Gradient Yield Improvement Efforts for Single and Multi-Cells and Progress for very high gradient cavities

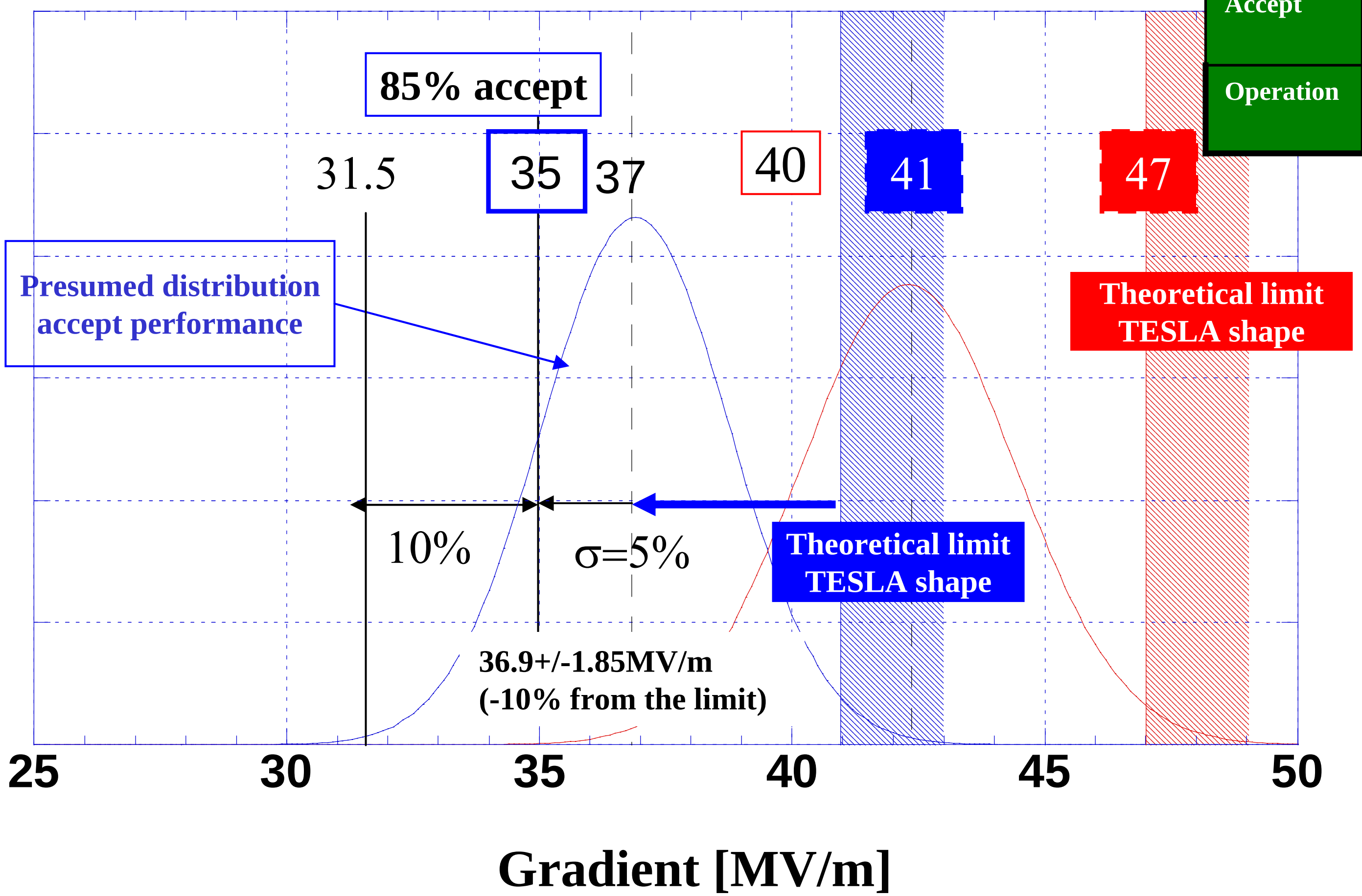
Kenji Saito, KEK

- **ILC cavity specification**
- **Multi-Cell Studies in Labs**
- **Single Cell Studies**
- **Progress for very H.G**
- **Summary**

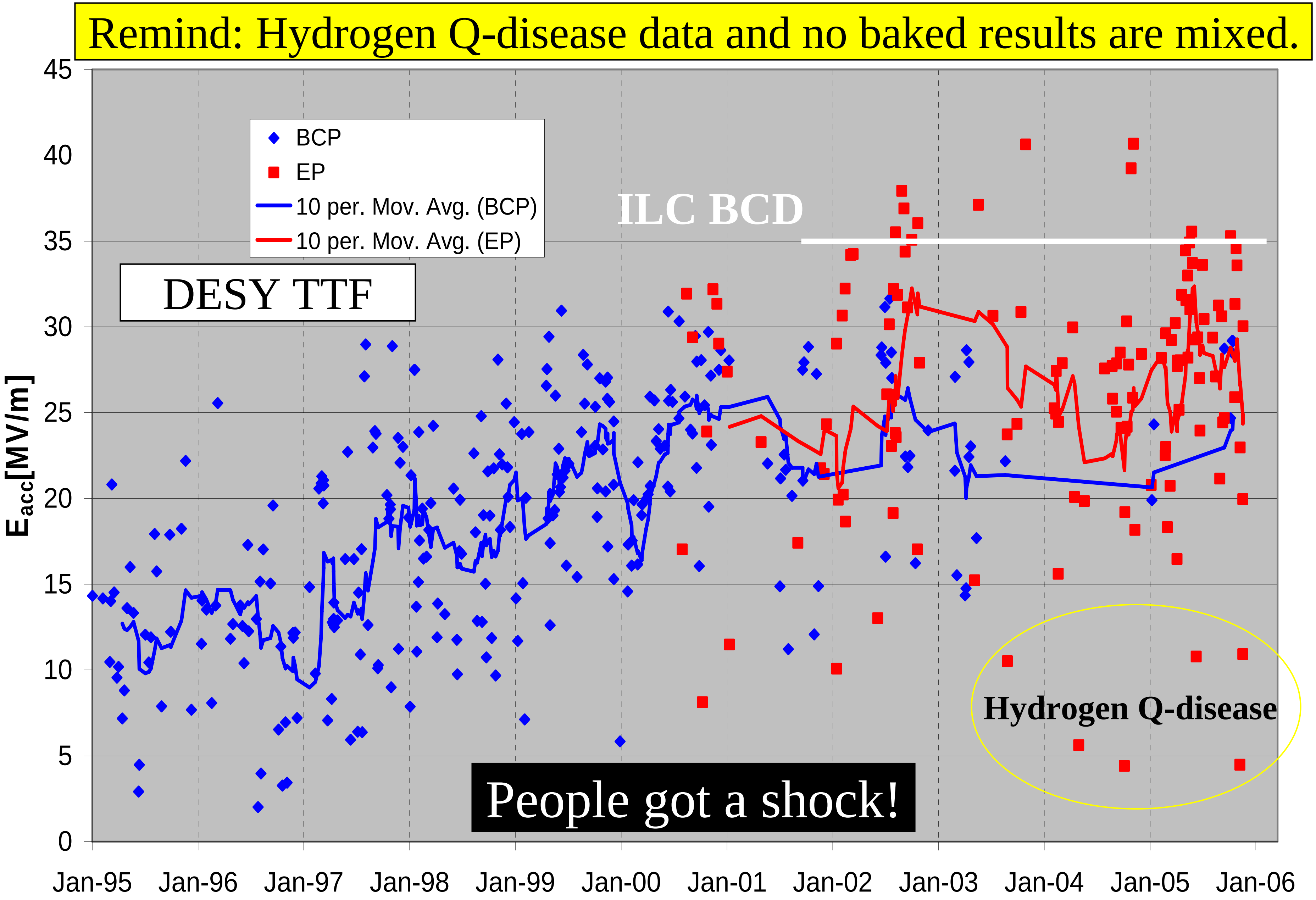
ILC cavity specification at Snowmass 2005

Most Tesla cavities should be able to reach 35MV/m accept
Most LL/RE cavities should be able to reach 40 MV/m accept
But note there is a low energy tail that fails

	TESLA(BCD)	LL/Reentrant(ACD)
Accept	Eacc =35MV/m, Qo=0.8 E10	Eacc =40MV/m, Qo=0.8 E10
Operation	Eacc=31.5MV/m, Qo=1.0 E10	Eacc=36MV/m Qo=1.0 E10



Scatter Problem developed after the Snowmass



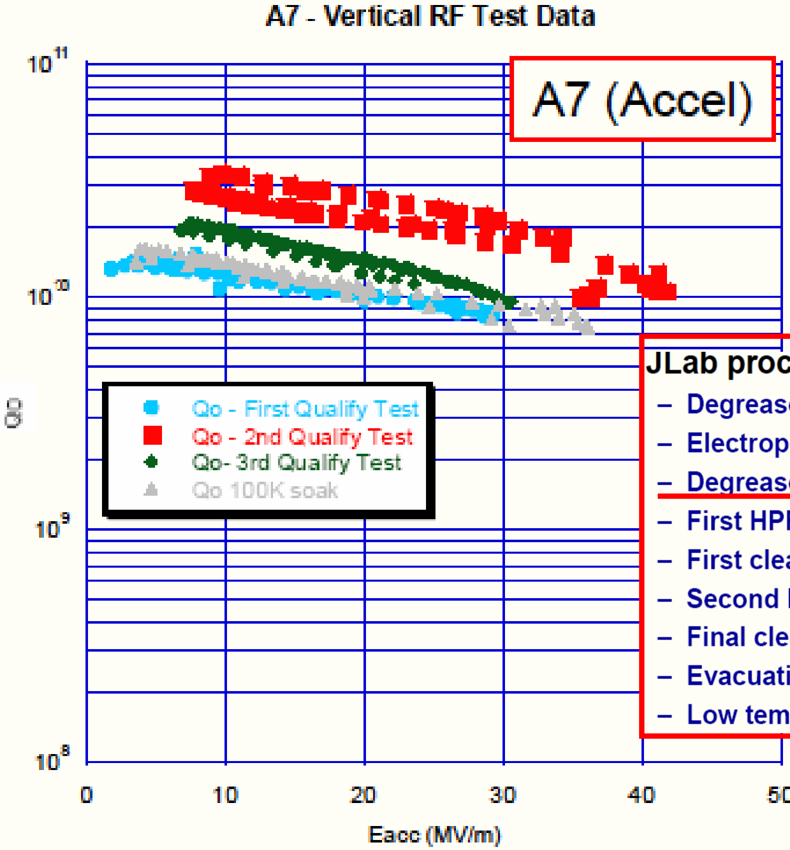
S0/S1 GDE Taskforce

- S0 task force membership
  - Hitoshi Hayano (KEK), Toshiyasu Higo (KEK), Lutz Lilje (DESY), John Mammosser (SNS), Hasan Padamsee (Cornell), Phil Pfund (FNAL), Marc Ross (FNAL), Kenji Saito (KEK), Bill Willis (Columbia), Camille Ginsburg (FNAL)
- Goal for cavity performance in vertical test
  - ILC baseline (RDR): $E_{acc} \geq 35$ MV/m, $Q_0 \geq 0.8 \times 10^{10}$
  - Proof of principle: $E_{acc} \geq 35$ MV/m and $Q_0 \geq 10^{10}$, with yield > 90% for >100 cycles
- Plan for achieving goal
  - Two steps
    - S0 : Tight loop to improve "final preparation" yield
      - Process and test few cavities repeatedly; test of processing
    - S1 : Production-like activities to determine overall yield for cavity materials, fabrication and full cavity processing
      - Process and test batches of 10's of cavities; test of full cycle including fabrication, surface processing, assembly
  - Closely coordinated global execution
    - Reproducibility from lab to lab
      - Complete description of preparation and testing processes
      - Common minimum test procedure and reporting of results
      - Compare regional preparation setup performance
    - Time scale should be commensurate with completion of the EDR (mid 2009)

