The FNPL Photoinjector & SRF R&D

H Edwards, LRPC Acc R&D Nov 03

These activities are to bring to FNAL connection with and experience in concepts and technologies of the future. They have a strong link to LC's, proton drivers, collaboration.

The FNPL Injector Program

Piot, Barov, Desler, Huening, Mihalcea, Santucci, Tikhoplav, Sun, Voronov, Berenc, DeGraff, Thompson, Bollinger, Prieto, Reid, Muranyi, Rauchmiller, Heinz, Beutler, Pfeffer, Kucera, D. Edwards

Superconducting RF R&D & Materials Research

Bellantoni, Solyak, Terechkine, Khabiboulline, Gonin, Bauer, Foley, Rowe, Mitchell, Boffo, Carcagno, Elementi, Klebaner, Soyars, Nicol, Darve, Kuchnir, Wanzenberg (DESY)

Motivation- Seed activities for the Future

The Photoinjector & the SRF Activities give FNAL an introduction to and experience with important areas of accelerator physics and technology.

SRF is an enabling technology of the future- Experience and expertise in it will payoff as the lab thinks about future directions.

The photoinjector is an instrument by which the srf is applied to real beam operations. It brings a much needed Lab connection to AARD physics.

The photoinjector is a research tool for development of low emittance, high space charge, and high charge beams.

It is a platform for advanced accelerator concepts and diagnostics development.

The activities are strongly connected to collaborative efforts and student involvement.

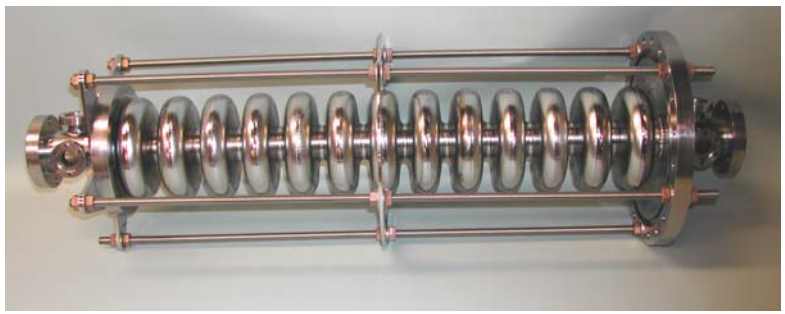
SRF R&D- (joint BD & TD activity)

An initial start toward gaining proficiency and expertise-

This effort is hopefully just a start toward greater activities (LC, proton driver)

Design/development work has been at 3.9GHz- CKM deflecting mode, 3rdHar(of 1.3GHz) accelerating mode

Operational experience with 1.3GHz TESLA cavity - install and operate in Photoinjector



3.9GHz prototypes will be installed and operated in FNPL injector.

