

# Cavity Gradient for the R&D and ILC Operation

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**ILC-GDE SCRF**

**Presented at the AD&I meeting held at DESY, Dec. 2-3, 2009**



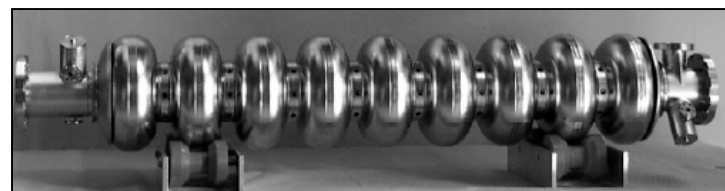
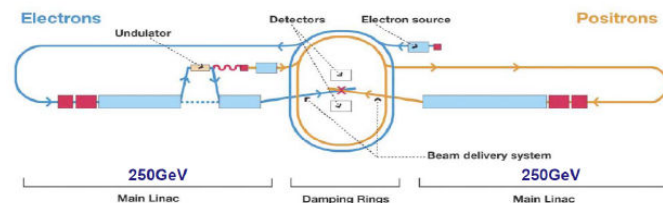
# Outline for Discussion

- What is the Operational Gradient assumed?
  - **S-ilc:  $<31.5 \text{ MV/m}>$  for  $\gg 1,000$  cryomodules**
- What are the R&D milestones?
  - **S0: 35 MV/m for 9-cell cavity in vertical test,**
  - **S1:  $<31.5 \text{ MV/m}>$  for cryomodules without beam acceleration,**
  - **S2:  $<31.5 \text{ MV/m}>$  for cryomodule for beam acceleration**
- Where we are?
  - **R&D milestone (S1) and the ILC operation (S-ilc) are the same,**
  - **Is it reasonable to prepare for the project phase after TDP2?**
- How we shall re-evaluate it and re-optimize it, by when?
  - **It is to be discussed, here.**



# SCRF Technology Required

Parameter	Value
C.M. Energy	500 GeV
Peak luminosity	$2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
<b>Av. field gradient</b>	<b>31.5 MV/m</b>
<b># 9-cell cavity</b>	<b>14,560</b>
<b># cryomodule</b>	<b>1,680</b>
<b># RF units</b>	<b>560</b>





# Global Plan for SCRF R&D

Year	07	2008	2009	2010	2011	2012
Phase	TDP-1			TDP-2		
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%			→ Yield 90%		
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration			FLASH (DESY) , NML (FNAL) STF2 (KEK, extend beyond 2012)			
Preparation for Industrialization				Production Technology R&D		