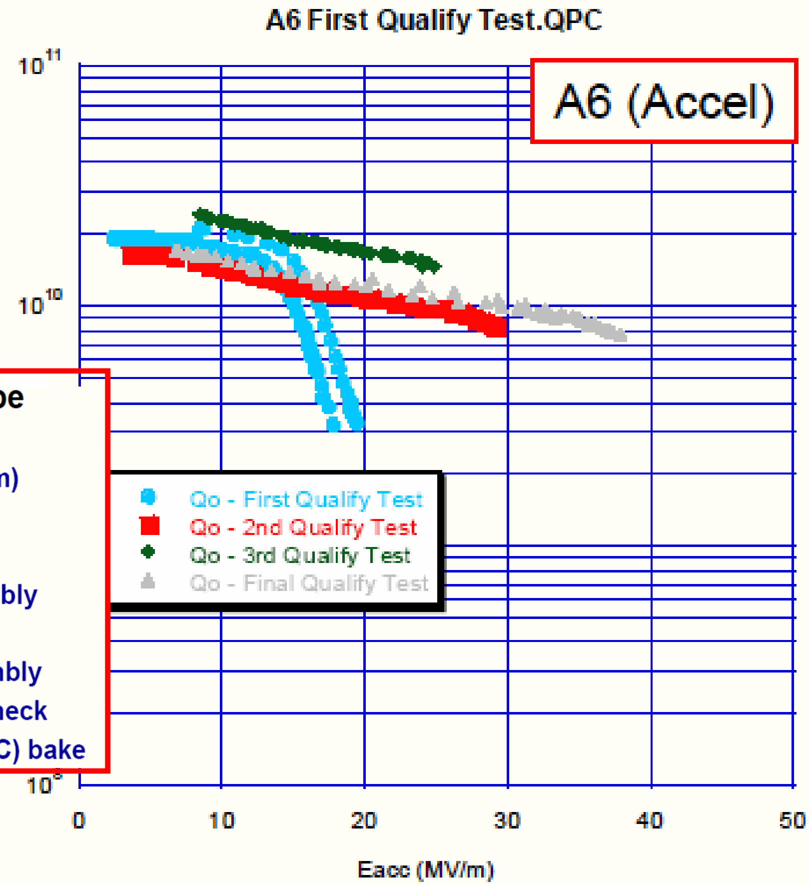
JLab: Process reproducibility

J. Mammosser, TTC Meeting at Fermilab, April 2007

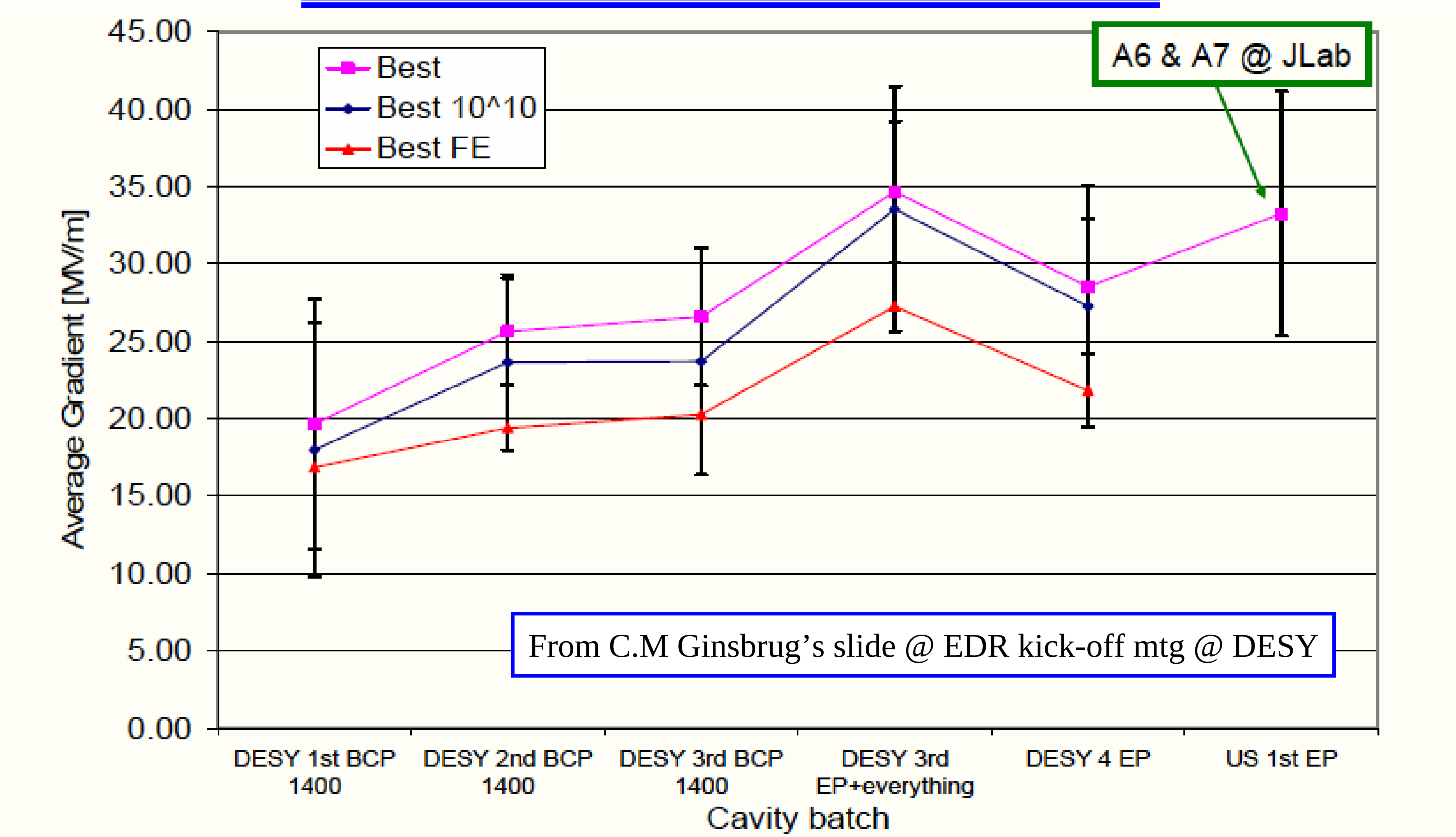
- Accel cavities – already qualified vendor, same treatment for all cavities
- All curves but one limited by quench; A6 final test limited by FE
- Large distribution of quench gradients with multiple tests of same cavity



JLab processing recipe
- Degrease
- Electropolishing (20 μm)
- Degrease
- First HPR+dry
- First cleanroom assembly
- Second HPR+dry
- Final cleanroom assembly
- Evacuation and leak check
- Low temperature (110 C) bake



Well Qualified Vendors

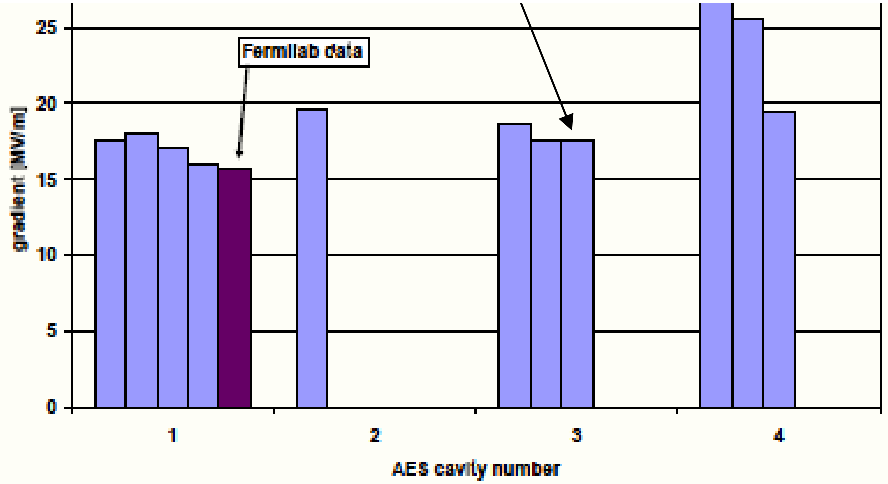


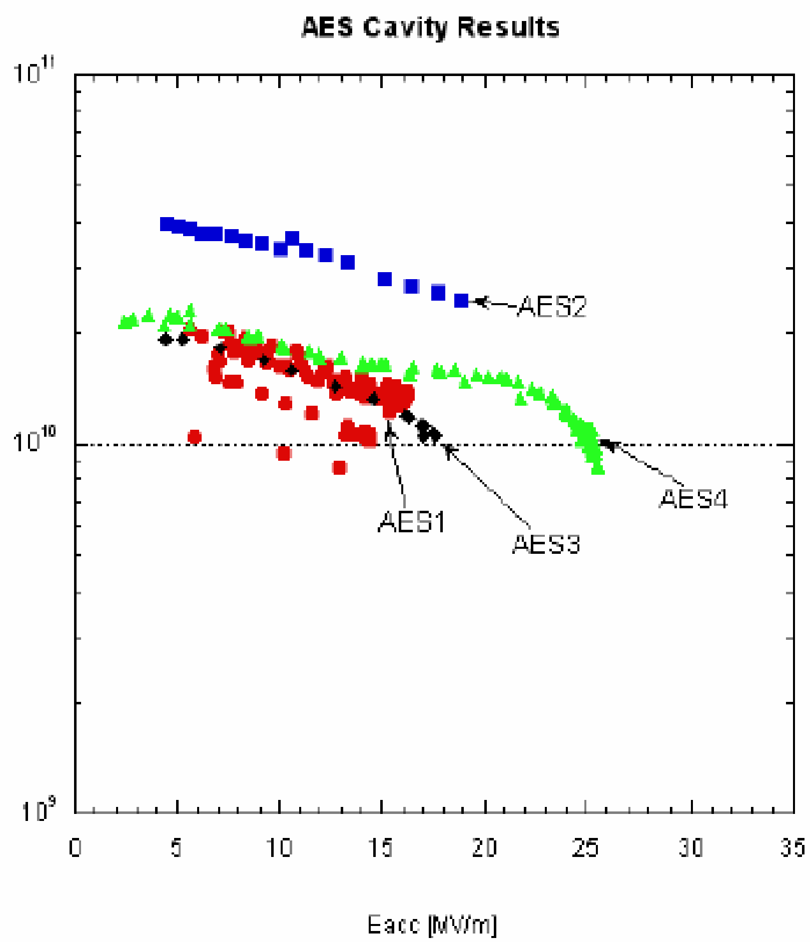
The average is getting the ILC target but the large scatter is still a problem!