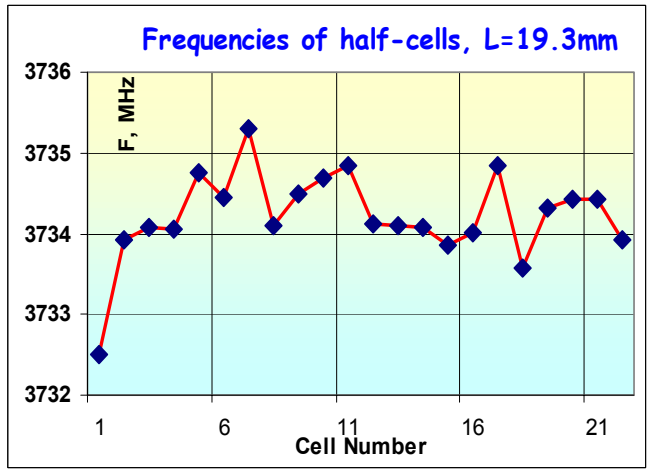
Future Collaboration with DESY-

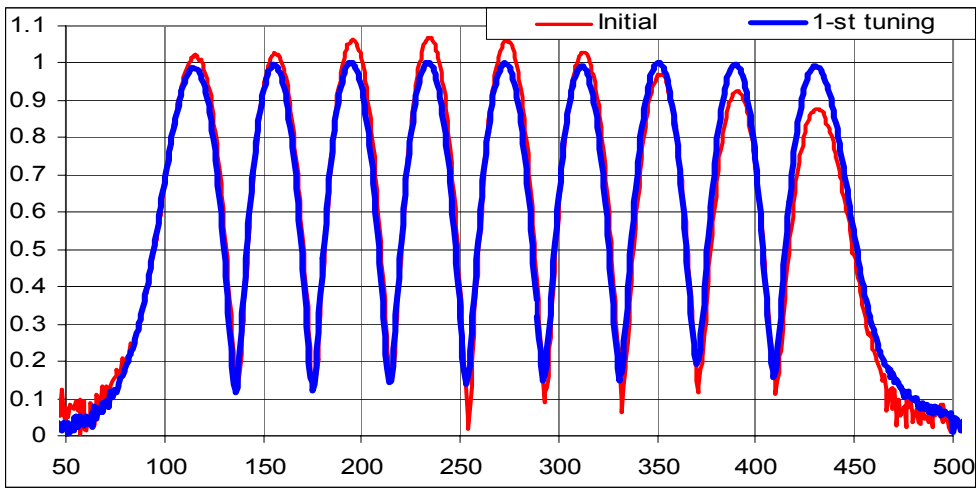
- Hi gradient TESLA cavity considered for installation at FNPL
- 4 cavity 3rdHar module under consideration for TTF

3rdHar Cavity Warm Test Results TM_{110}

Khabiboline, Gonin, Solyak, Terechkine

Individual half cell uniformities and f_0 *very* good

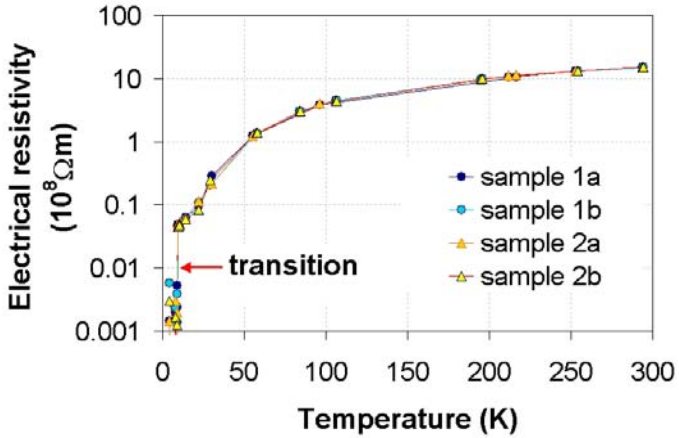




Field flatness in cavity after brazing (red) and after 1st tuning.

Materials Studies for SC RF Cavity Development

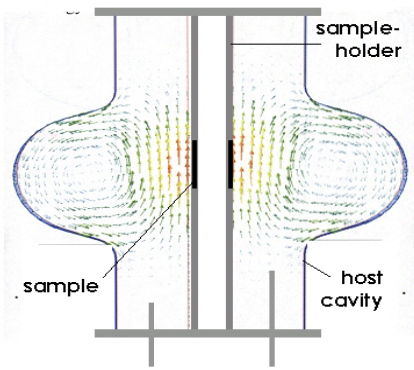
P. Bauer



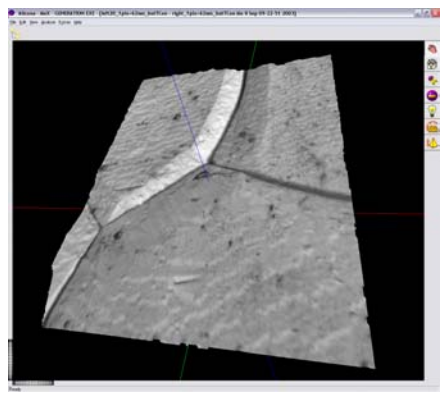
Characterization of materials in support of SRF development program

