Cavity Gradient for the R&D and ILC Operation

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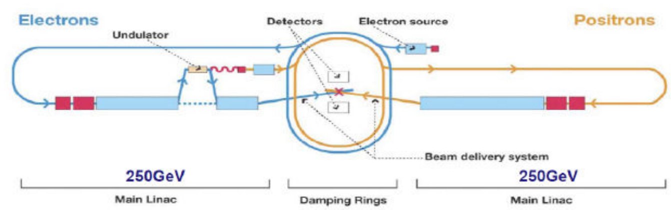
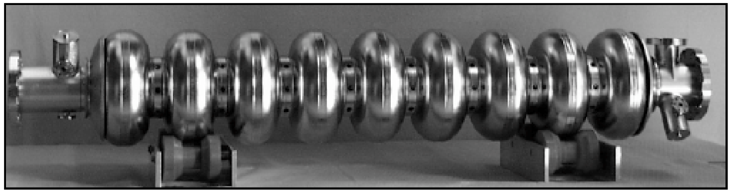
Outline for Discussion

- What is the Operational Gradient assumed?
  - **S-ilc: <31.5 MV/m> for >> 1,000 cryomodules**
- What are the R&D milestone?
  - **S0: 35 MV/m for 9-cell cavity in vertical test,**
  - **S1: < 31.5 MV/m> for cryomodules without beam acceleration,**
  - **S2: <31.5 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	$2 \times 10^{34}\ cm^{-2}s^{-1}$
Beam Rep. rate	5 Hz
Pulse time duration	1 ms
Average beam current	9 mA (in pulse)
Av. field gradient	**31.5 MV/m**
# 9-cell cavity	**14,560**
# cryomodule	**1,680**
# RF units	**560**