New Vendor Issue @ USA

T-map:Heating @ Equator

From C.M Ginsbrug's slide @ EDR kick-off mtg @ DESY





- New cavity vendor: AES
- Standard JLab surface treatment
- Results
  - Gradient summary: 19.2 +- 3.8 MV/m
  - Best cavity at 28 MV/m

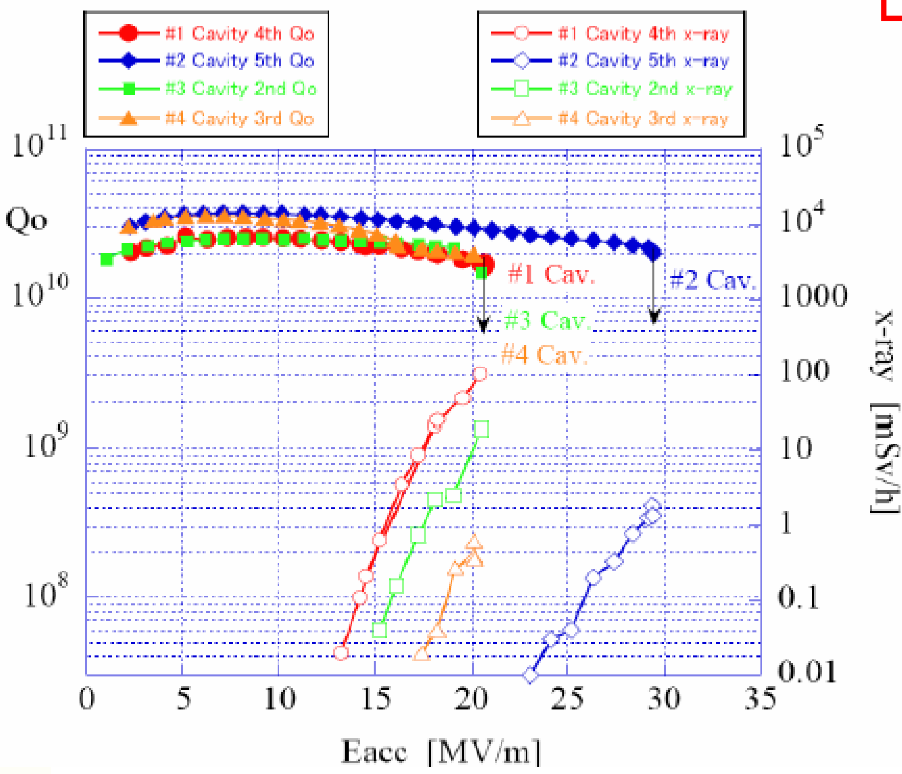
EBW @ equator might be a issue !

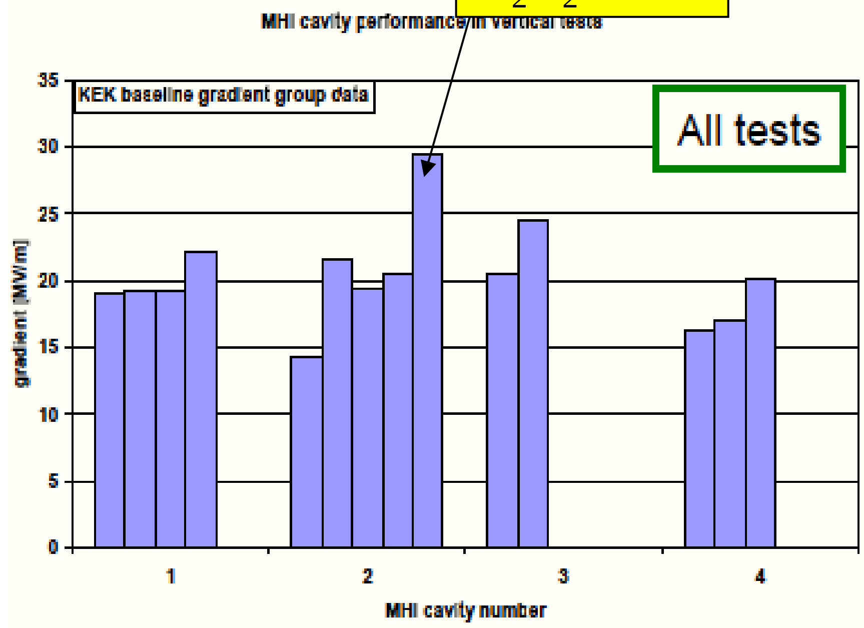
KEK Baseline Cavities

By E.Kako et al.

New Vendor in Japan

Process: [CBP(~100μm)+EP(~100μm)]x2 +EP(~30μm)+HPR+Bake

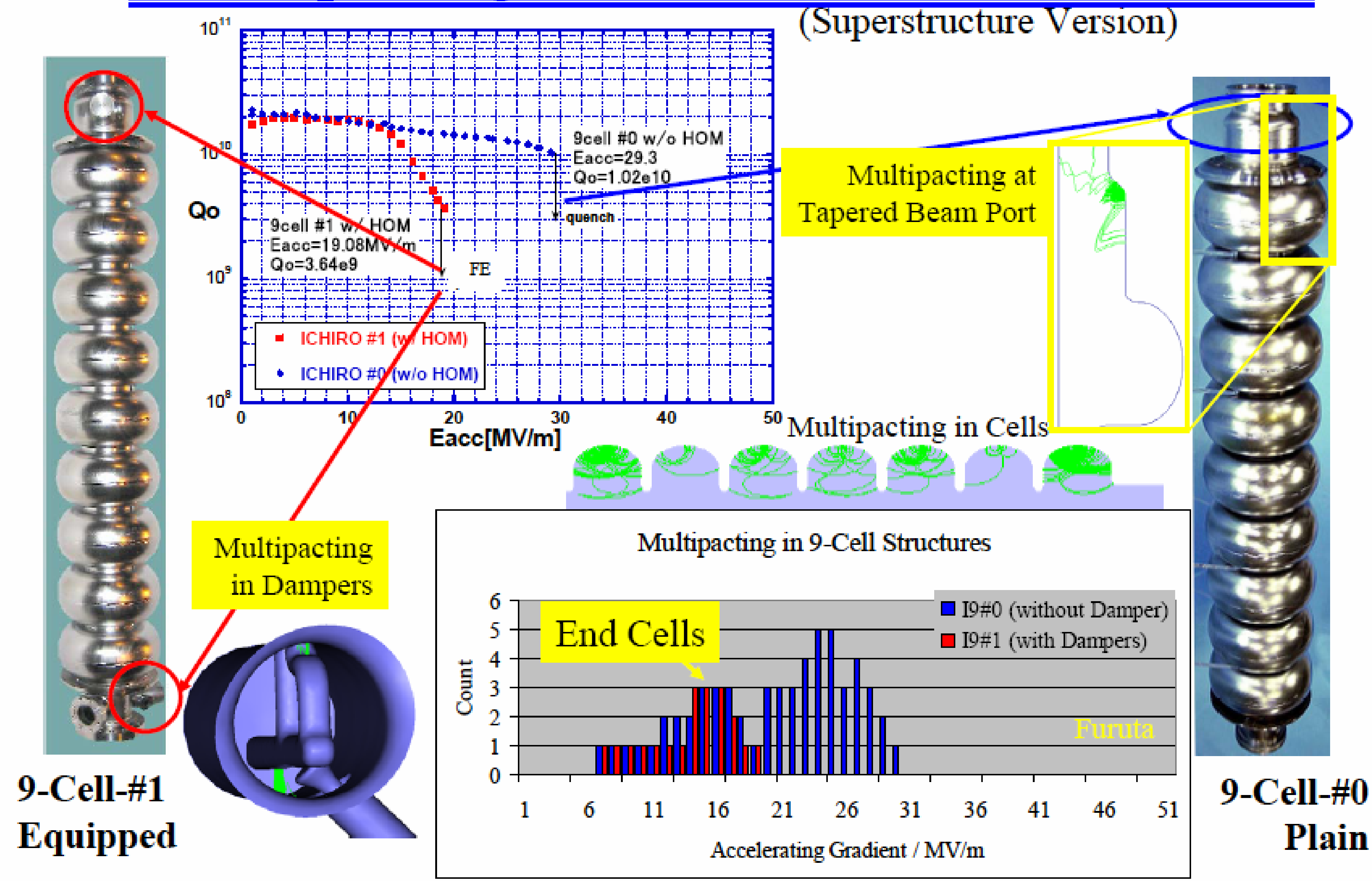




Why every cavity does limit often around 20MV/m ?
EBW @ equator might be a problem.

Problems in Ichiro 9-cell cavity

(Superstructure Version)

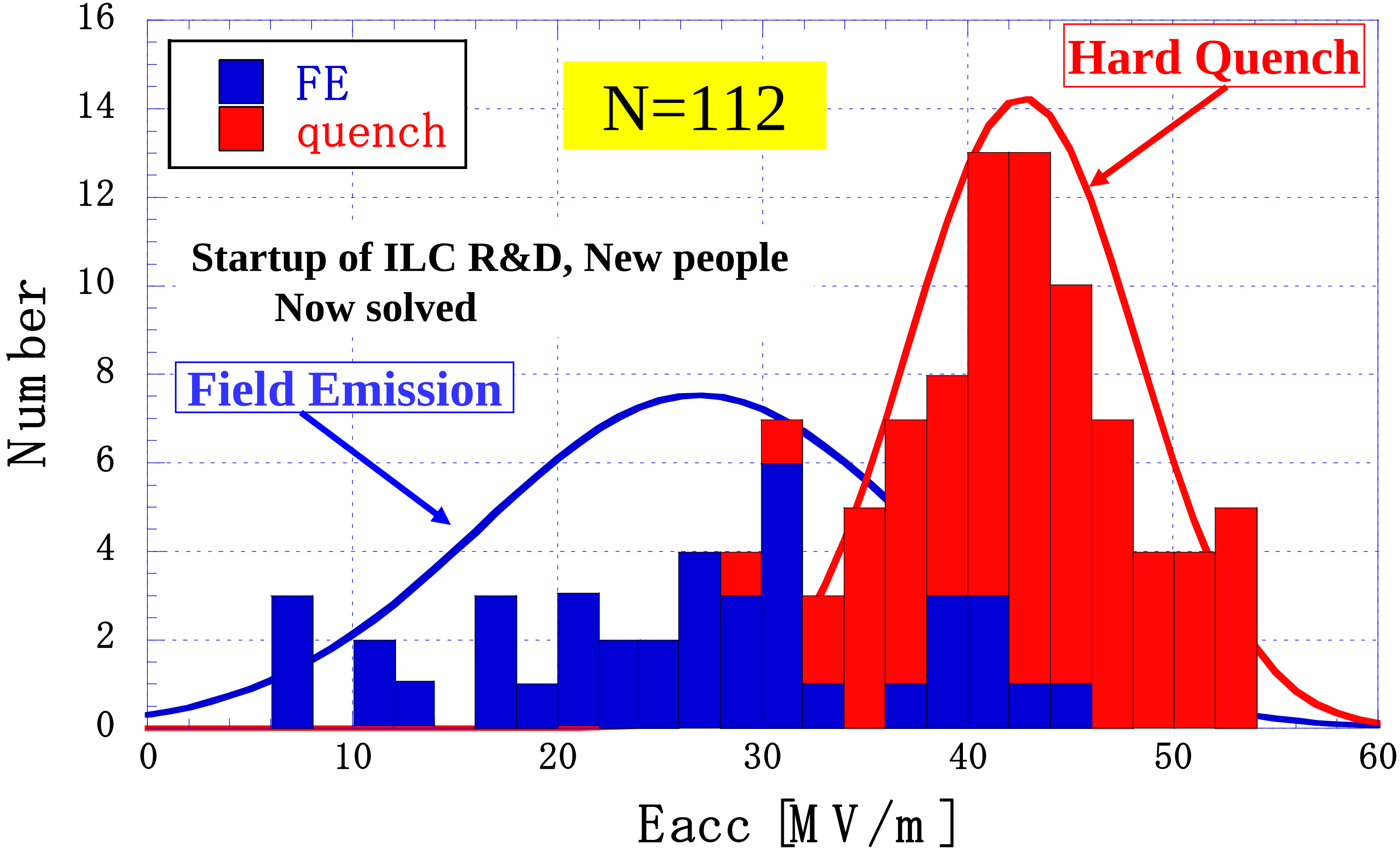


Probably main problem is in END groups !
Redesigned cavity fabrication is under way.