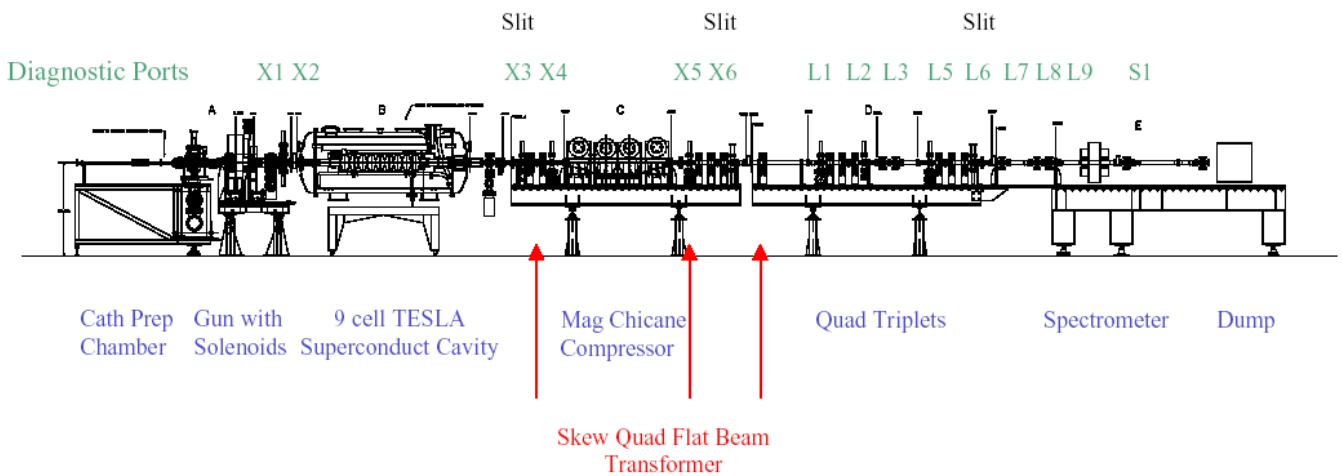
- RRR measurements
- Surface characterization

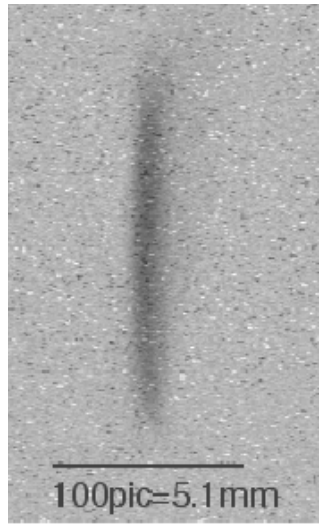
Peoples Fellowship project
"Small Sample High Field SRF Materials Test Facility"



Collaboration with Univ Wisc on fundamental SRF properties of materials







Flat Beam Exp

Present PhotoInjector using TESLA cavity ~15MeV

Flat Beam (new beam dynamics)

Space charge beams (learn to control and compensate), low emittance

Operation of SRF system (experience)

Upgrade Plan

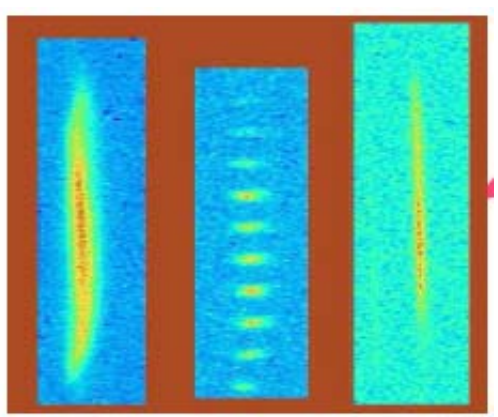
Install 3 new SRF cavities: Hi Gradient TESLA, CKM, 3rdHar

