CKM

Superconducting RF Cavity Development

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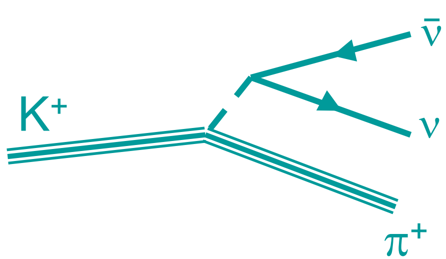
CP Violation and $K^+ \rightarrow \pi^+\nu\bar{\nu}$

Charge-Parity violation is surely one of the most peculiar aspects of weak decay physics

In the Standard Model, the CKM matrix creates CPV, but:

1. Precise values of the matrix element are not known
2. Many existing constraints have large, hard-to-quantify systematic uncertainties

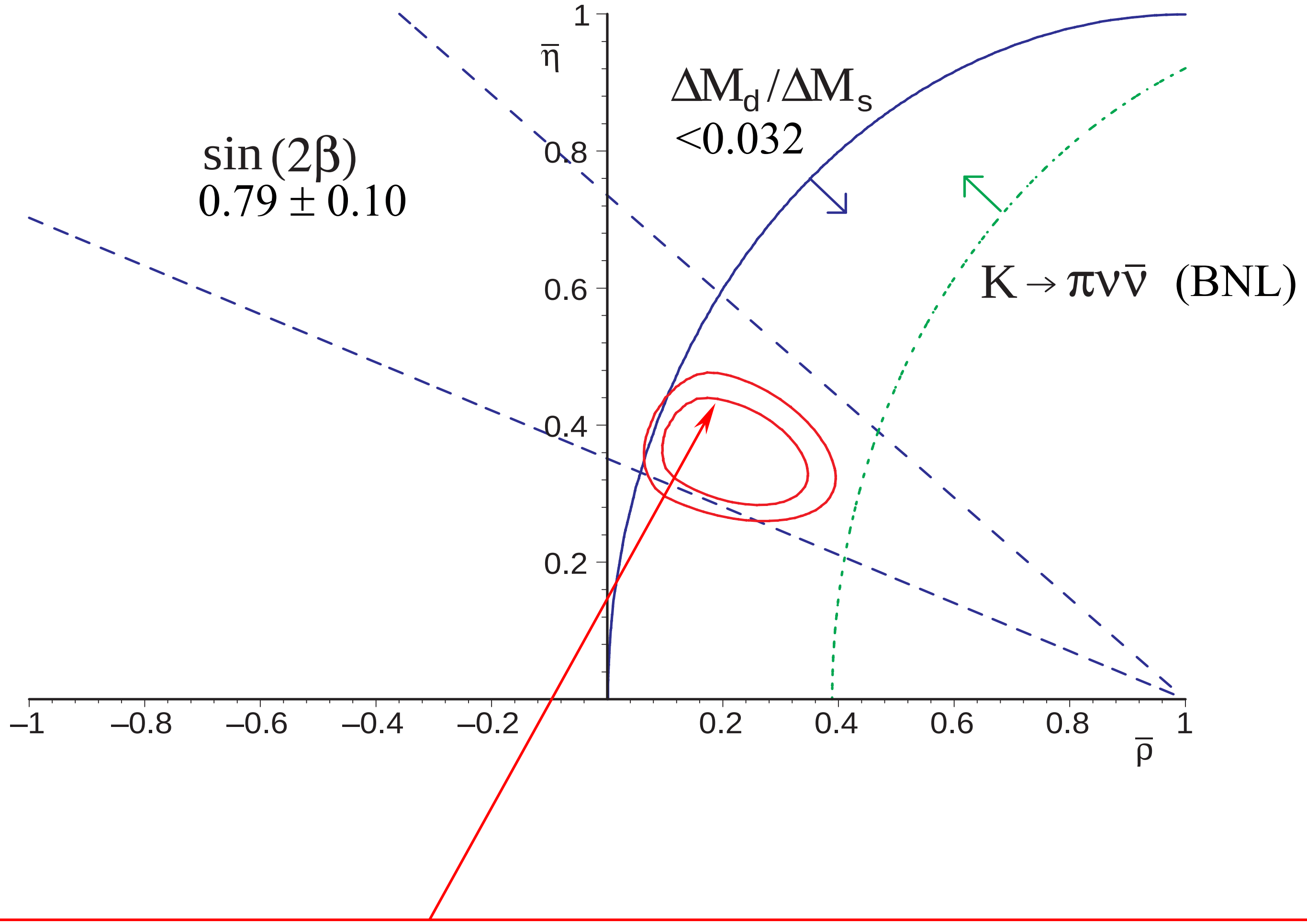


A ~10% measurement of $\mathcal{B}r(K^+ \rightarrow \pi^+\nu\nu)$ will give a reliable constraint that may be used to unambiguously validate the CKM assumption – and may possibly signal new physics.