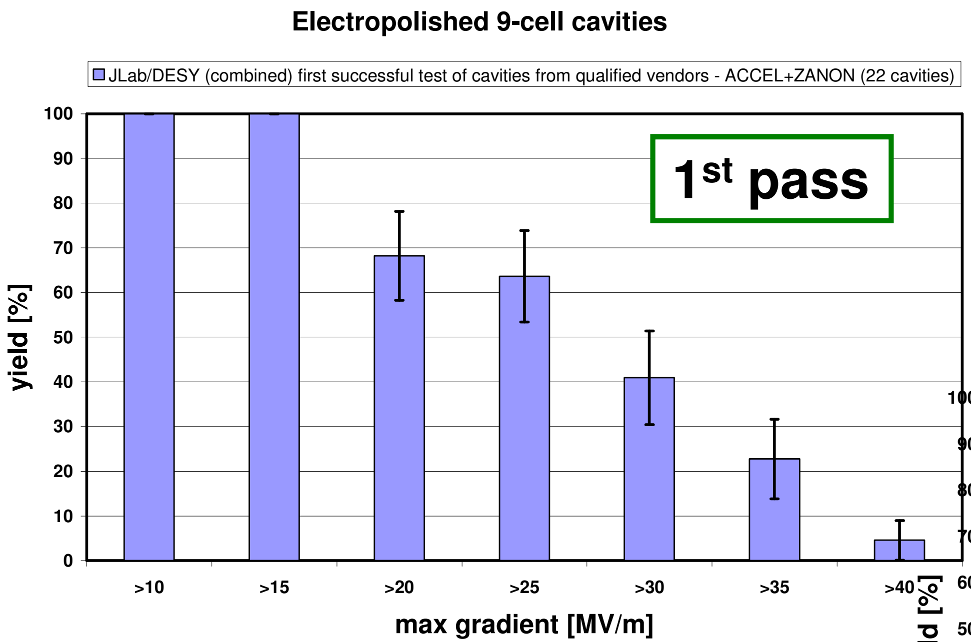




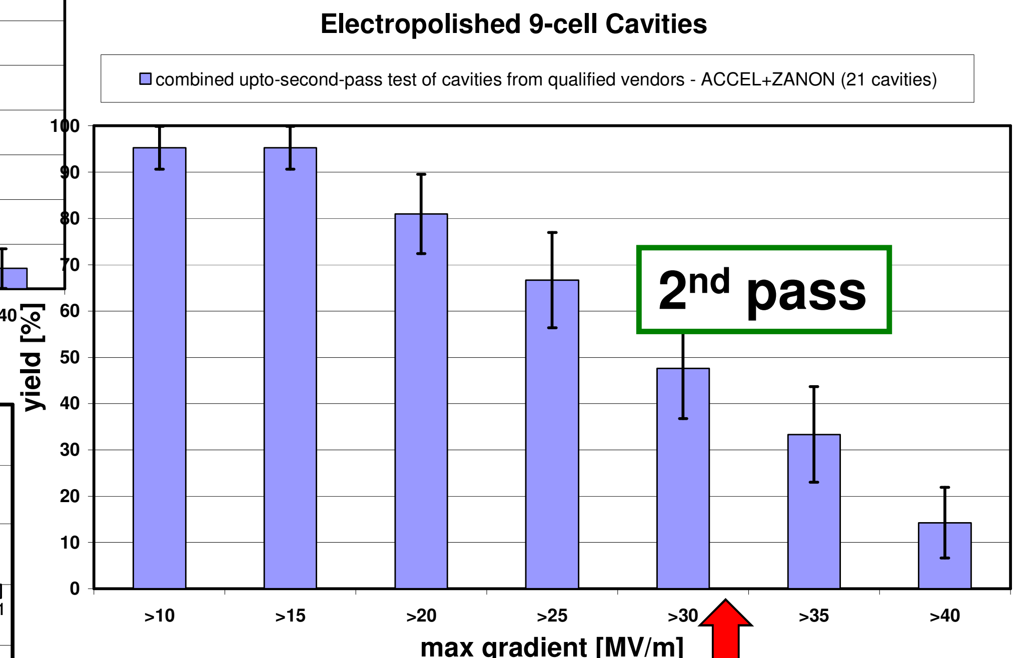
Global Plan for SCRF R&D

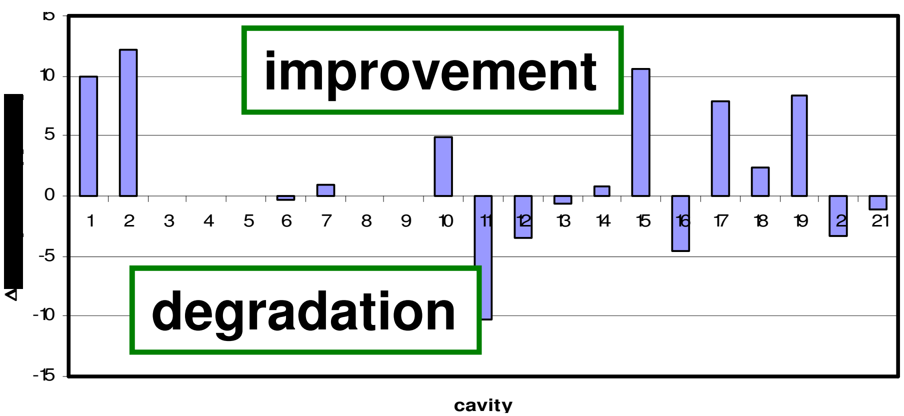
Year	07	2008	2009	2010	2011	2012
Phase	TDP-1			TDP-2		
Cavity Gradient in v. test to reach 35 MV/m	→ Yield 50%			→ Yield 90%		
Cavity-string to reach 31.5 MV/m, with one-cryomodule		Global effort for string assembly and test (DESY, FNAL, INFN, KEK)				
System Test with beam acceleration		FLASH (DESY)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