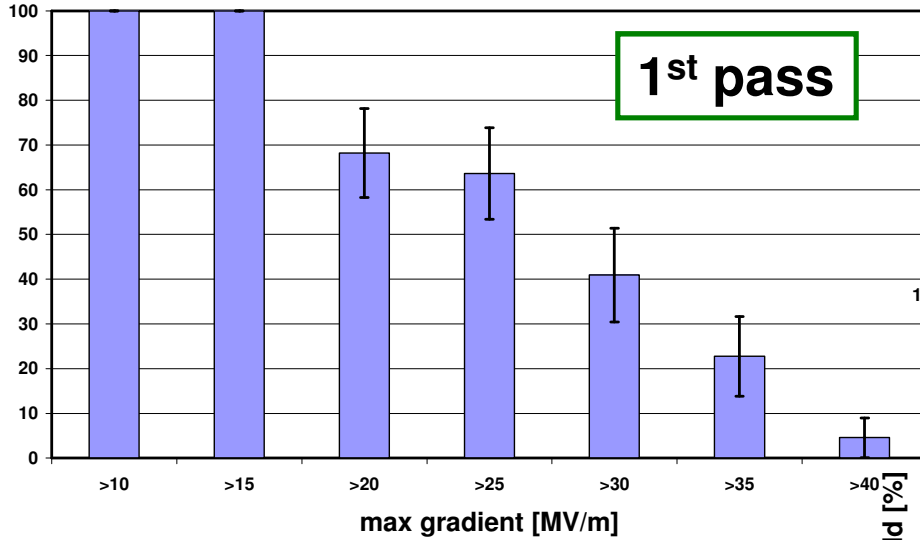


# New Production Yield

## after 1<sup>st</sup> and 2<sup>nd</sup> Pass (RF) Test

### Electropolished 9-cell cavities

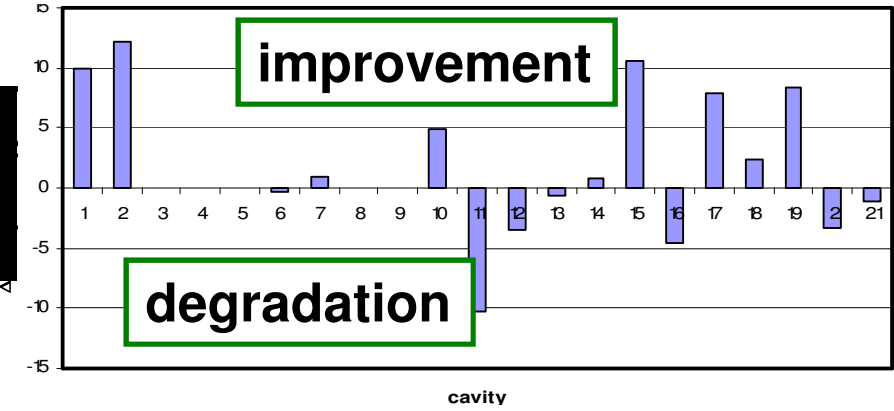
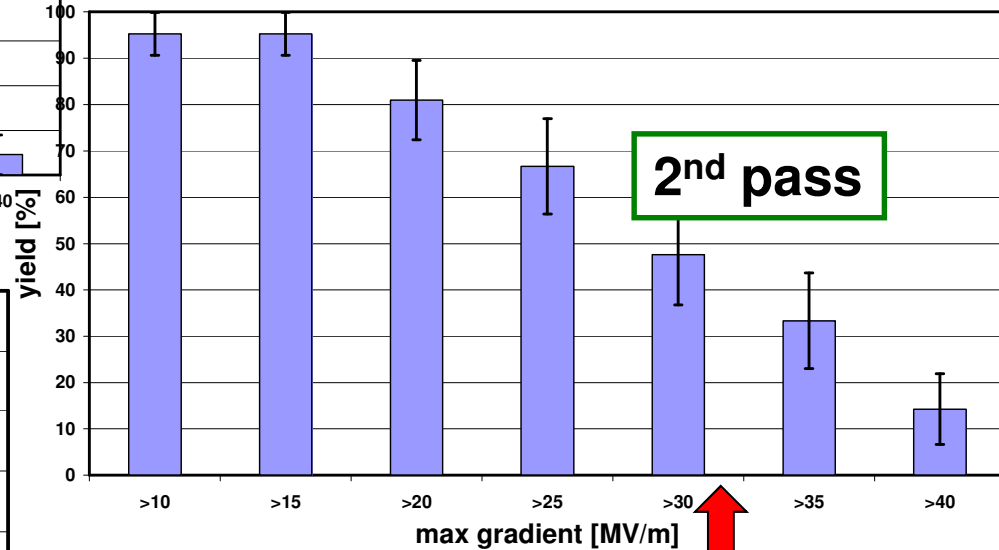
JLab/DESY (combined) first successful test of cavities from qualified vendors - ACCEL+ZANON (22 cavities)



Yield at 35 MV/m:  
 22 % at 1<sup>st</sup> pass  
 33 % at up to 2<sup>nd</sup> pass

### Electropolished 9-cell Cavities

combined upto-second-pass test of cavities from qualified vendors - ACCEL+ZANON (21 cavities)