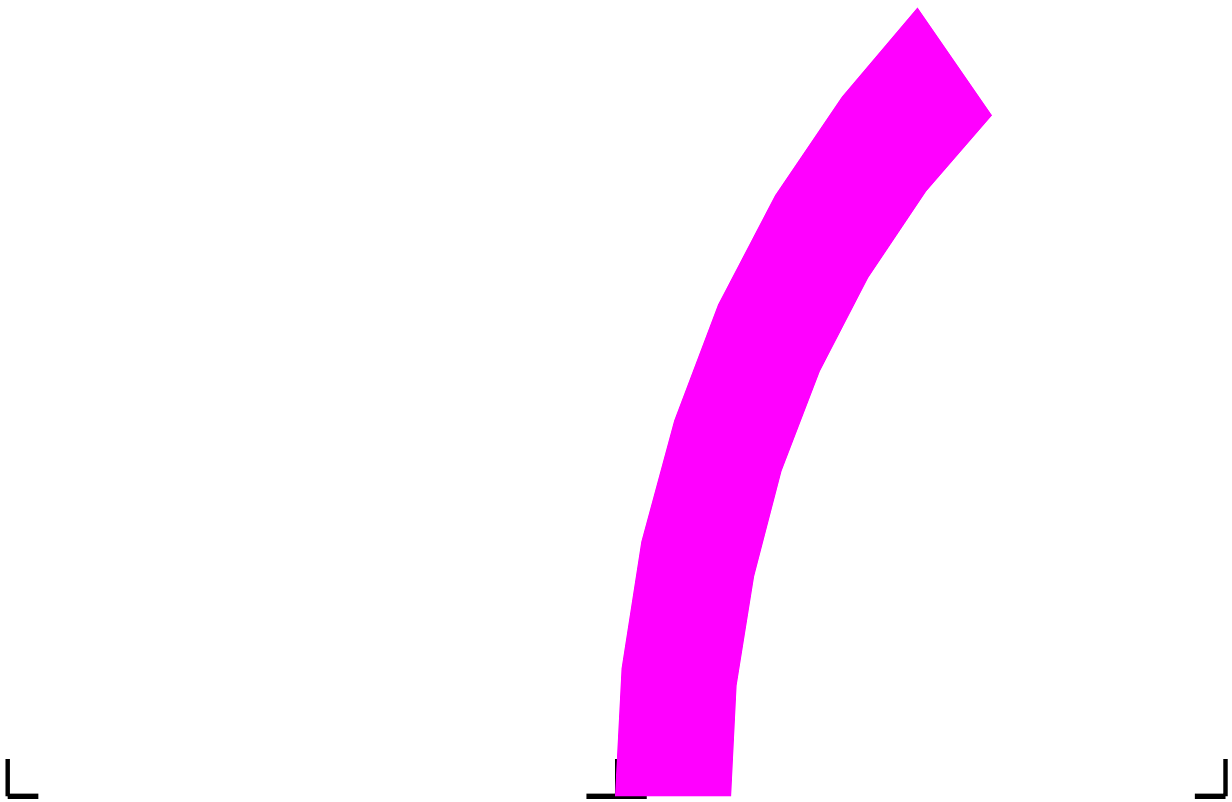
- Because of low $\mathcal{B}r$ (~7 x 10^{-10} in SM) and detection hurdles, need ~ 4 x 10^{14} K^+ data sample

- This data sample can be created with the FNAL Main Injector, superconducting RF technology, and the RF separation method of Panofsky and Schnell