Performance Scatter seen in LL single cell study @ KEK

IS cavities all results (1st pilot study)

Ave.Eacc max=37.0±10.9MV/m, Ave. FE onset=31.2±11.3MV/m



TESLA collaboration Meeting @ Frascati Dec. 2006

List and prioritize R&D activities

P.Kneisel @ JLAB

- Re-visit residual contamination of EP surfaces: XPS,SIMS? FE
- Investigate different rinsing methods:
  hot water (Henkel, KEK), H_2O_2 + US, anodizing, oxipolishing,..
  on samples, single cells: either several or reference cavity of known performance
- Removal of sulfur from mixture:
  filtering?, solvents,…
- Implement “on line” monitoring of HF concentration and polarization curves, purity (gas chromatography)
- Shaping of cathode:
  more uniform material removal, more uniform polarization curves over whole surface, lower voltage to achieve required current density, more uniform T-distribution?
- Does it make sense to explore other acid mixtures? Or should one concentrate on making present process “fool proof”?

Single cell study issues and the Priority list at KEK

	Expected yield rate	Disadvantage	Comment	Simplicity & Safety	Cost increase	Score	Priority
EP(20)+HPR+Bake	0.7		ILC BCD	1.0	1.0	1.0	Reference
EP(20)+H_2O_2+ HPR+Bake	0.9	Cost increase	TRISTAN Recipe	1.1	1.1	1.17	1
EP(20)+Degreasing+ HPR+Bake	0.9	Cost increase	29MV/m with TESLA 9-cell cavity @ Jlab	1.1	1.1	1.17	1
EP(20)+Alcohol +HPR+Bake	0.85	Cost increase Cure against burst	Stopped @ KEK Desy trying	1.15	1.15	1.06	2
EP(20)+HF rinsing+HPR+Bake	0.8	Cost increase Hazardous	Not so big potential but low FE @ KEK	1.1	1.15	0.99	3
EP(20)+Boling W +HPR+Bake	0.8	Cost increase complex	Hydrogen doping	1.1	1.15	0.99	3
EP(20)+EP(3 with fresh)+HPR+Bake	1.0	Cost increase	45MV/m with LL shape @ KEK	1.1	1.2	1.19	1
EP(20)+Oxipolishing +HPR+Bake	0.9	Additional process	Stopped @ KEK	1.5	1.3	0.99	3

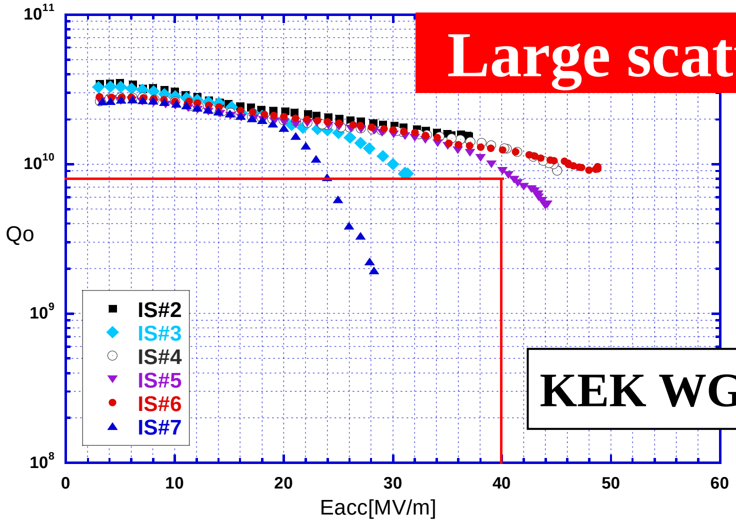
Score : (Expected yield rate / 0.7) /Cost increase

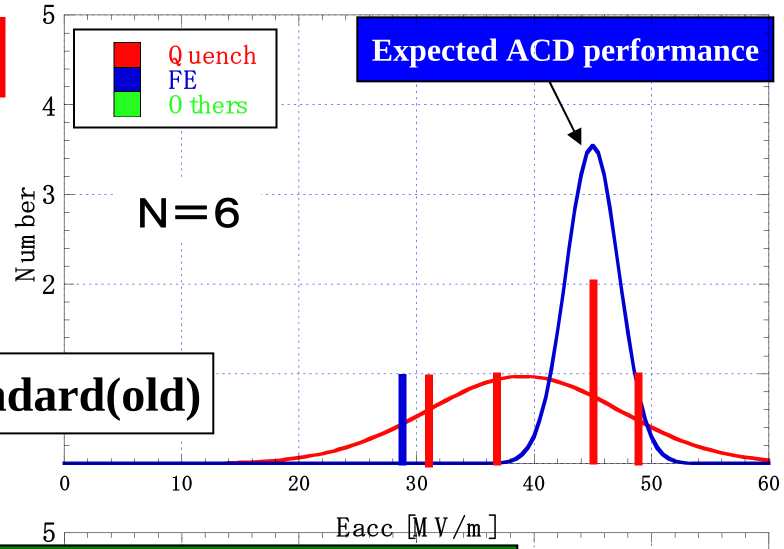
Detail information TUP10 by Furuta et al.

Current recipe study by single cell @ KEK

CBP(100µm)+BCP(10µm)+AN(750^{O}C, 3hr)+EP(80µm)+HPR+Bake:

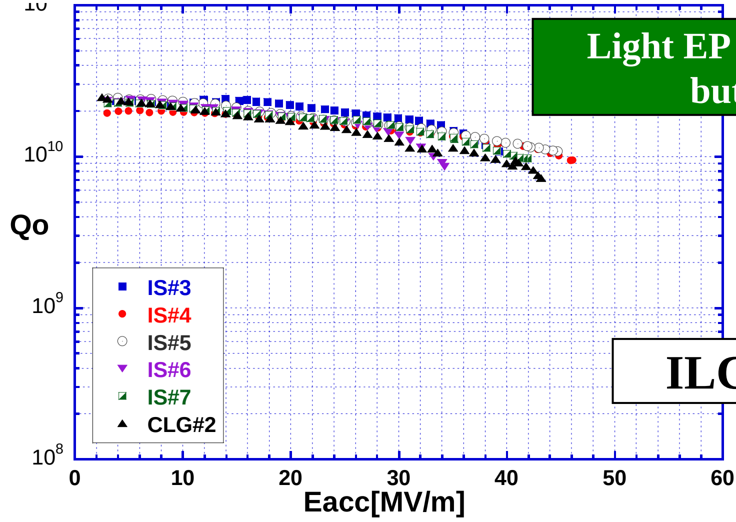
Ave. Eacc=39.1±8.2MV/m, Scattering:20%, Acceptability@40MV/m(ACD):50%



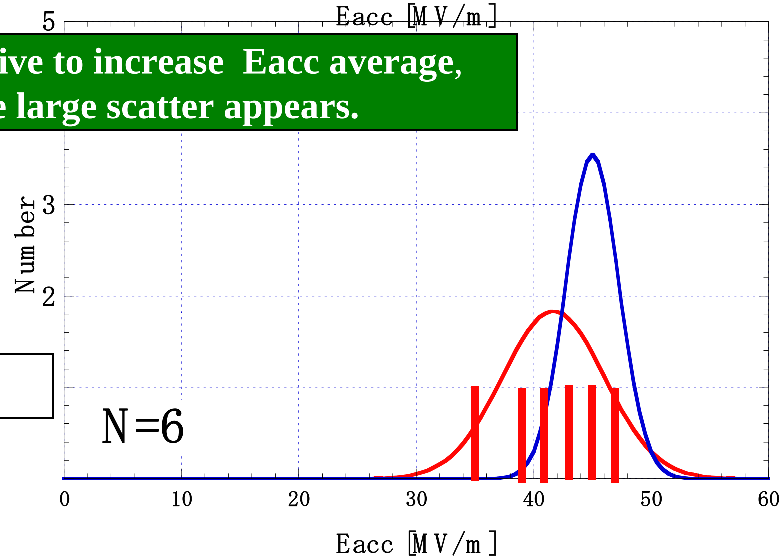


KEK WG5 standard(old)

Light EP is effective to increase Eacc average, but still the large scatter appears.



ILC BCD



K.Saito

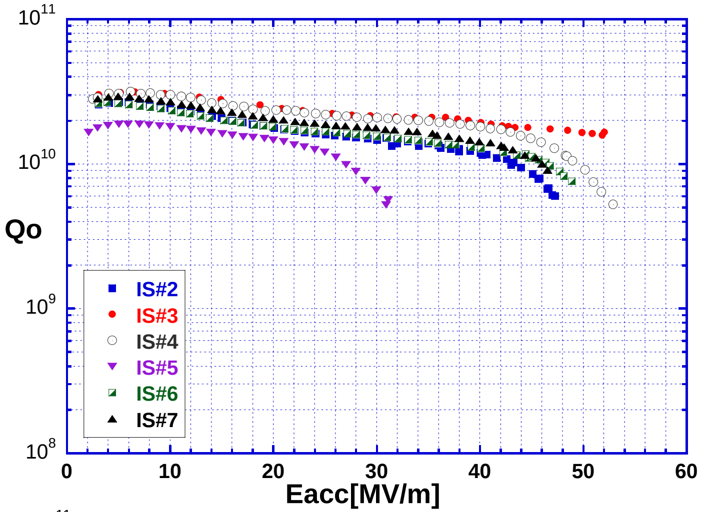
+EP(20µm)+HPR + Bake

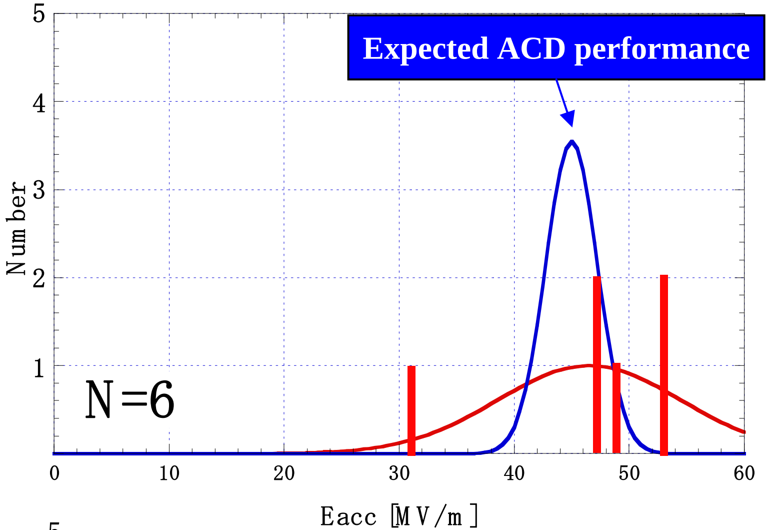
Ave. Eacc=46.5±8.0MV/m, Scattering:17%, Acceptability@40MV/m(ACD):83%