ILC Operation at <31.5 MV/m>  
 Yield reaching ~ 40 %

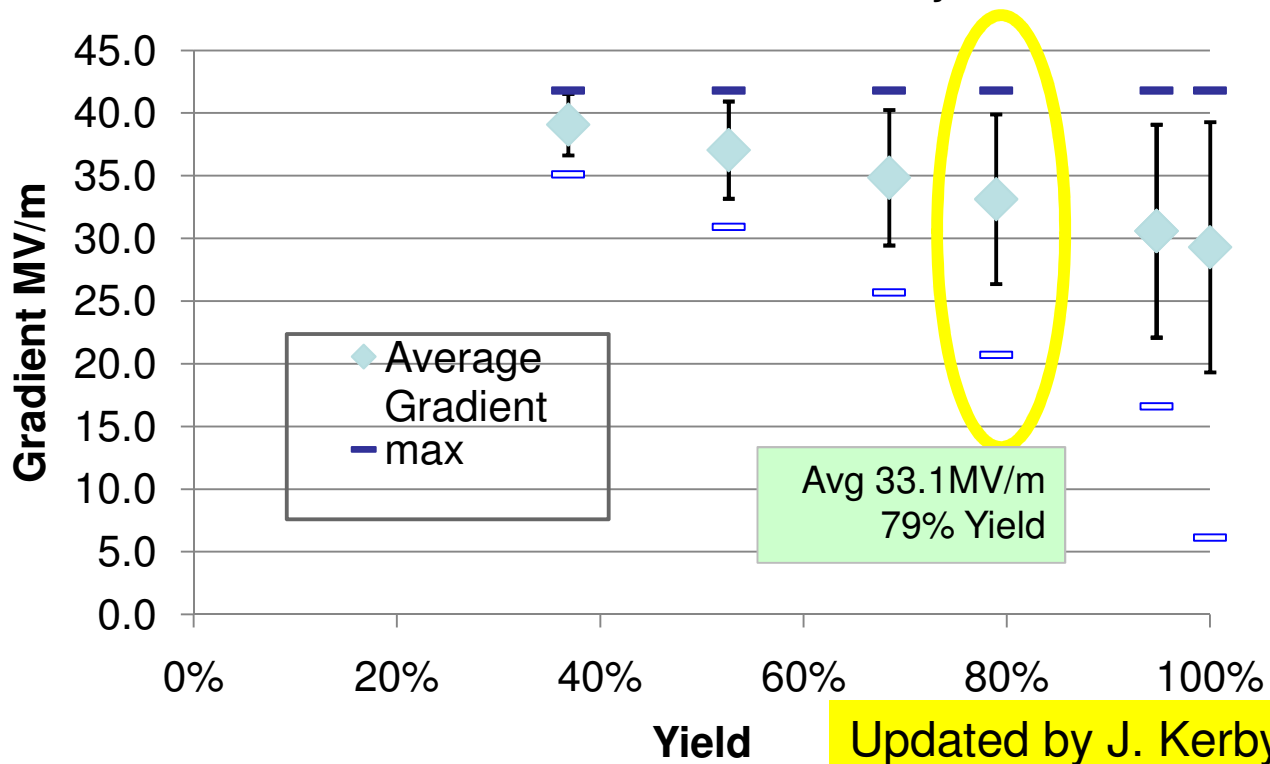
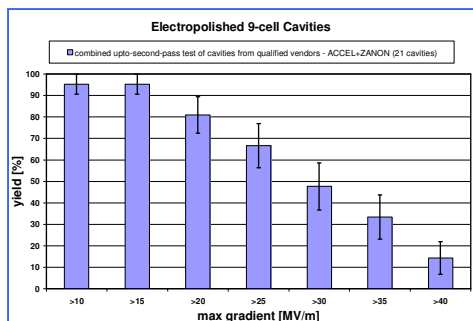
Reported by C. Ginsburg and GDB team



# Alternate Yield Plot

July 2009 Data

1st +2nd Pass, 1st pass cut 35MV/m, Accel or Zanon  
Alternative Yield Analysis



Updated by J. Kerby

Yield is estimated assuming a specific lower cut-off in cavity performance, below which cavities are assumed 'rejected'.  
 Error bar is +/- one RMS value (standard deviation of the population) of the remaining (accepted) cavities (gradient above cut-off).  
 Additional bars (min, max) indicated the minimum and maximum gradients in the remaining (accepted) cavities.