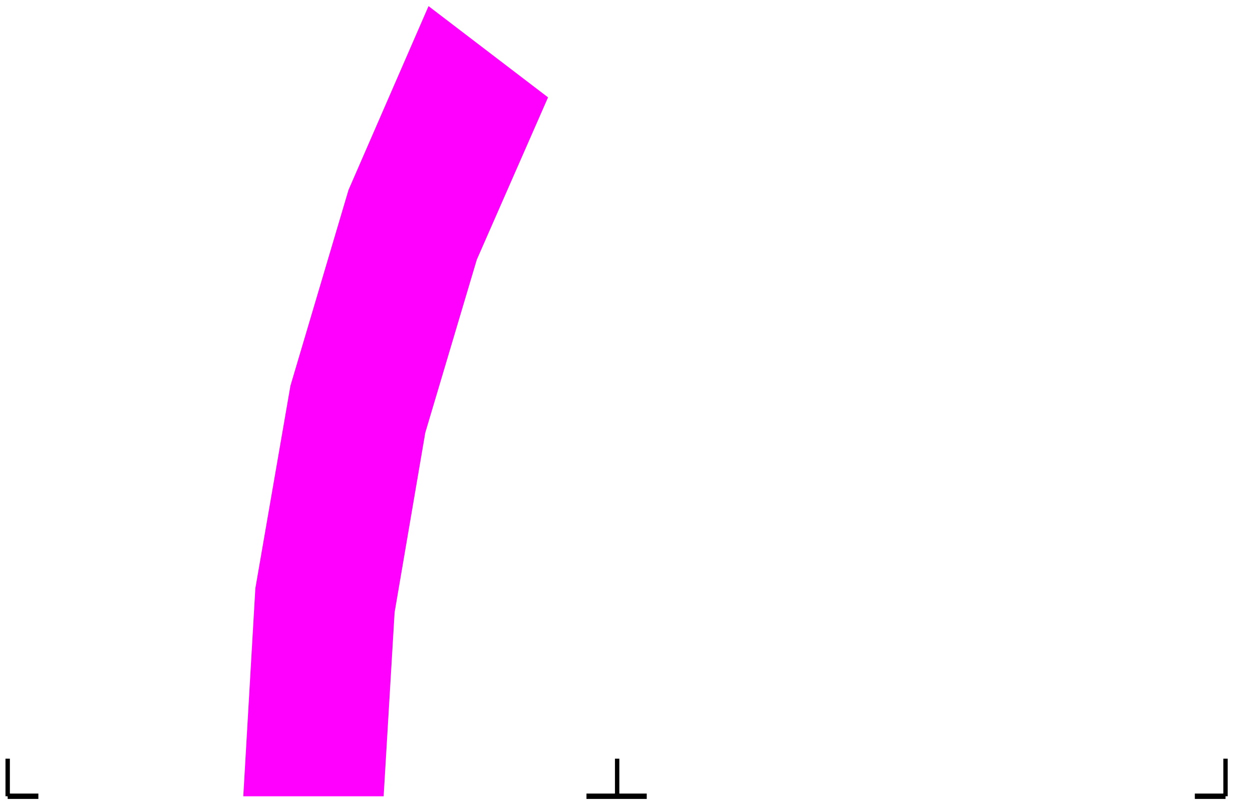
CP Violation and $K^+ \to \pi^+ \nu \nu$



From fit by D'Ambrosio and Isidore, PL B530 (2002) 108 using above constraints, $|V_{ub} / V_{cb}|$, ε_K, and $\Delta m(B_d)$