New Production Yield after 1st and 2nd Pass (RF) Test



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

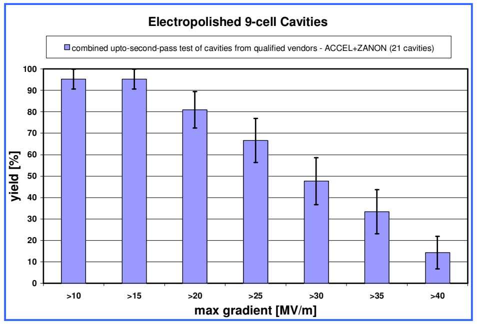


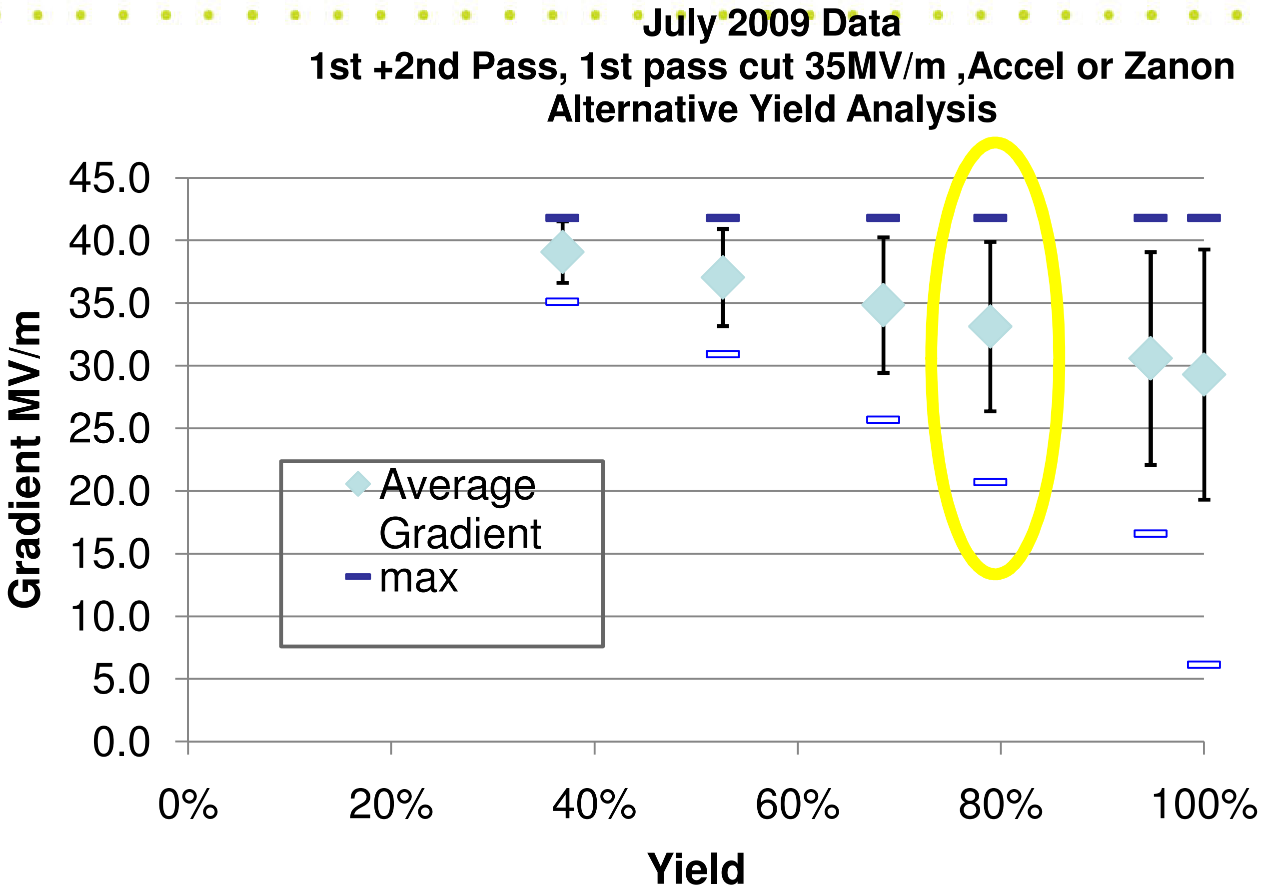


ILC Operation at <31.5 MV/m>
Yield reaching ~ 40 %

Reported by C. Ginsburg and GDB team

Alternate Yield Plot





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) inidcated the minimum and maximum gradients in the remaining (accepted) cavities.