# Progress and Prospect of Cavity Gradient Yield Statistics

	<b>PAC-09 Last/Best 2009-05</b>	<b>FALC 1<sup>st</sup> Pass 2009-07</b>	<b>ALCPG 2nd Pass 2009-10</b>	<b>To be added (2009-11)</b>	<b>Coming Prod. Y. (2010-06)</b>	<b>Research cavities</b>
DESY	9 (AC) 16 (ZA)	8 (AC) 7 (ZA)	14 (AC/ZA)	10 (Prod- 4)	5	8 (large G.)
JLAB FNAL/A NL/Corn ell	8 (AC) 4 (AE) 1 (KE-LL5) 1 (JL-2)	7 (AC)	7 (AC)	~ 5 (AE)	12 (AC) 6 (AE)	6 (NW)  (including large-G)
KEK/IH EP				5 (MH)	2 (MH)	~5 (LL) 1 (IHEP)
Sum	39	22	21	20	25	~ <b>20</b>
G-Sum				41	66	

Statistics for Production Yield in Progress to reach > 60, within TDP-1.  
We may need to have separate statistics for 'production' and for 'research',



# A Proposal for Re-baseline Cavity Gradient and Yield, in TDP-2

- Cryomodule field gradient of **<31.5 MV/m>** (@  $Q_0 = 1E10$ )
  - Keep it, as the ‘**averaged field gradient**’ with cryomodule string, as a R&D milestone, and
  - **Accept the gradient distribution** of ( $\sim 20\%$  **(b/w 25 – 38 MV/m)** in operation (exact number needs to be further studied)
    - See the recent progress at DESY PXFEL cryomodule test result
- Cavity gradient of **35 MV/m** (@  $Q_0 = 8E9$ ) in vert. test
  - keep our R&D goal of the yield of **90%** at 35 MV/m, as R&D target,
  - **Recognize that the yield** may be acceptable to be  $\sim 50\%$  with the **+/-20% distribution (i. e., b/w 28 and 42 MV/m) of the gradient.**