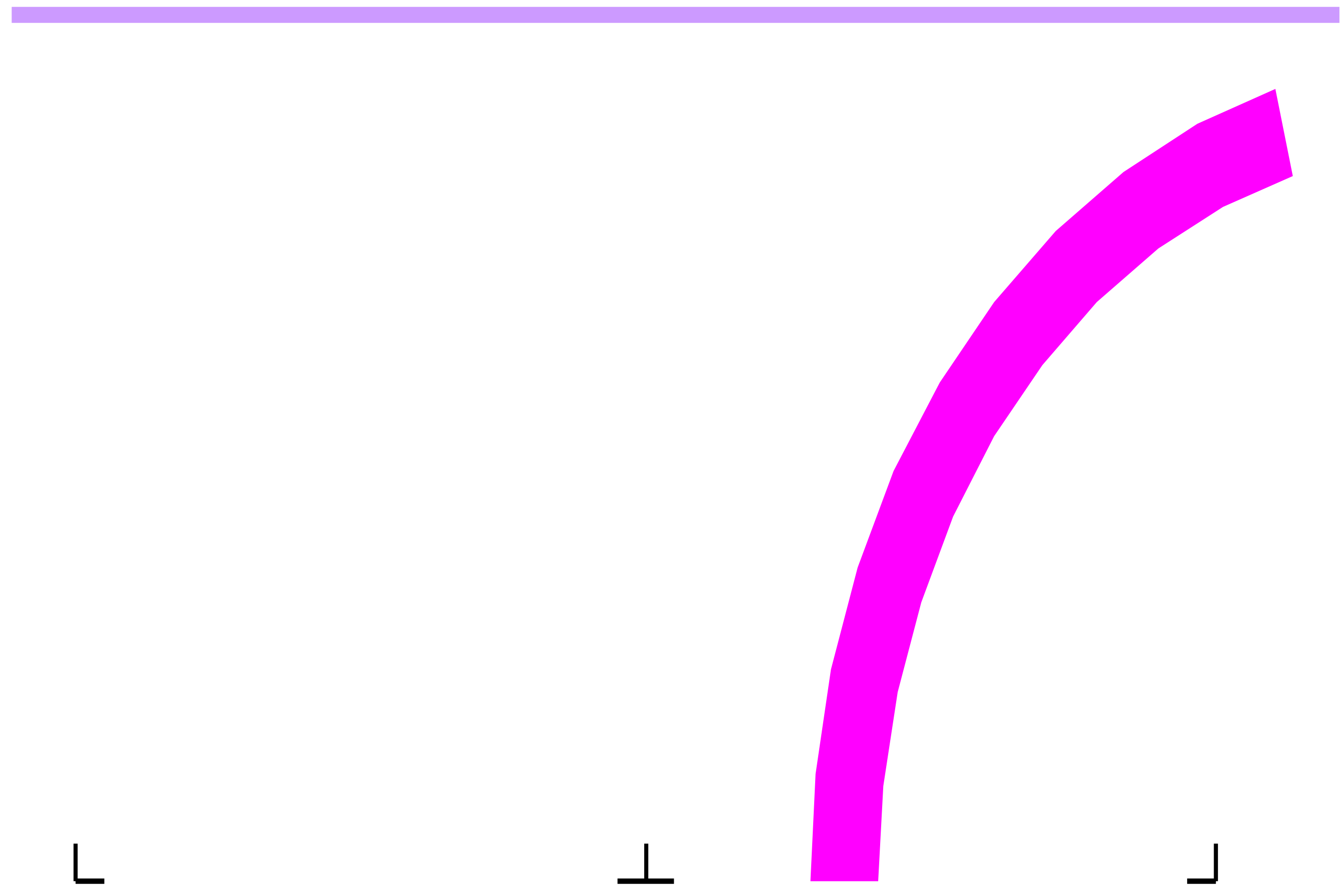


The CKM result in the event of no new physics



In SUSY, branching ratio could be up to 210% (conceivably, much more) of the Standard Model value, leading to the above CKM result

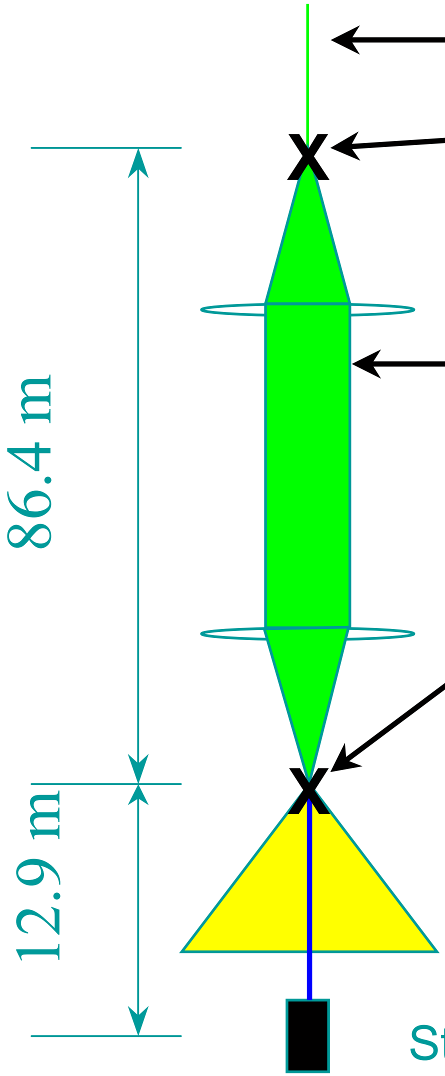
Buras,Colangelo,Isidori,Romanino,Silvestrini
Nucl.Phys B566(2000)3.



In MSSM, branching ratio could be between 65 to 102% the Standard Model value, leading to the above CKM result

Buras,Gambino,Gorban,Jager,Silvestrini
Nucl.Phys B592(2001)55.

