious how the processing proceeds and how high we can obtain without serious damage.

Pulse heated temperature rise and hardness change



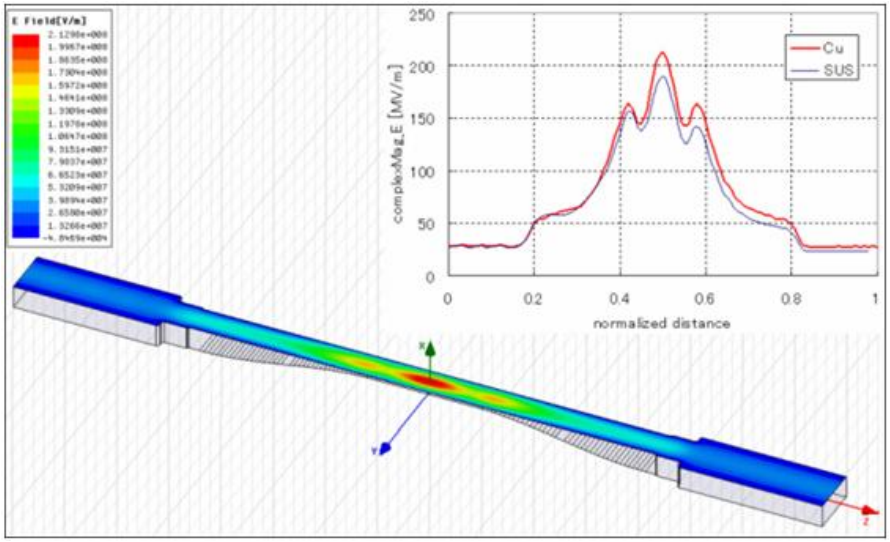


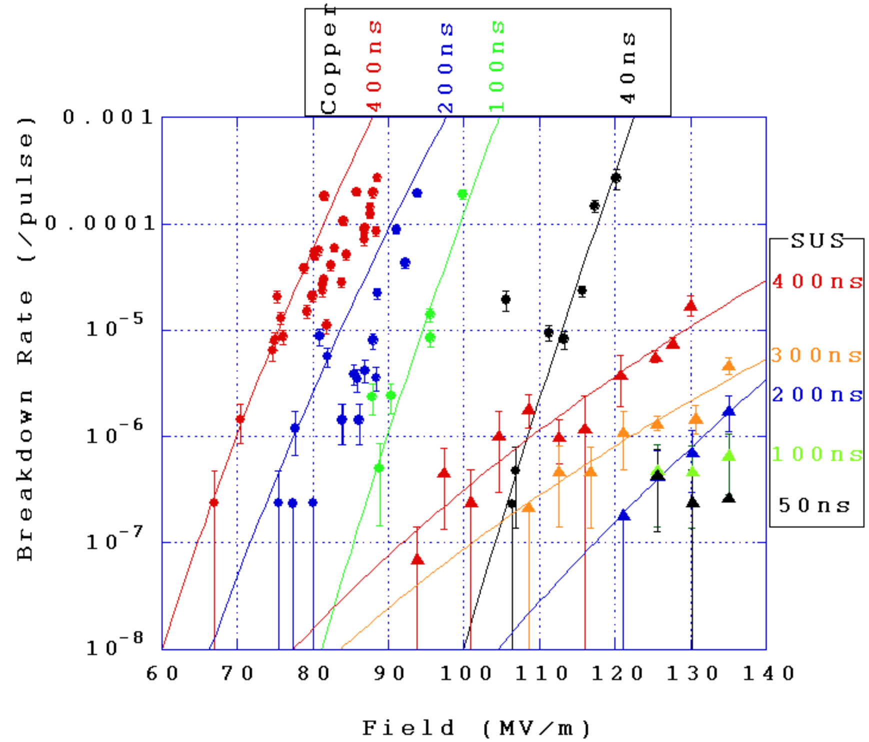


V.A. Dolgashev, 18July 2008

Surface hardens due to pulse heating. Hard surface speculates to be preferable for high gradient but it needs to be proven.

High gradient study with narrow waveguide at KEK





Materials are compared with breakdown rates.

Copper BDR >> Stainless-steel BDR

Materials and surfaces

- Any hint to understand the trigger to breakdown?
- 7N, LG, etc.
- Crystal structure; boundary, direction,,,
- Defects underneath; X-ray analysis…
- Surface cleanness and dust; water cleaning…

- These need to be addressed at shield-B of KEK hopefully in 2010.

化学成分 (Chemical
外観
元素
最大許容値
(ppm)
規定無し
規定無し
合格
合格
Order No.)
Spec. No.)
高純度銅鋳塊熱処理

Preparation for basic study at KEK

- A pair of mode launchers for KEK
  - Improved flange design for higher power
  - Almost completed by SLAC
- Directional coupler with high directivity
  - Mechanical design is on-going at SLAC
- Shield-B was constructed
  - Transport from KT1 klystron to the shield-B is being prepared by KEK

2010年度の研究計画（1）赤字は日米予算適用

- 加速管、試験構造の製作
  - SLAC＋KEK　の通常の分担を活用
  - CLICプロトタイプ＆試験構造
- 高電界試験とその比較解析
  - 加速管対象：　SLAC：NLCTA　＆　KEK：Nextef
  - 試験構造対象：　SLAC：ASTA　＆　KEK：KT1
  - TD18_Diskの試験結果の詳細比較
    - 試験分析、製造過程分析、、、、
  - T24、TD24の試験

2010年度の研究計画（2）赤字は日米予算適用

- 試験設備の拡充＠KEK
  - Nextefでのパルス圧縮
  - KT1→Shiled-B 輸送路確保
  - Shield-B内の基礎試験準備
- 基礎試験
  - パルス加熱、単空洞の試験＠SLAC
    - 純度、結晶構造、表面処理を変えた試験体を製作と評価
  - 狭導波管 （高純度Mo）＠KT1
  - 単セル試験＠シールドB

最終年度としての計画

- リニアコライダー主加速ユニットの設計
  - KEK:進行波管での試験結果を基に
    - RFユニット方式での設計
    - 二ビーム方式での可能性検討
  - SLAC:各セルをフィードする方式
    - 機械設計とある程度の試験
- 日米協力の継続へ向けて
  - 共同研究目標の再設定
  - 基礎研究進展への展望

日米協力の課題と予算の重要性

- 高電界特性の調査･改良
  - 基礎試験をKEK内確立すべき
  - 日米予算は機器や試験体の整備に不可欠
- SLACの製造工程
  - 表面洗浄～ベーキングの工程はクリティカル
  - 当面維持すべきであり、日米は重要な枠組み
- 高電界特性の定量的比較
  - SLACとKEKの高電界特性の定量的比較が重要
  - 相互に乗り入れて現場からの調査が必須で日米枠組みが重要
- SLAC/USの超高電界へ向けた研究
  - 基礎情報を得ることが重要