# XFEL Prototype achieve $< 32 \text{ MV/m} >$ , and FLASH operation to be at $< 30 \text{ MV/m} >$

## Around the World

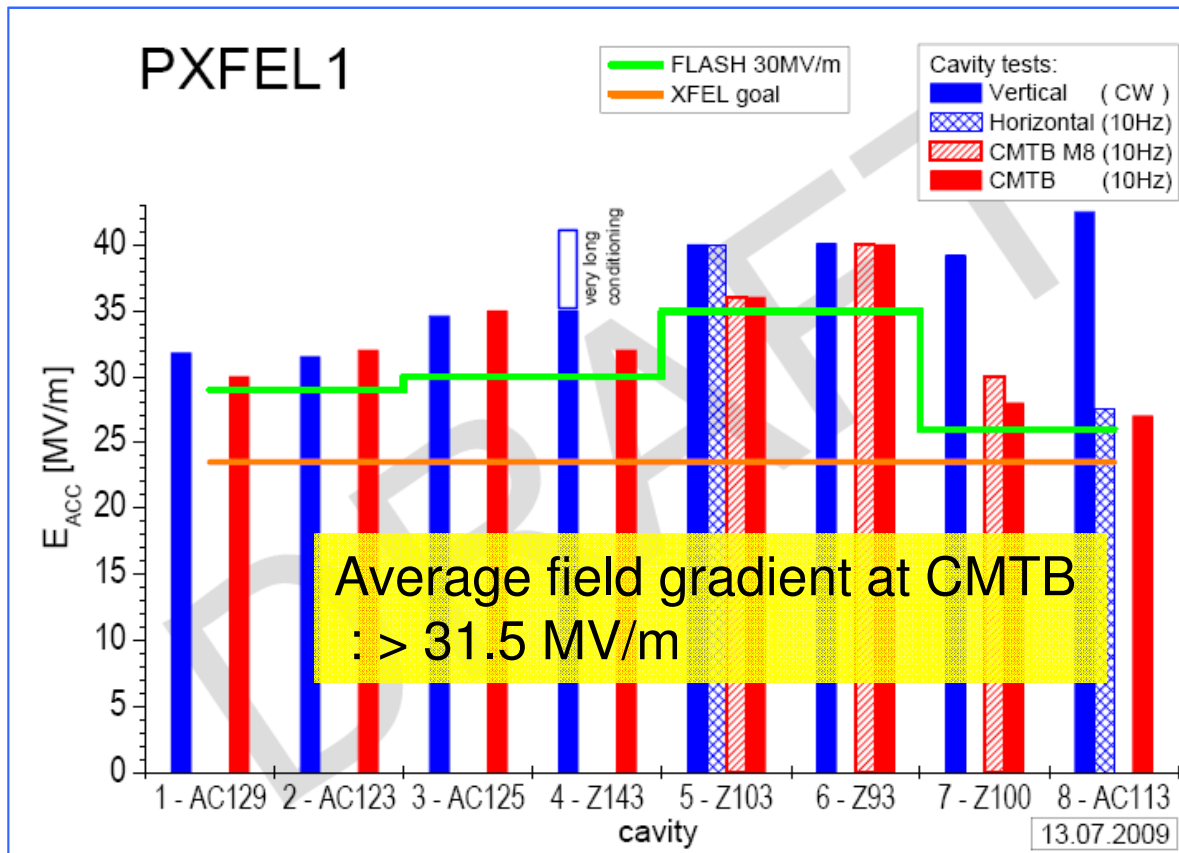
### Cryomodule surpasses ILC gradient test

European-XFEL cryomodule using SCRF technology sets new record



The cryomodule that set the world gradient record in the testbench at DESY

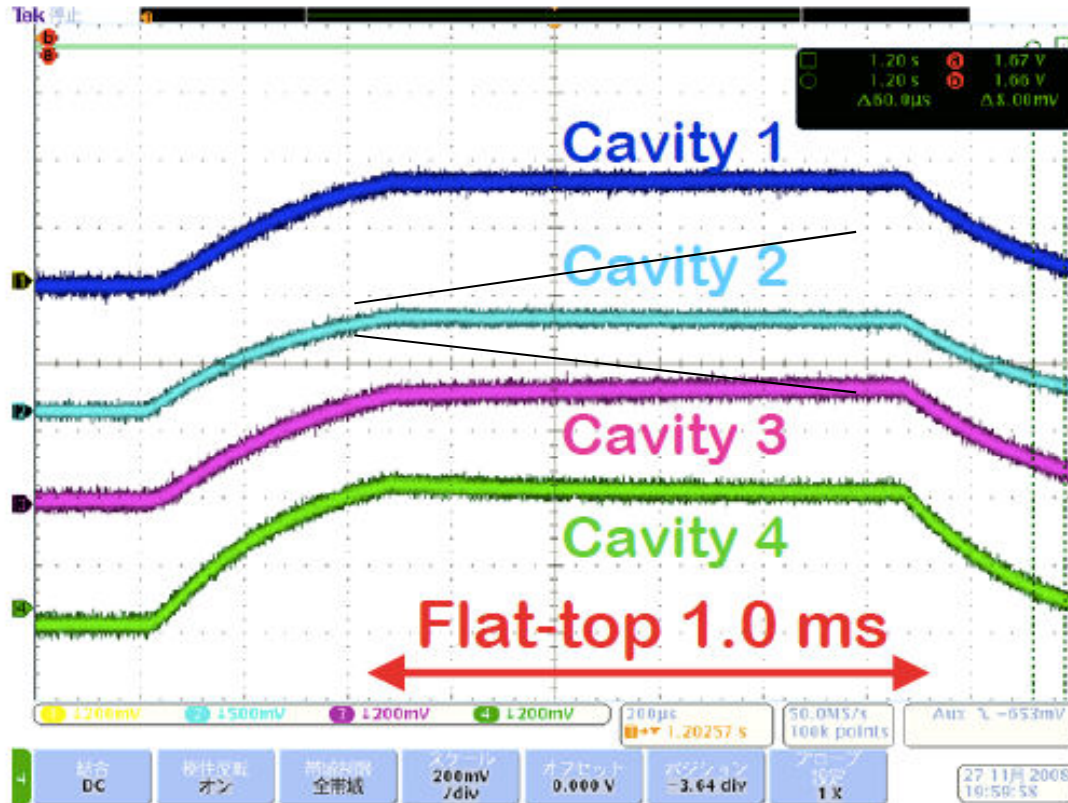
A cryomodule prototype for the European XFEL has set the world gradient record for cryomodules built with superconducting radiofrequency technology, reaching an average accelerating gradient of more than 32