RF separated K^+ beam



Initial momentum-selected beam (π^+, p, K^+) $\Delta P/P \sim 2\%$

RF deflection: $A \sin(\omega t)$

Transport until $L/\beta_\pi c$ - $L/\beta_p c = 1/f$

Pions then arrive one cycle before protons

2nd RF deflection *e.g.* 180º out of phase: $-A\sin(\omega t+\omega\Delta t)$

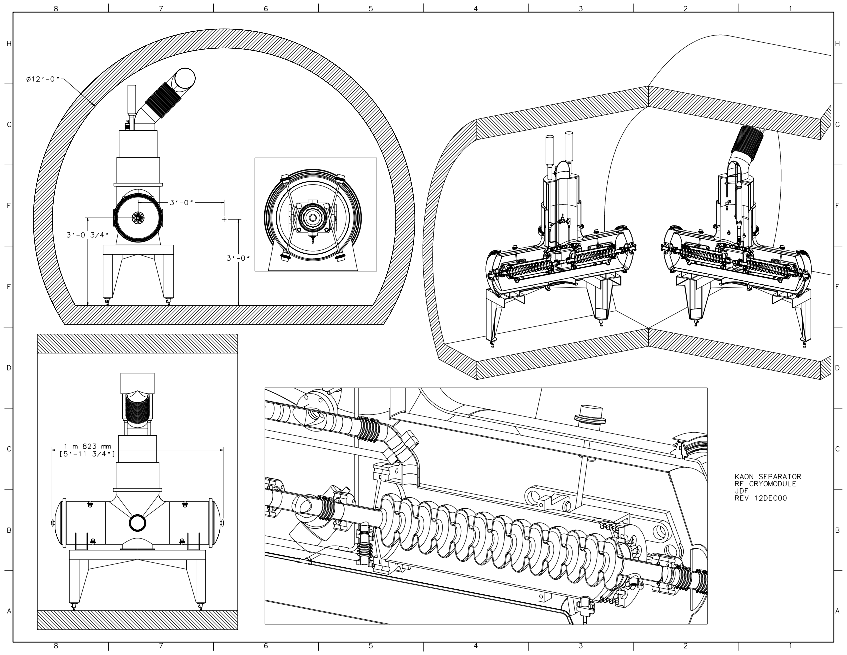
For π^+, no net deflection

For K^+, deflection is

$2A \sin(\pi n \beta_\pi/\beta_K) \bullet \cos(wt+ \pi n \beta_\pi/\beta_K)$

Stop π^+, p with beam plug, collect K^+

Baseline Design



2 stations each have 8 cavities ⇒ total 8 meters of deflection

- 3.9 GHz, TM_{110} π mode
- 5 MeV/m $P_{\perp}$ kick; 15 MeV/station

	B_{MAX}	E_{MAX}
5 MV/m TM_{110} 3.9 GHz	80 mT	18.5MV/m
25 MV/m TM_{010} 1.3 GHz	105 mT	50MV/m

We have been able to draw extensively upon recent advances in SC cavity technology at DESY, Cornell, and Jefferson Lab.

Technical Issues:

Basic RF design

Cavity shape optimal?	Well studied, thanks DESY
Sensitive to multipacting?	Neither seen nor expected
Effects of Lorentz pressures?	~500Hz, ms time frame

Manufactured Performance / QC

- Facilities and vendors
- Field strength tests
- Residual resistance tests

Piezoelectrics and fast frequency control

Cryovessel & Cryoplant Design

Manufactured Performance / QC

We purchase pure (RRR=300) Nb sheet from industry, and DESY has done eddy current scanning for us

Stamp and e-beam weld near FNAL under clean conditions

Field flatness tuning at FNAL

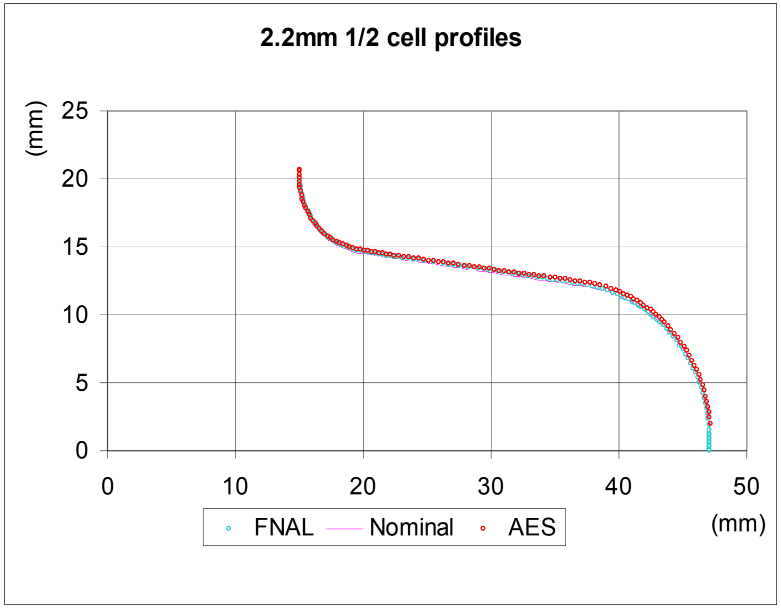
We have an on-site vacuum bake facility (1000 C) to remove H_2 and anneal - have not done Titanium gettering

BCP Acid etch has kindly been done for us by JLab, to be done in collaboration with Argonne