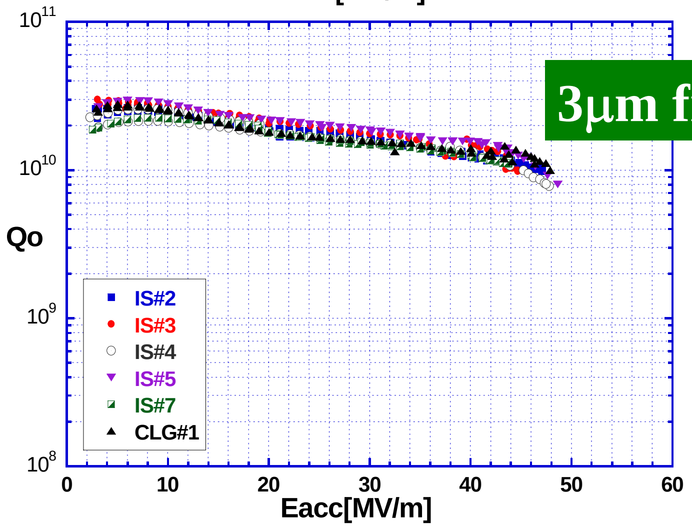
New Recipes Search by single cell @ KEK

CBP(100μm)+BCP(10μm)+AN(750^{O}C, 3hr)+EP(80μm)+EP(3μm, fresh acid) + HPR+Bake:

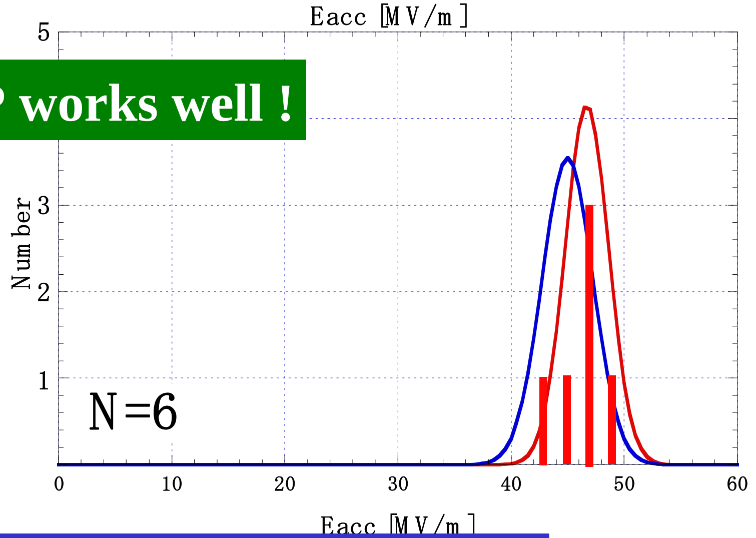
Ave. Eacc=41.7±4.4MV/m, Scattering:10%, Acceptability@40MV/m(ACD):67%







3μm fresh EP works well !

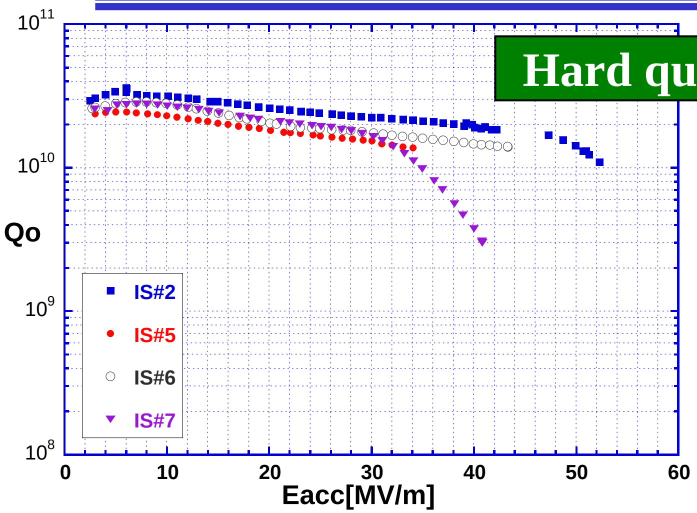


K.Saito

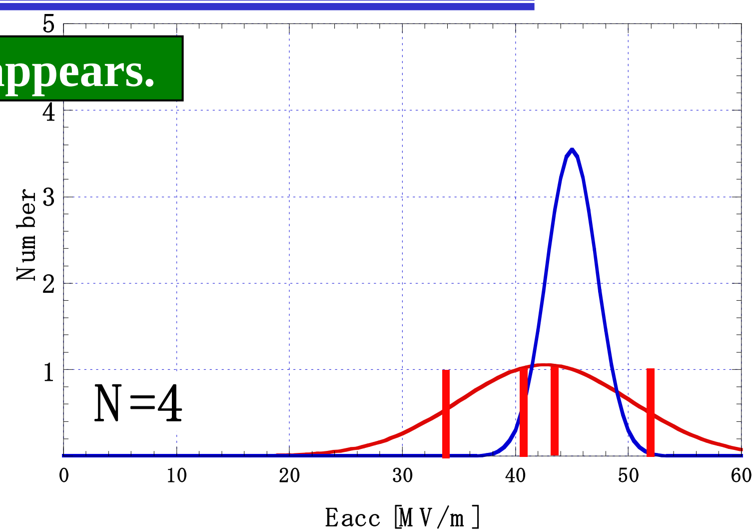
+EP(20μm)+ EP(3μm, fresh acid) + HPR + Bake:

Ave. Eacc=46.7±81.9MV/m, Scattering:4%, Acceptability@40MV/m(ACD):100%

Rinsing study by single cell @ KEK

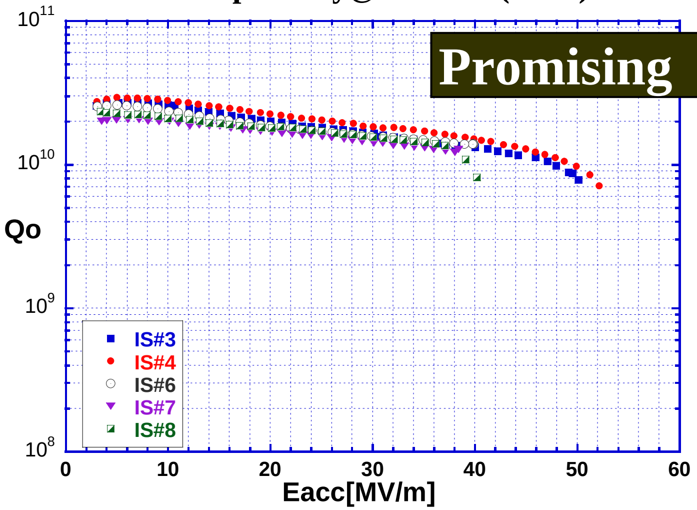


Hard quench appears.

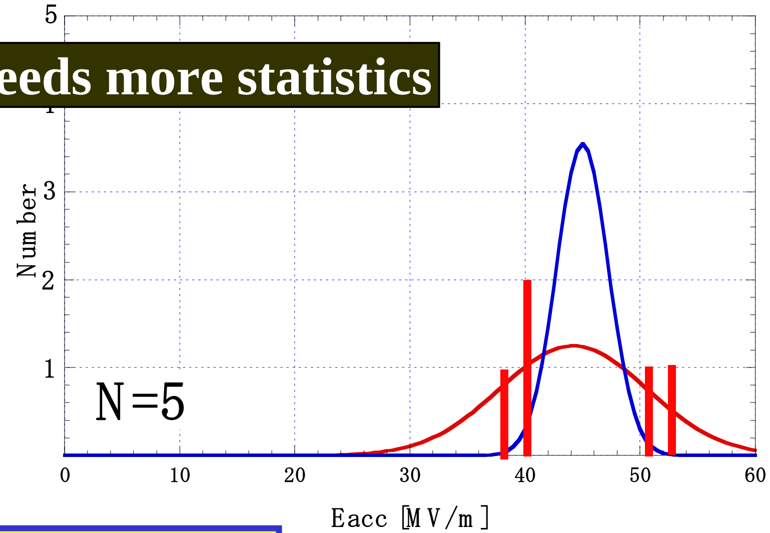


+EP(20μm)+H_2O_2 rinsing+HPR+Bake

Ave. Eacc=42.6±7.6MV/m, Scattering:18%, Acceptability@40MV/m(ACD):50%



Promising but needs more statistics

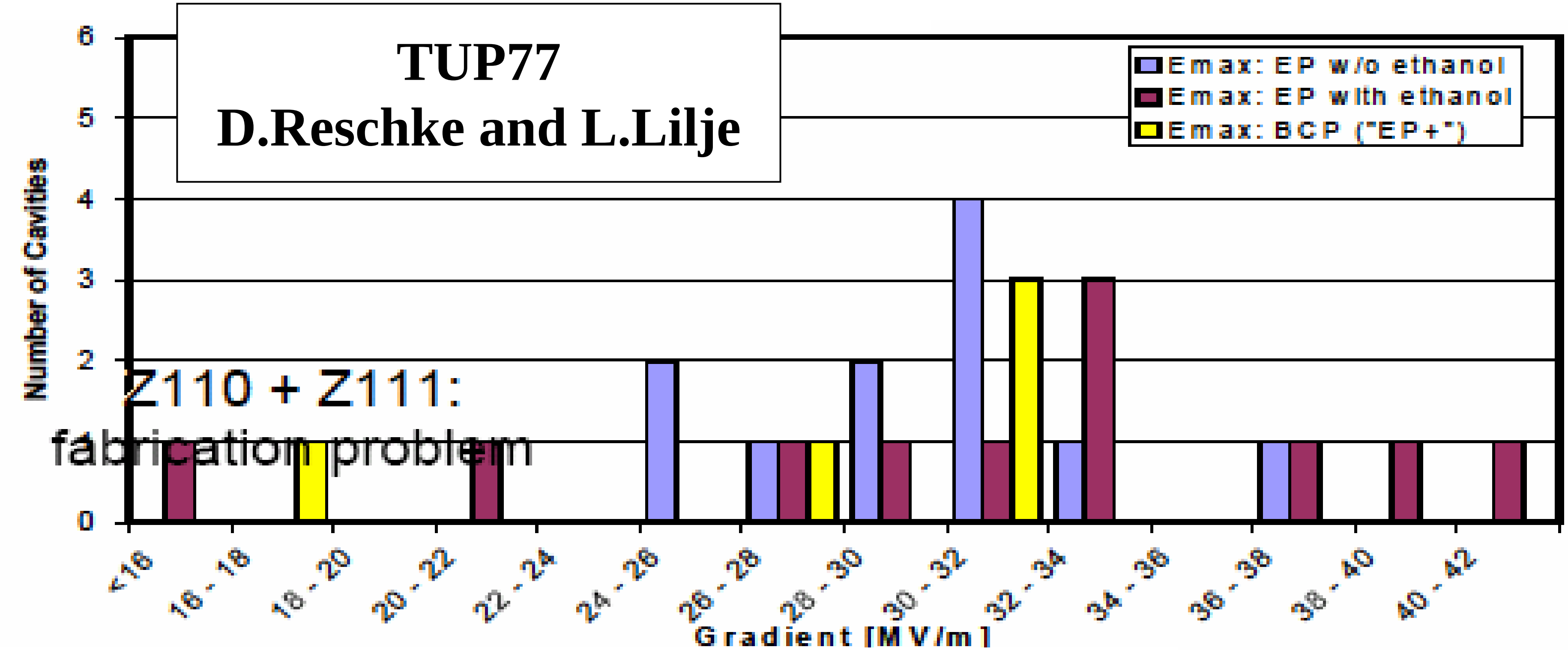


K.Saito

Ave. Eacc=44.2±6.4MV/m

Scattering:14.5%, Acceptability@40MV/m(ACD):60%

Ethanol Rinsing @ DESY 9-cell



⇒ **EP w/o eth:** $< E_{acc,max} > = (30 \pm 4)$ MV/m
$< E_{acc,usable} > = (29 \pm 3)$ MV/m