- Increase energy to ~40-50 MeV,

Flat Beam emittance transformation

- Photo-cathode is immersed in a B_z-field
  → e- born with canonical angular momentum
- Downstream of solenoid (Bz=0 and CAM conserved) → CAM convert to pure kinetic angular momentum
- A skew quad channel decouples the motion and yields an asymmetric beam with the transverse emittances ratio : $\frac{\varepsilon_x}{\varepsilon_y} - 1 \propto B_z^2 \frac{\sigma_r^2}{\sigma_{r'}^2}$

SPOT YMS XMS



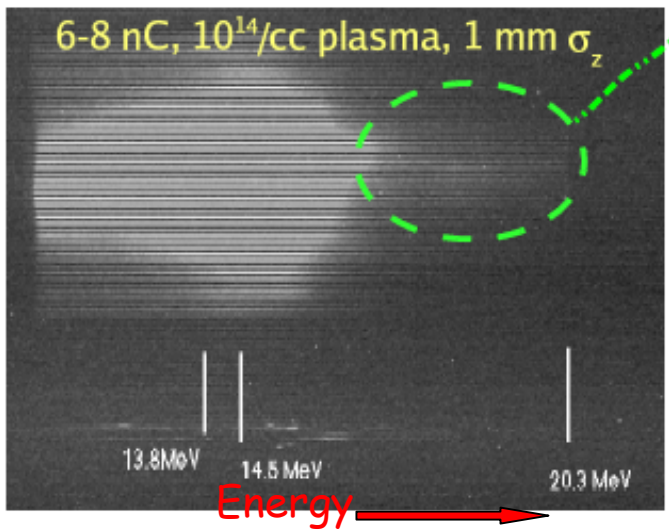
Proof of principle experiment obtained an emittance ratio of ~ 50.

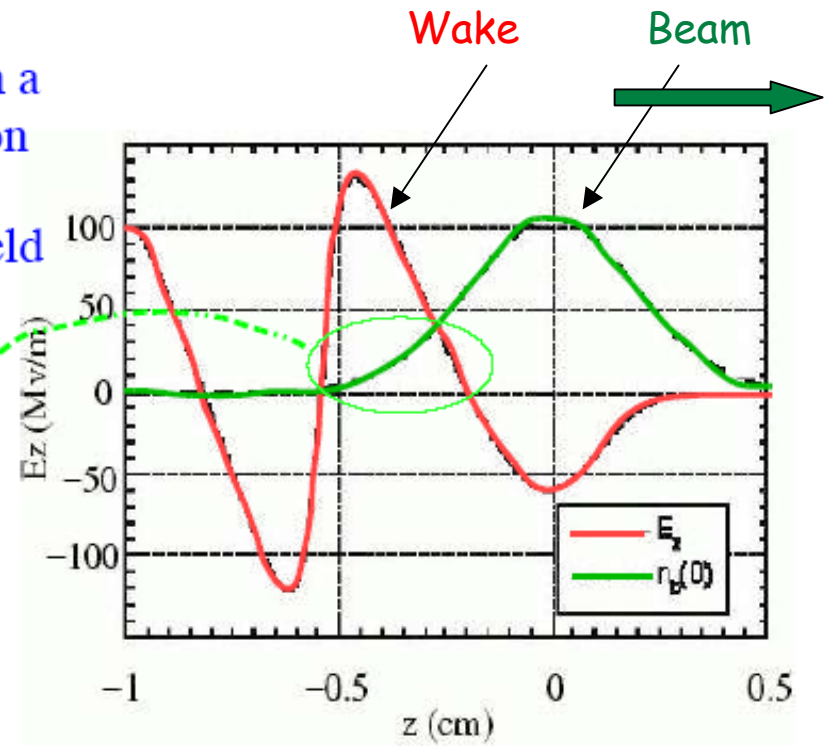
Piot

Plasma Acceleration

Barov, UCLA, NIU

- High current e- beam injected in a plasma induces density modulation
- Energy in the bunch is modified according to the induced wake-field