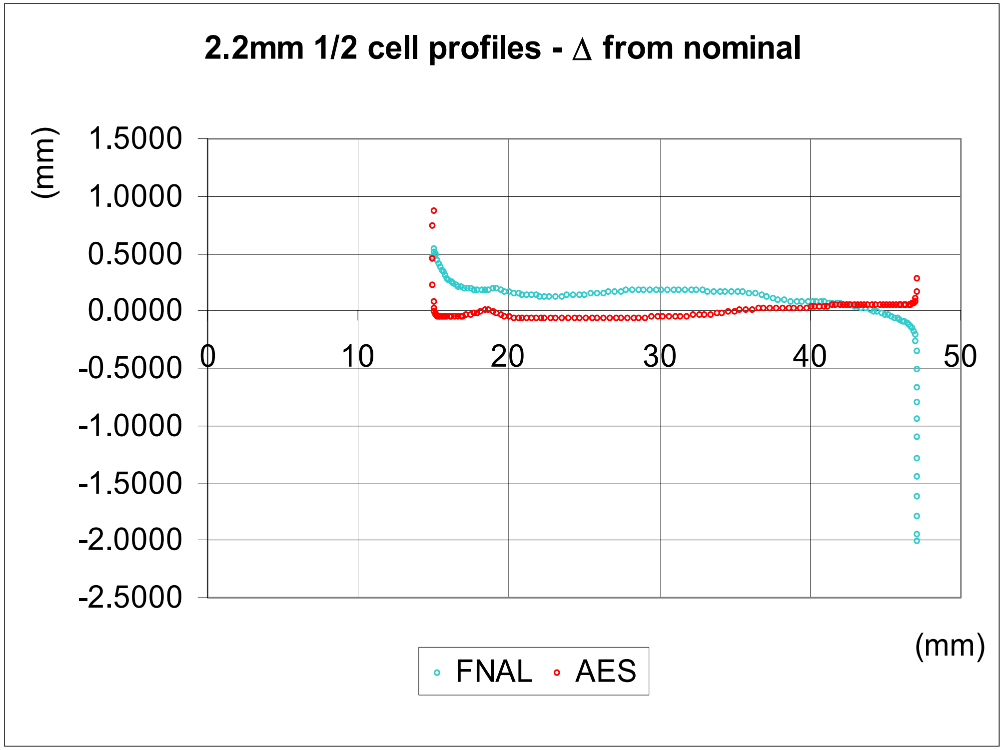
On-site high pressure rinse with 18MΩ H_20

We have made a total of 8 cavities which are mostly small structures, but one is a full 13 cell prototype

Manufactured Performance / QC



Also are contracting with Advanced Energy Systems to build a few cavities

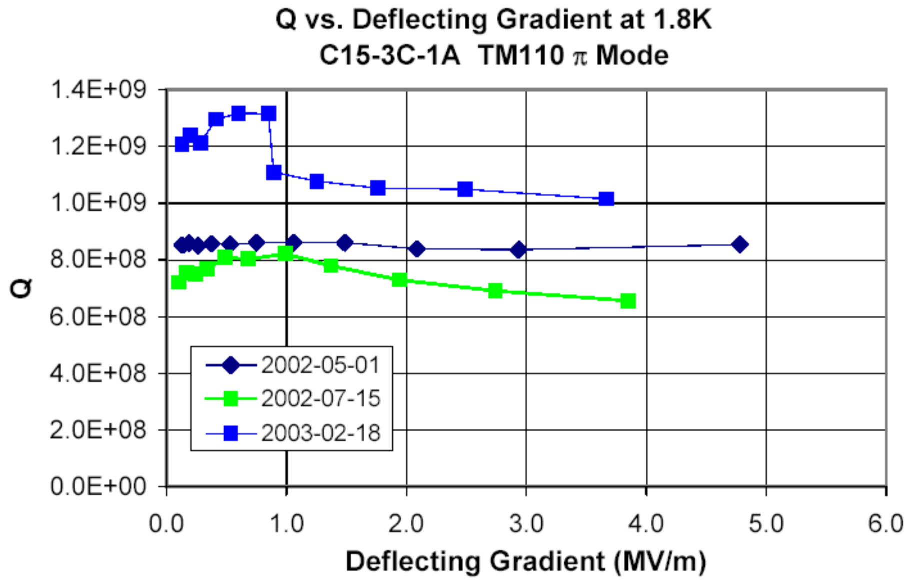


Initial profiles look very good, have not welded anything together yet.