We would respect the XFEL progress and Further Practical Plan

- First XFEL prototype module exceeds 31.5 MV/m average
- Module will see beam in FLASH in 2010 (av. of 30MV/m)
- Cryostat (cryomodule cold-mass) contributed by IHEP

# How we need to include dynamic operation margin to the cavity operation itself?



- We need to keep some tunability and dynamic operational margin in order to keep reasonably high availability



# Milestones for the SCRF R&D Program

(see: TDP R&D plan, V. 4, July 2009).

## R&D Goals in TD Phase 1 and 2 (given in TDP R&D plan)

9-cell cavity performance at 35 MV/m according to the specified chemical process with a process yield of 50% in TDP1, and with a production yield of 90% in TDP2 (S0)	2010
	2012

Cavity-string performance in one cryomodule with the average gradient 31.5 MV based on a global effort (S1 and S1-global)	2010
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Cryomodule-string performance achieving the average gradient 31.5 MV/m with full-beam loading and handling (S2)	2012
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## Operational Gradient for the ILC ML, in the Project Phase (added to be discussed)

(> 1,000) Cryomodule-string performance to be stably operated with sufficiently high availability, including dynamic tuning and operational margin and with sufficient redundancy, Operational gradient to be ?? (S3?)	To be discussed
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**Question: (S3?, can it be the same as S1 and S2?)**



# Summary and Proposal

- **Cavity R&D goals** to be unchanged:
  - **35 MV/m at  $Q_0 > 8 \times 10^9$ , (S0)**
    - at 9-cell cavity vertical test
    - With the process/production yield 50/90 % in TDP-1/-2, even though we may practically accept spread of gradient with a level of  $\sim 20$  %,
  - **31.5 MV/m, in average, at  $Q_0 > 1 \times 10^{10}$ , (S1, S2)**
    - at Cavity string in cryomodule , w/o beam (S1) and w/ beam acc. (S2)
- **ILC Operational gradient** (S-ilc) to be re-evaluated,
  - **Key Point:  $S_0 > S_1 \geq S_2 \geq S\text{-ilc} \text{ ??}$** 
    - **Absolute** values from R&D, and wait for the progress by 2012,
    - **Relative** difference to be determined with system design, and it should be determined soon,
    - Operational margin for sufficiently **high availability** for  $> 1000$  cryomodule string including tunability and dynamic margin for cavity, input-coupler, tuner, cryogenic system (pressure) variation,