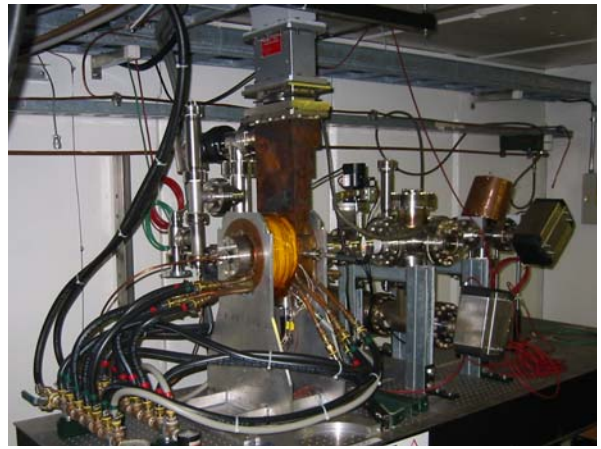


- Demonstrated energy gradient of ~ 100 MeV/m

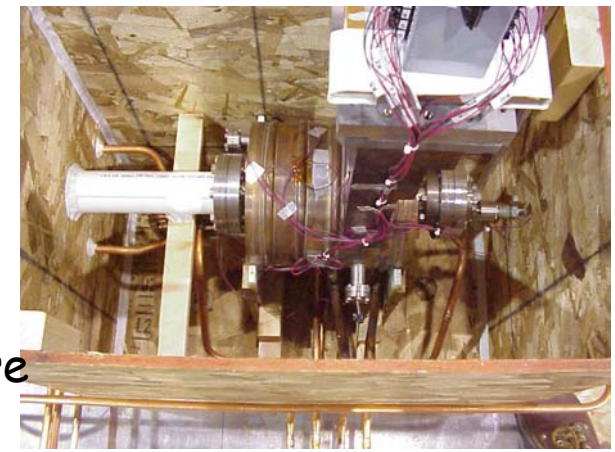
- Present experiment aims in sampling the plasma wake using a witness bunch following the drive beam

R&D toward a polarized RF Gun

M. Huening



- Polarized e- source required for LC, at present DC gun
- Polarized guns require NEA GaAs cathodes
- GaAs cathodes require excellent vacuum (10^{-12} Torr)
- The vacuum in rf guns typically ranges around 10^{-9} Torr

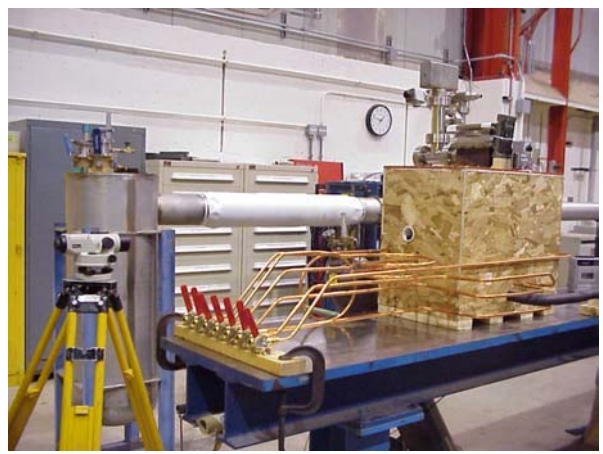


- Operate copper gun at liquid nitrogen temperature

Phase 1 - Cool down to 80K, measure pressure, run RF, measure pressure, measure dark current.

Phase 2 - Build GaAs cathode system, measure QE, lifetime, dark current.