Manufactured Performance / QC

Have field flatness to ~6% level while maintaining polarization to ~4°
Low field cold test confirms RF field/mode analysis
High field testing awaits better chemistry facilities

Manufactured Performance / QC



Most high field tests done with 3 cell cavity – 6 tests in past year alone

Acid etch facilities need upgrade for 13 cell test

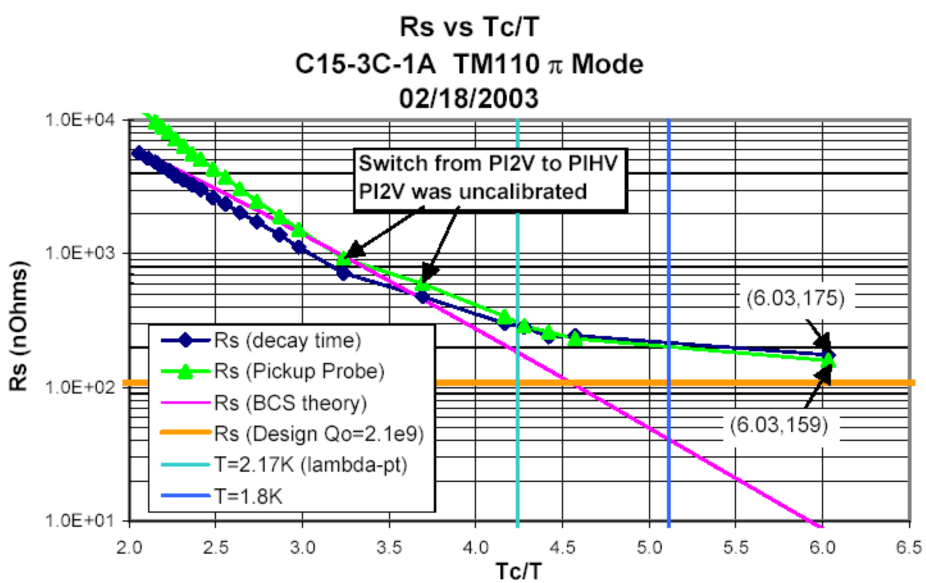
$P_{\perp}$ originally ~5.1MV/m but has decreased to about 3.5MV/m with repeated tests

R_{surf} vs. T design goal is 110nΩ

This is a major cost driver

Recently obtained ~165nΩ in deflection mode, ~65nΩ in accelerating mode. ($\Leftrightarrow$126nΩ in TM_{110})

Beam pipes were too short, but we have yet to prove this is the whole story.



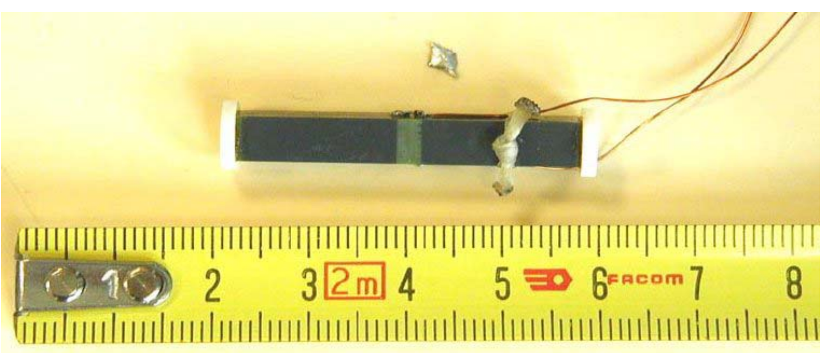
Piezoelectrics and Frequency Control

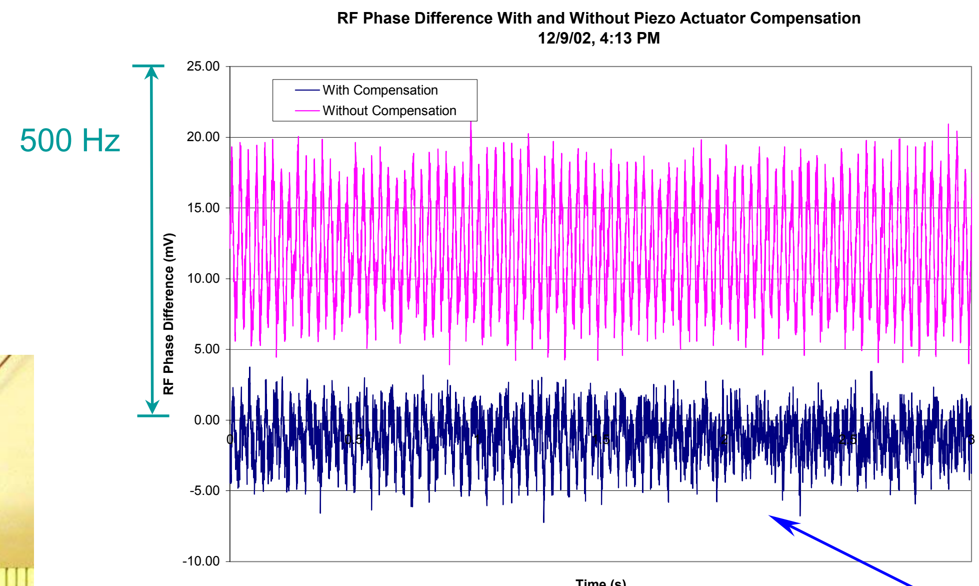
In order to reduce RF power demands, we propose to dynamically adjust the length of the cavities in response to mechanical vibrations, temperature and pressure changes, etc. The idea is to do this with piezoelectrics driven at acoustic frequencies with an adaptive filtering algorithm.