backup





# MTBF List for Improvements

reported by J. Carwardine

**RDR**

## Needed ILC MTBF Improvements

Device	Needed Improvement factor	Downtime (%) due to these devices	Nominal MTBF (hours)	Nominal MTTR (hours)
power supplies	20	0.2	50,000	2
power supply controllers	10	0.6	100,000	1
flow switches	10	0.5	250,000	1
water instrumentation near pump	10	0.2	30,000	2
magnets - water cooled	6	0.4	3,000,000	8
kicker pulser	5	0.3	100,000	2
coupler interlock sensors	5	0.2	1,000,000	1
collimators and beam stoppers	5	0.3	100,000	8
all electronics modules	3	1.0	100,000	1
AC breakers < 500 kW		0.8	360,000	2
vacuum valve controllers		1.1	190,000	2
regional MPS system		1.1	5,000	1
power supply - corrector		0.9	400,000	1
vacuum valves		0.8	1,000,000	4
water pumps		0.4	120,000	4
modulator		0.4	50,000	4
klystron - linac		0.8	40,000	8
coupler interlock electronics			100,000	1
vacuum pumps			100,000	4
controls backbone			100,000	1

*Have these higher numbers already been achieved?*

Tom Hime

AD&I Meeting at DESY, 2-3 Dec 09: Estimating MTBFs (Carwardine)

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- Cavity itself? Assuming availability 100 %?



# Again from J. Cardwardine' report

For SB2009: consider five categories of equipment...

- **Technical systems with large operating base**
  - Magnets, power supplies, controls,...
  - Sufficient data for making reasonable reliability (in many cases)

Accelerators
- **Technical systems with little or no operating base**
  - Newly developed parts, challenging specs
  - Insufficient data for estimating MTBF

Hmm...
- **'Standard' accelerator components**
  - COTS parts
  - Vacuum pumps, flow switches, ...

Accelerators  
+ industry
- **Industrial equipment with extensive installed base**
  - Eg, electrical utilities
  - Published data is available on in-service failure rates

Industry
- **Commodity equipment**
  - Eg controls backbone network, computing infrastructure
  - We buy the quality of service we want (or can afford)

Industry

AD&I Meeting at DESY, 2-3 Dec 09: Estimating MTBFs (Carwardine)

- **Cavity: Is it listed as “which category?”**



# Standard Process Selected for Further Yield Plot

	<b>Standard Cavity Recipe</b>
<b>Fabrication</b>	<b>Nb-sheet (Fine Grain)</b>
	<b>Component preparation</b>
	<b>Cavity assembly w/ EBW (w/ experienced vendors)</b>
<b>Process</b>	<b>1st Electro-polishing (~150um)</b>
	<b>Ultrasonic degreasing with detergent, or ethanol rinse</b>
	<b>High-pressure pure-water rinsing</b>
	<b>Hydrogen degassing at &gt; 600 C</b>
	<b>Field flatness tuning</b>
	<b>2nd Electro-polishing (~20um)</b>
	<b>Ultrasonic degreasing or ethanol</b>
	<b>High-pressure pure-water rinsing</b>
	<b>Antenna Assembly</b>
	<b>Baking at 120 C</b>
<b>Cold Test (vert. test)</b>	<b>Performance Test with temperature and mode measurement (1<sup>st</sup> / 2<sup>nd</sup> successful RF Test)</b>





# Cavity Gradient Study - Summary

- Yield at 35 MV/m (w/ established vendors: **RI, Zanon**)
  - **22 % at 1<sup>st</sup> pass (statistics 22)**
  - **33 % at 2<sup>nd</sup> pass (statistics 21, as of 2009-07)**
    - Average Gradient reaching 30 MV/m
  - DESY Prod-4 data to be added, (10 more statistics)
- New statistics coming (w/ potential vendors)
  - **AES: to be counted from #5** (to be confirmed)
  - **MHI: to be counted from #5** (to be confirmed)
- Selecting statistics needed for ‘Production Yield’
  - **to evaluate readiness of industrialization and cost**

**Note:** *Numbers of Cavities for ‘gradient research’: need to be separately counted.*