Progress and Prospect of Cavity Gradient Yield Statistics

	PAC-09 Last/Best 2009-05	FALC 1st Pass 2009-07	ALCPG 2nd Pass 2009-10	To be added (2009-11)	Coming Prod. Y. (2010-06)	Research cavities
DESY	9 (AC) 16 (ZA)	8 (AC) 7 (ZA)	14 (AC/ZA)	10 (Prod-4)	5	8 (large G.)
JLAB FNAL/ANL/Cornell	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/IHEP				5 (MH)	2 (MH)	~5 (LL) 1 (IHEP)
Sum	39	22	21	20	25	~ **20**
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> (@ Q0 = 1E10)
  - **Keep it, as the 'averaged field gradient' with cryomodule string, as a R&D milestone, and**
  - **Accept the gradient distribution of (~ 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 (@ Q0 = 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 ~ 50 % with the +/-20 % distribution (i. e., b/w 28 and 42 MV/m) of the gradient.**

XFEL Prototype achieve < 32 MV/m>, and FLASH operation to be at <30 MV/m>

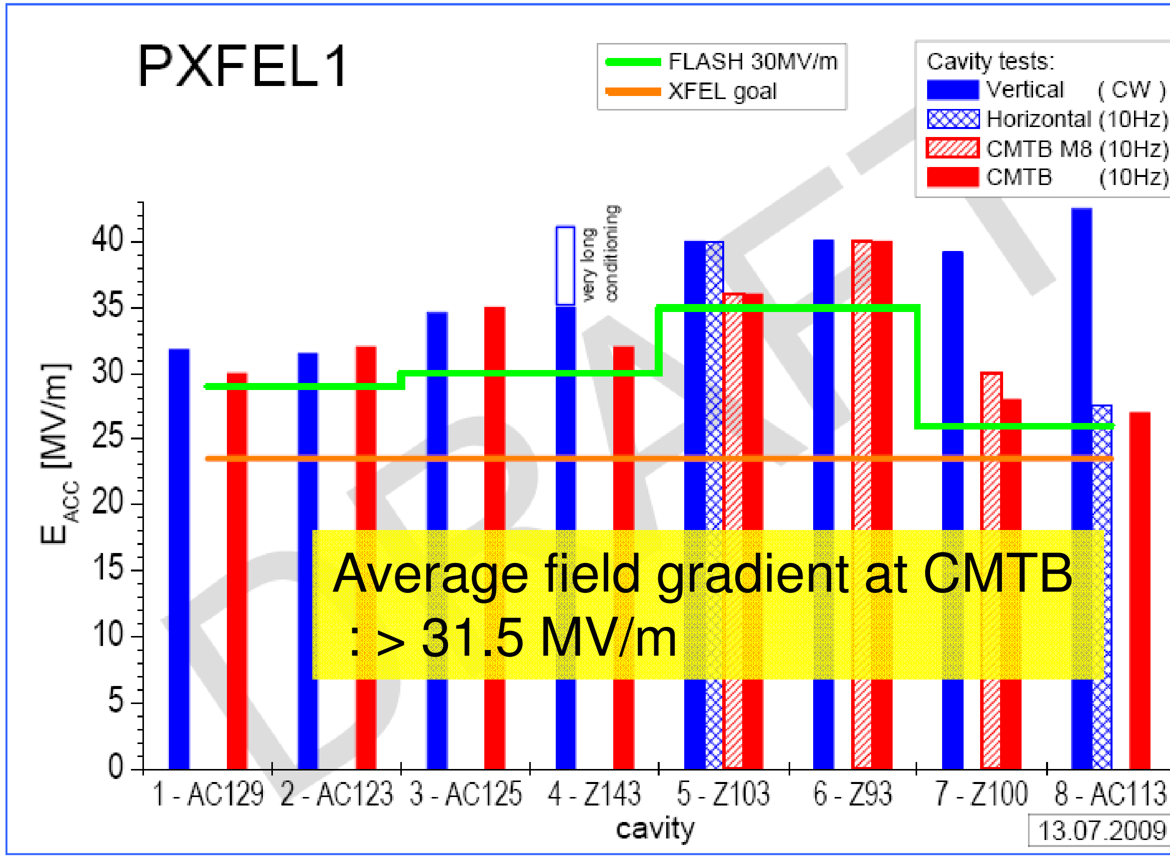
Around the World

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

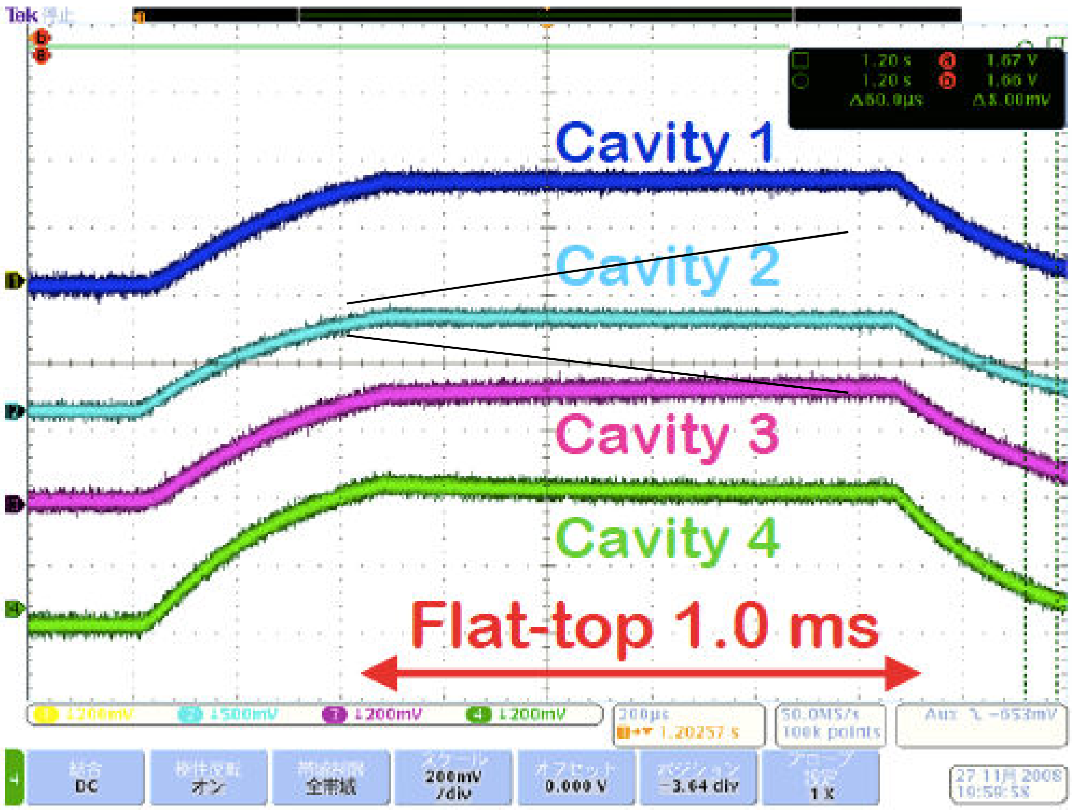
A cryomodule prototype for the European XFEL has set the world gradient record for cryomodules built with superconducting radiofrequency technology, reaching an average accelerating gradient of more than 32



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
Cryomodule-string performance achieving the average gradient 31.5 MV/m with full-beam loading and handling (S2)	2012
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

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 Q0 > 8x10E9, (S0)**
    - at 9-cell cavity vertical test