Q_{ext} of 6 x 10^7 ⇔ bandwidth of 65 Hz ⇔ δL = 31nm

At 300K:

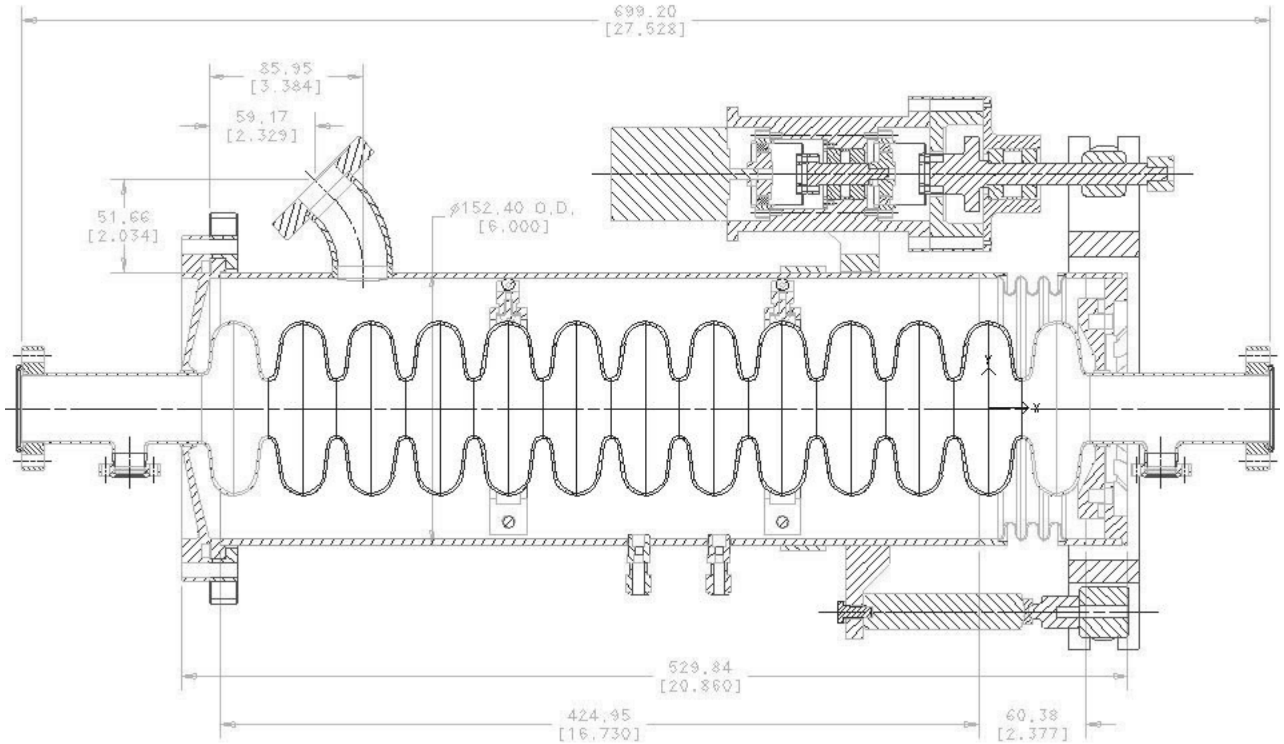
Open loop resolution	O [10nm]
Loads	O [1000N]
Range of motion	O [10μm]





Manual suppression of undamped vacuum pump vibrations

Cold Tuner



	Mechanical	Piezoelectric
Range	± 1MHz	± 8kHz
Slew rate	1 kHz / sec	8 MHz / sec
Resolution	± 20Hz	± 4 Hz

Cryovessel Prototype

Outer steel, LN_2 shield built

Inner LHe vessel construction started

Measurement of heat load crucial for cryoplant design

What Needs to be Done:

Basic RF design
- Verify that thicker wall is OK
- Beam test planned for FY04

Manufactured Performance / QC
- Chemistry at ANL is limiting item as of today
- $P_{\perp}$, R_0 tests ongoing
- Qualify the AES cavities

Piezoelectrics and fast frequency control
- Test of adaptive filtering algorithm
- Installation & running in prototype LHe cryostat with mechanical tuner

Cryovessel & Cryoplant Design
- Prototype system module with (at first) 1 cavity, RF, coupler, tuner
- Review cryovessel design
- Design and build a cryoplant