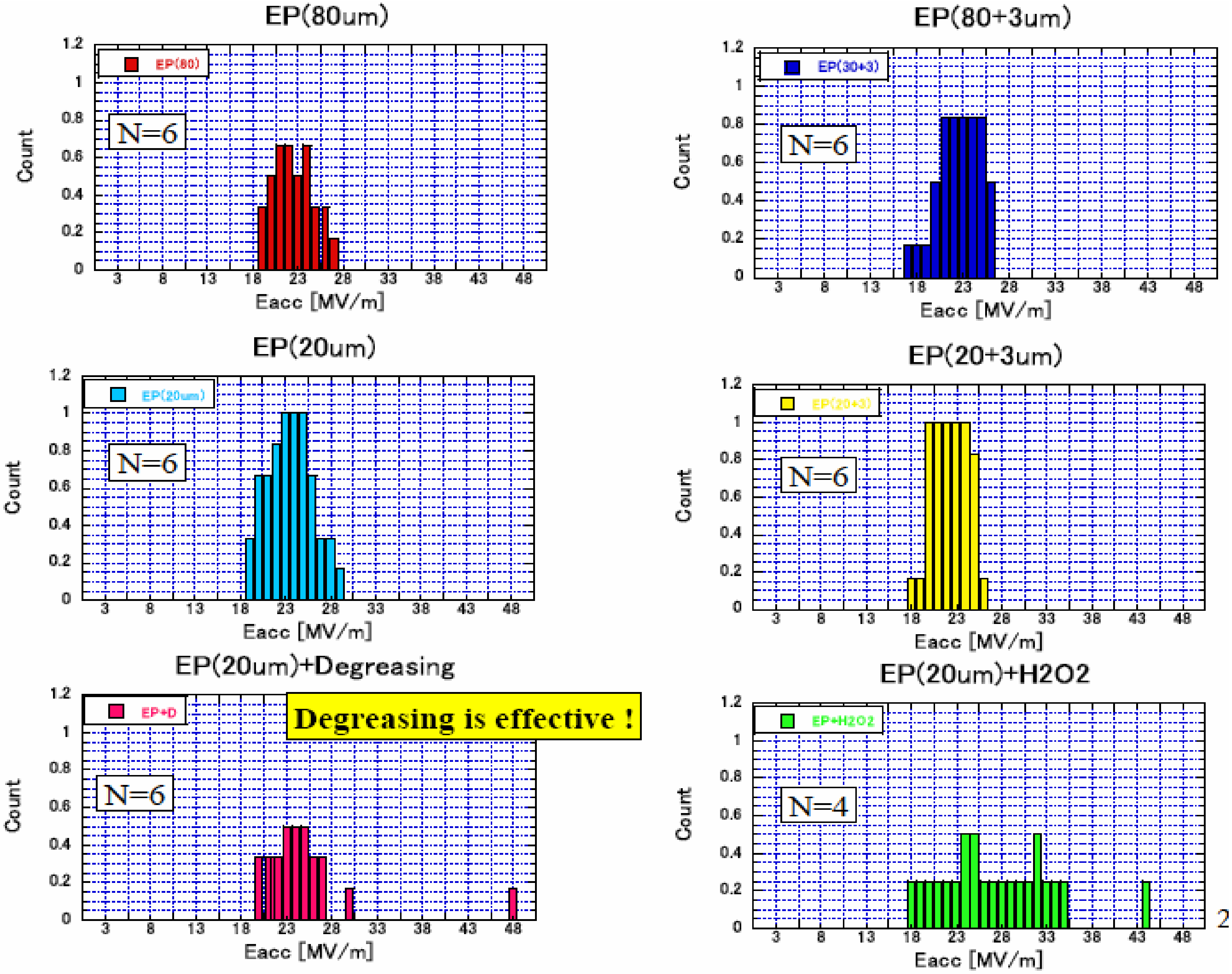
Ethanol rinsing is effective!

⇒ **EP with eth:** $< E_{acc,max} > = (32 \pm 6)$ MV/m **(w/o Z110)**
$< E_{acc,usable} > = (30 \pm 4)$ MV/m

⇒ **BCP ("EP+"):** $< E_{acc,max} > = (30 \pm 2)$ MV/m **(w/o Z111)**
$< E_{acc,usable} > = (29 \pm 2)$ MV/m

Multipacting

Probability of X-ray appearance



Degreasing is effective !

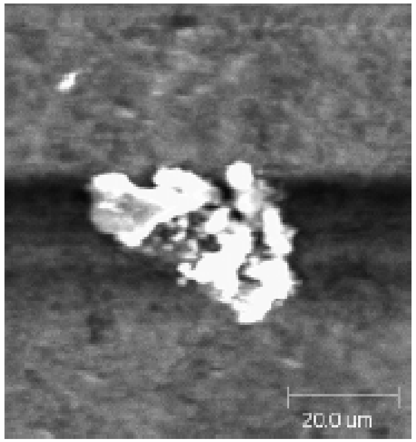
Basic Studies to Identify EP Residues That May Cause Field Emission

Cornell

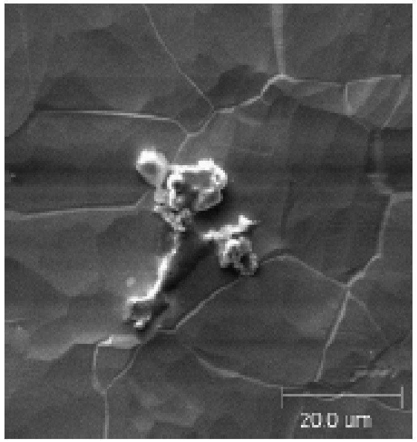
- Two main types of particles captured during EP,
  - S and niobium-oxide
  - Traces of Al also found with Auger, as expected due to Al cathode
- S particles dissolve in ethanol rinse but leave an imprint
- Oxide particles dissolve in HF rinse
  - But did not dissolve in EP !

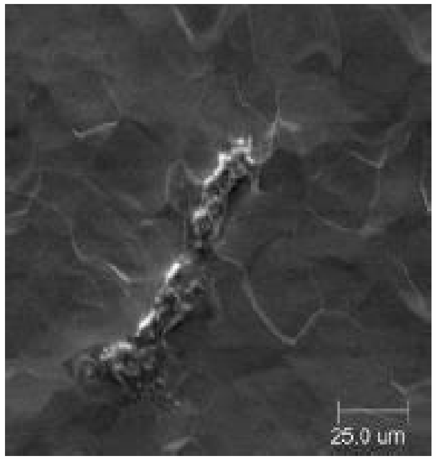
Nb sulfide !?

Oxide Particle



Typical S particles Deposited on Nb Surface During EP





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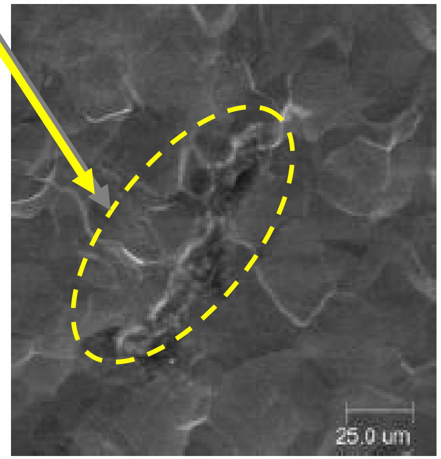
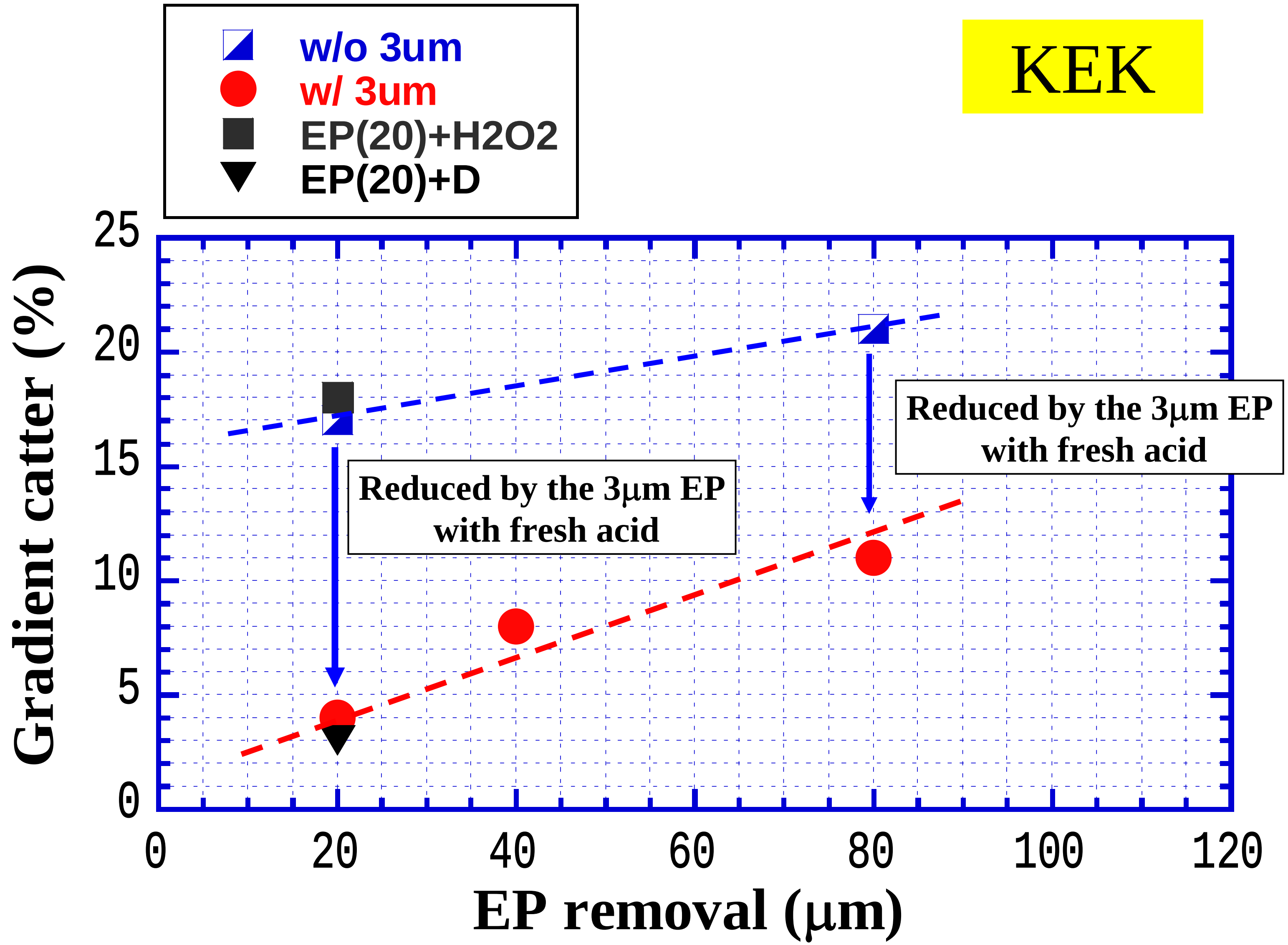
S-Particle