    - With the production yield 50 / 90 % in TDP1 /-2, even though we may practically accept spread of gradient with a level of ~ 20 %,
  - **31.5 MV/m, in average, at Q0 > 1 x 10E10, (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: S0 > S1 >= S2 >= S-ilc ??**
    - 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 instrumention 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		[illegible]	[illegible]00	1
vacuum pumps		[illegible]	[illegible]00	4
controls backbone		[illegible]	[illegible]00	1

Have these higher numbers already been achieved?

Tom Himel

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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** — Accelerators
  - Magnets, power supplies, controls,...
  - Sufficient data for making reasonable reliability (in many cases)
- **Technical systems with little or no operating base** — Hmm...
  - Newly developed parts, challenging specs
  - Insufficient data for estimating MTBF
- **'Standard' accelerator components** — Accelerators + industry
  - COTS parts
  - Vacuum pumps, flow switches, ...
- **Industrial equipment with extensive installed base** — Industry
  - Eg, electrical utilities
  - Published data is available on in-service failure rates
- **Commodity equipment** — Industry
  - Eg controls backbone network, computing infrastructure
  - We buy the quality of service we want (or can afford)

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

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

Cavity Gradient Study - Summary

- Yield at 35 MV/m (w/ established vendors: **RI, Zanon**)
  - **22 % at 1st pass (statistics 22)**
  - **33 % at 2nd 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.*