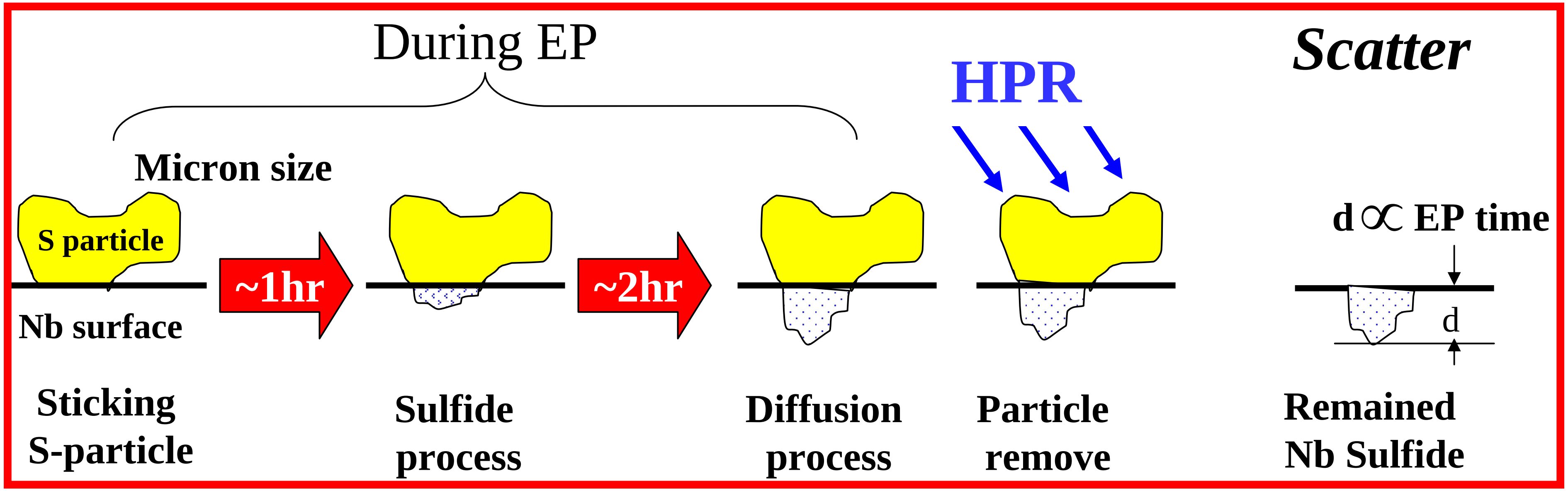
After Ethanol Rinse

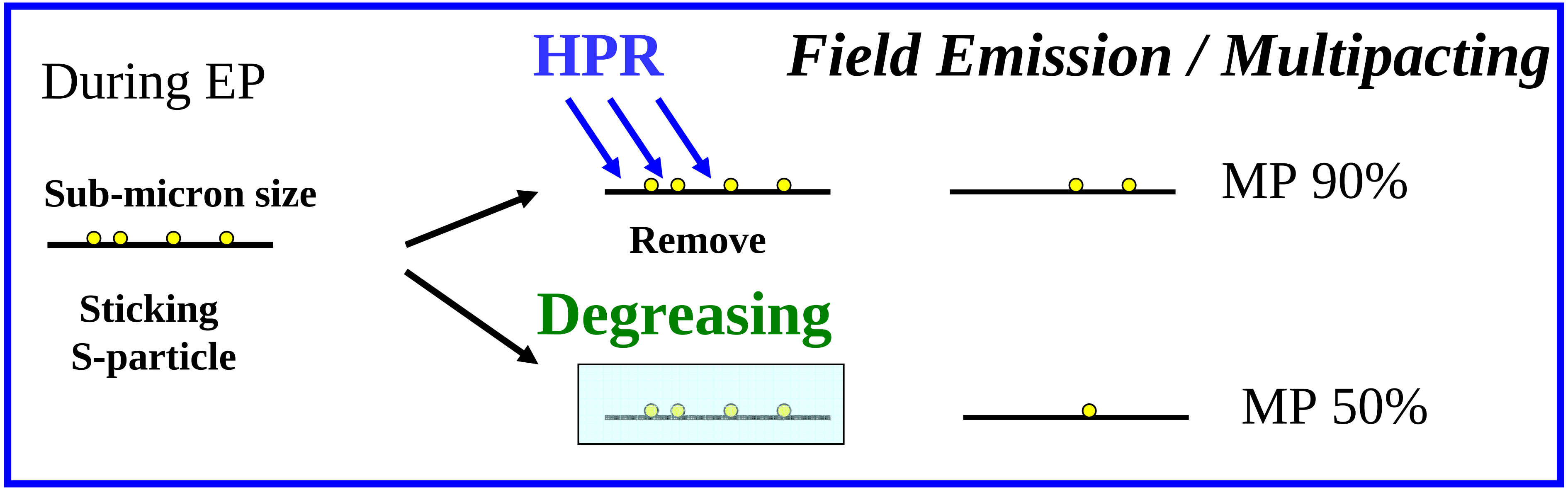


Gradient Scatter vs. EP removal



Mechanism to explain the scatter





Only strength of the rinsing method could not fix the scatter problem.
The EP flush would be important to make narrow scatter.

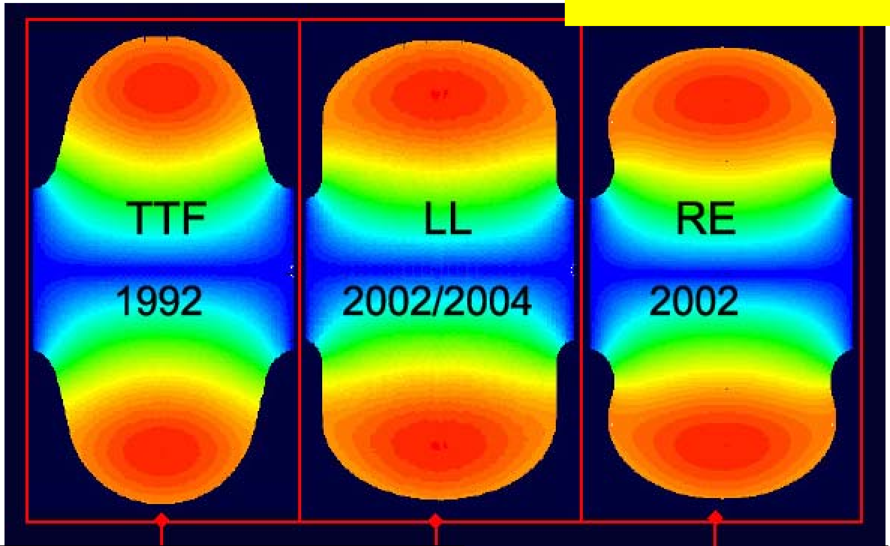
Progress for very high Gradient

High Gradient Cavity Shapes

Cavity shape designs with low Hp/Eacc

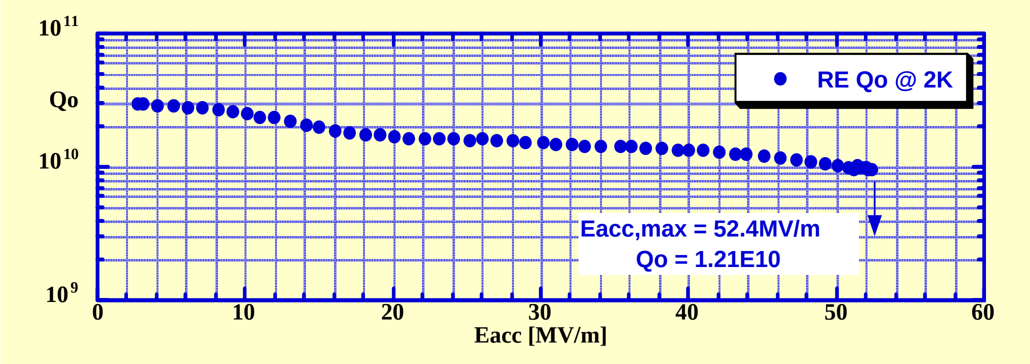
from J.Sekutowicz lecture Not

TTF: TESLA shape
Reentrant (RE): Cornell Univ.
Low Loss(LL)： **JLAB/DESY**
Ichiro-Single(IS)： **KEK**

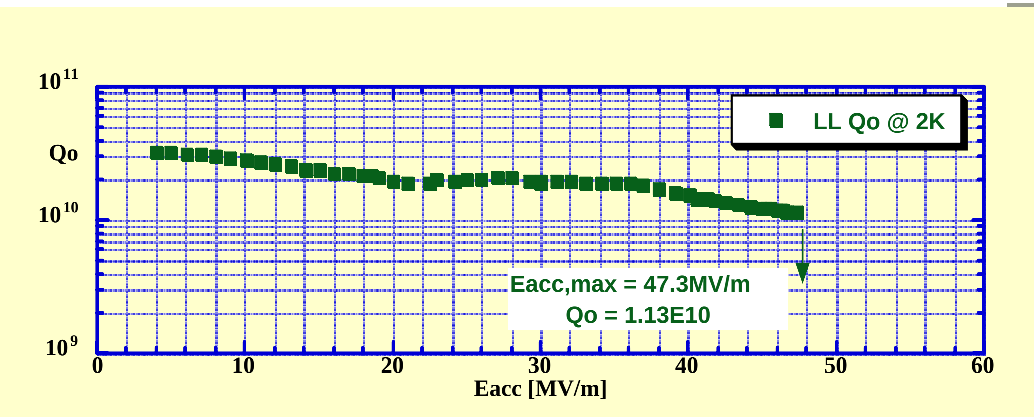


	TESLA	LL	RE	IS
Diameter [mm]	**70**	**60**	**66**	**61**
Ep/Eacc	**2.0**	**2.36**	**2.21**	**2.02**
Hp/Eacc [Oe/MV/m]	**42.6**	**36.1**	**37.6**	**35.6**
R/Q [W]	**113.8**	**133.7**	**126.8**	**138**
G[W]	**271**	**284**	**277**	**285**
Eacc max	**41.1**	**48.5**	**46.5**	**49.2**

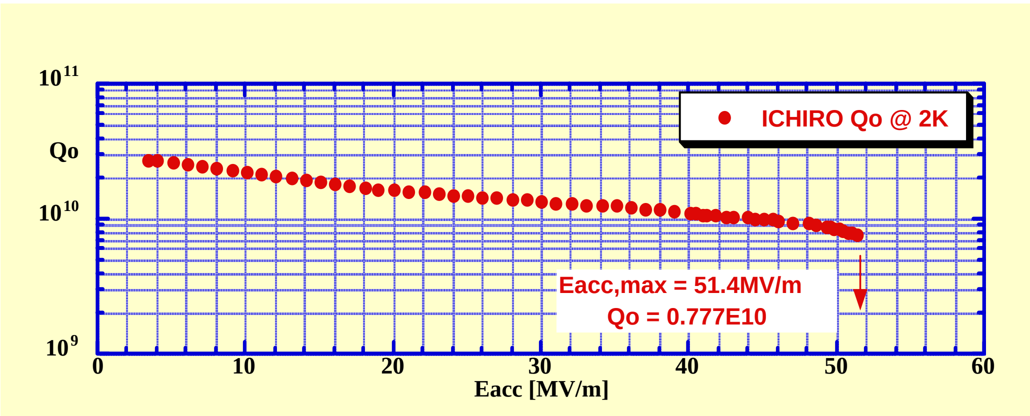
Successful Principle Proof of the 50MV/m at KEK



Diameter [mm]	60
Ep/Eacc	2.36
Hp/Eacc [Oe/MV/m]	36.1
R/Q [W]	133.7
G[W]	284
Eacc max	48.5



Diameter [mm]	66
Ep/Eacc	2.21
Hp/Eacc [Oe/MV/m]	37.6
R/Q [W]	126.8
G[W]	277
Eacc max	46.5



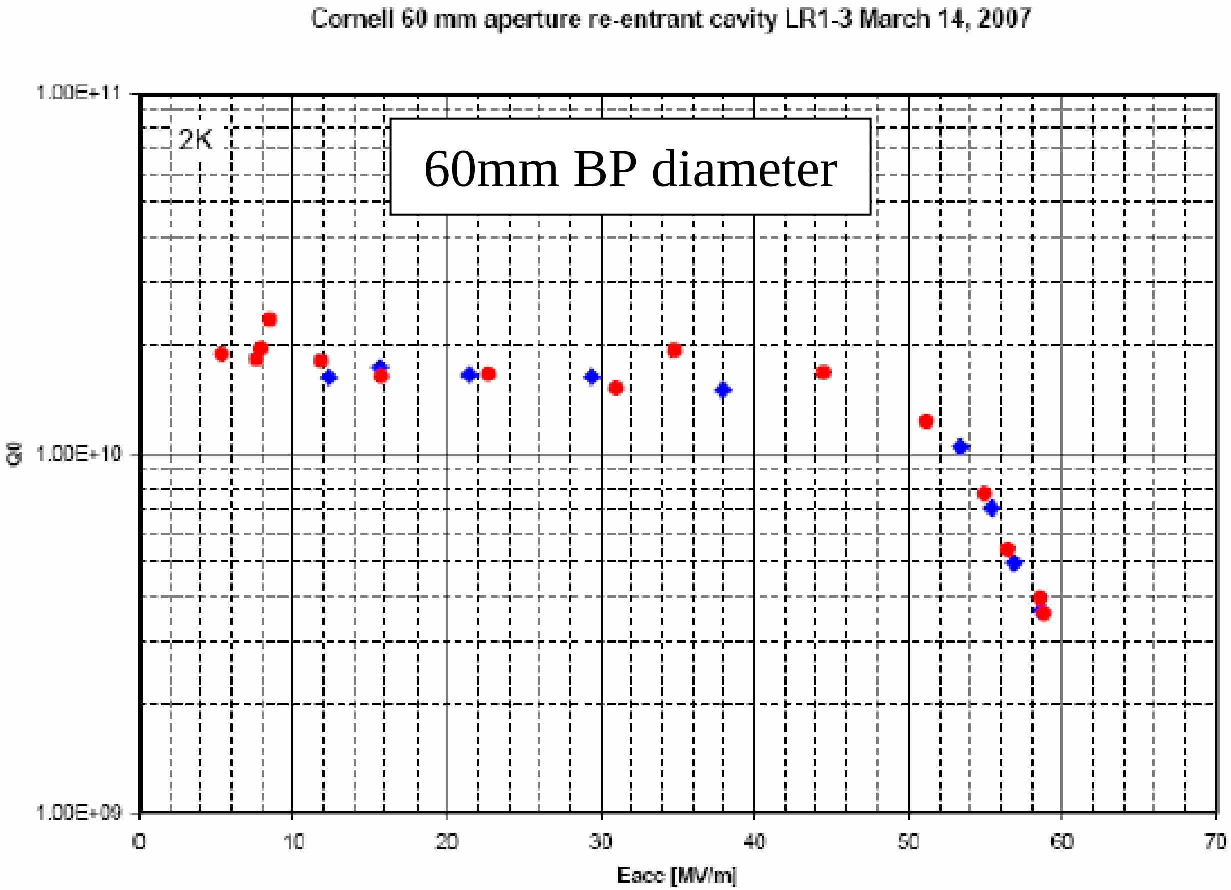
Diameter [mm]	61
Ep/Eacc	2.02
Hp/Eacc [Oe/MV/m]	35.6
R/Q [W]	138
G[W]	285
Eacc max	49.2

Alternate R&D, Single Cell Results

60mm-Aperture Re-Entrant Cavity - Best Eacc = 59 MV/m

Cornell/KEK

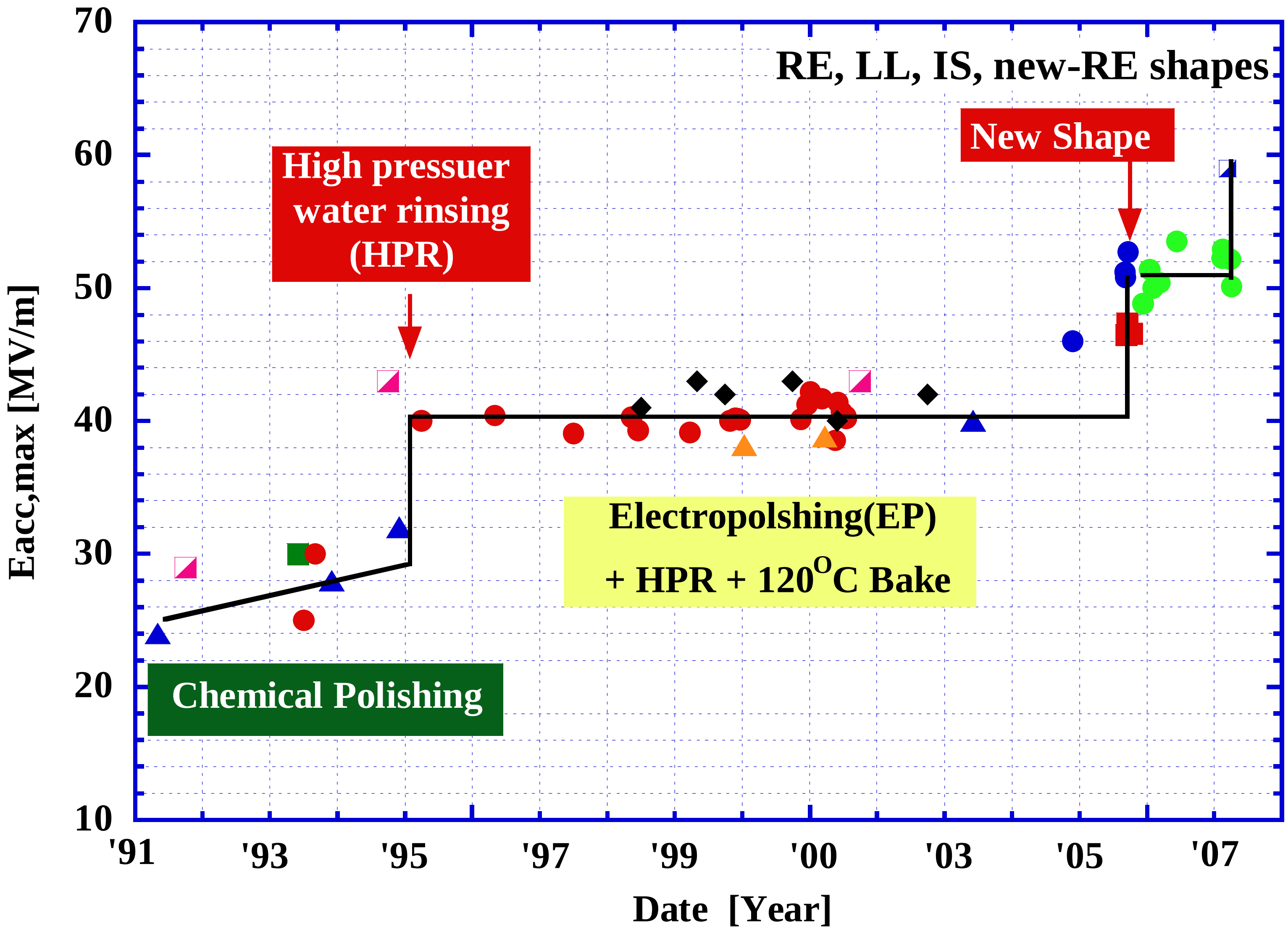
Re-entrant Shape Cavity



(EP+HPR+Bake+Test) @ KEK ⟹ Degreasing +HPR @ Cornell

45MV/m @ KEK due to HPR pump contamination problem

History of the H.G improvement last 15 years



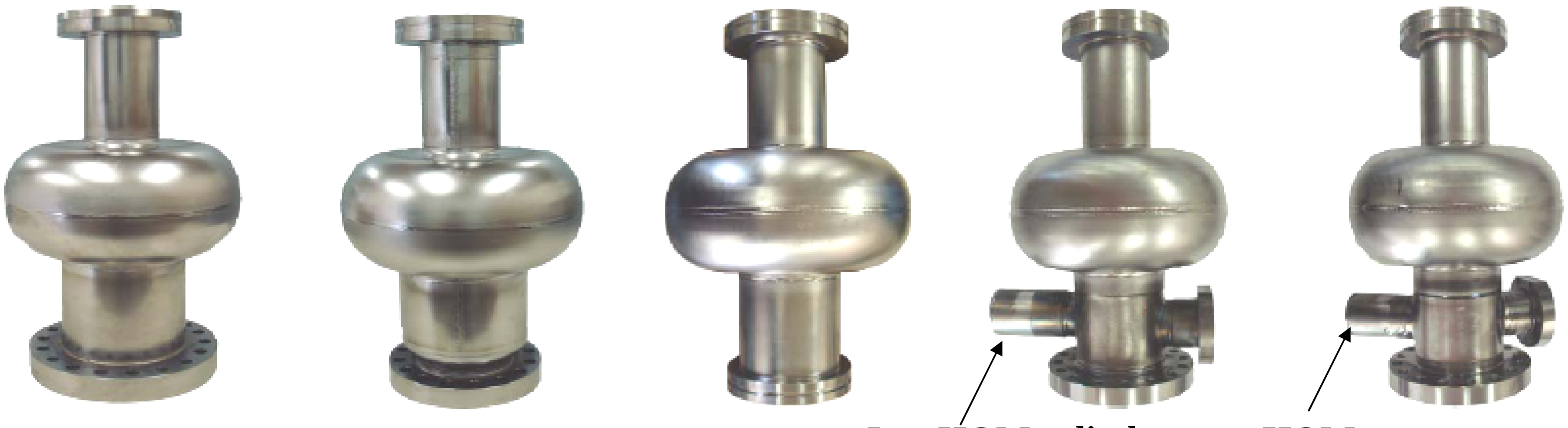
Now magnetic field limits the H.G !

Study on END Group Effects

We have to understand why single-cell and multi-cells have such different result so far.

ISE#1 ISE#2 ISE#3 ISE#4 ISE#5

Ichiro Cavity END Cell **Redesigned END Cell**



Just HOM cylinder **HOM**

So far: 35MV/m 41MV/m 50MV/m 20MV/m 32MV/m

Theoretical limitation : ~ 40MV/m **Theoretical limitation ~ 45MV/m**

Summary

- Gradient scatter in 9-cell cavity is a most concerned issue for the ILC cavity specification.

- GED has set the S0/S1 task force in order to solve this problem by middle of 2009. It is well started in several institutes as international collaboration.

- Single cell study is getting hints to understand the mechanism of the scatter problem.

  Degreasing or Alcohol rinsing after EP gives a better performance but can not solve the scatter problem perfectly.

  Fresh EP could be an important process to fix the problem.

- New cavity shapes have made a remarkable break-through to push gradient since the SRF 2005. Now the gradient is closing to 60MV/m.