Phase 3 - Design & build usable gun (working with AES on SBIR proposal.



Steps for a long range plan

1. Install a high gradient Tesla cavity at A0 this year
2. Install two 3.9GHz cavities ~ next year
   transverse mode cavity & decelerating mode cavity
3. Build 4 cavity 3.9 GHz decelerating mode TTF module ~ next year plus
4. Invest in infrastructure and materials development for SRF 2K cryoplant (takes 3 years), materials lab (Bauer)
5. Work toward US lab collaborative SRF Test Facility with beam ~ > 100 - 200 MeV

LRPC R&D Evolution Plans & Steps (multi year) (1)

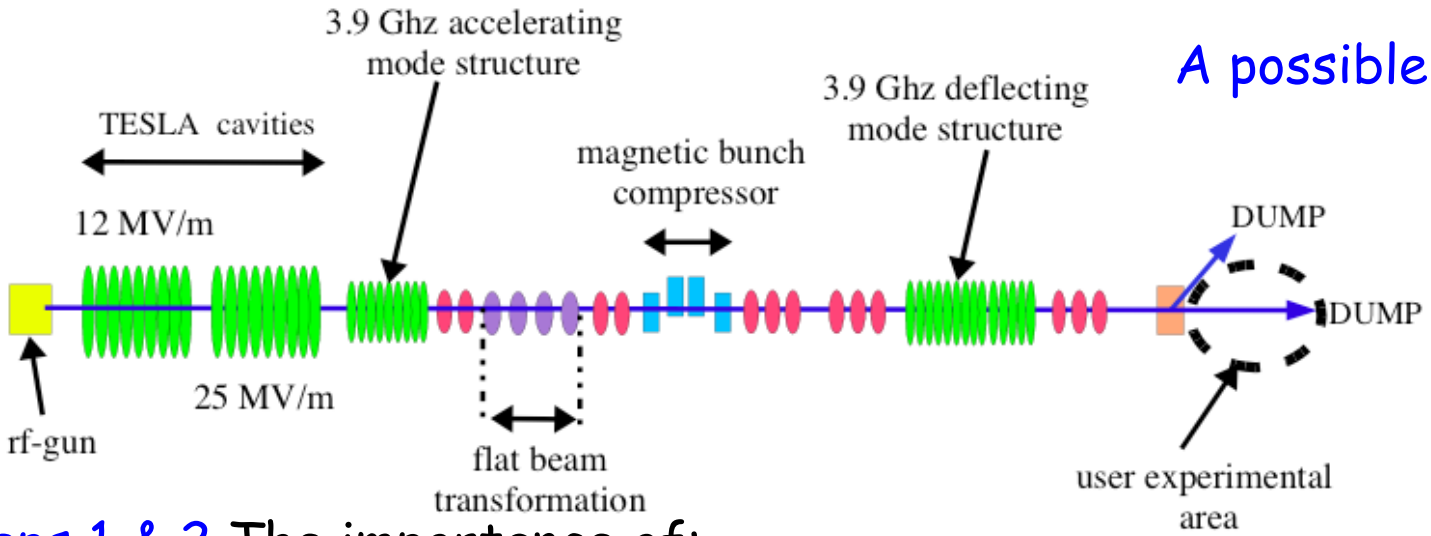
The main steps of the integrated program are:

1) Upgrade FNPL at A0 with a high gradient 1.3GHz srf cavity to provide up to 40-50 MeV beam energy. Operational test of high gradient cavity with beam.

2) Install in FNPL two 3.9GHz srf cavities (a transverse mode cavity, and a field linearization cavity). This tests both the srf development and leads to diagnostic and emittance tools.

3) Build a 3.9GHz srf four cavity module for the TTF collaboration. This provides important emittance, bunch length reduction capability to TTF. It also through the collaborative effort with DESY provides full technology transfer of srf design & engineering to Fermilab.

A possible layout



Steps 1 & 2 The importance of:

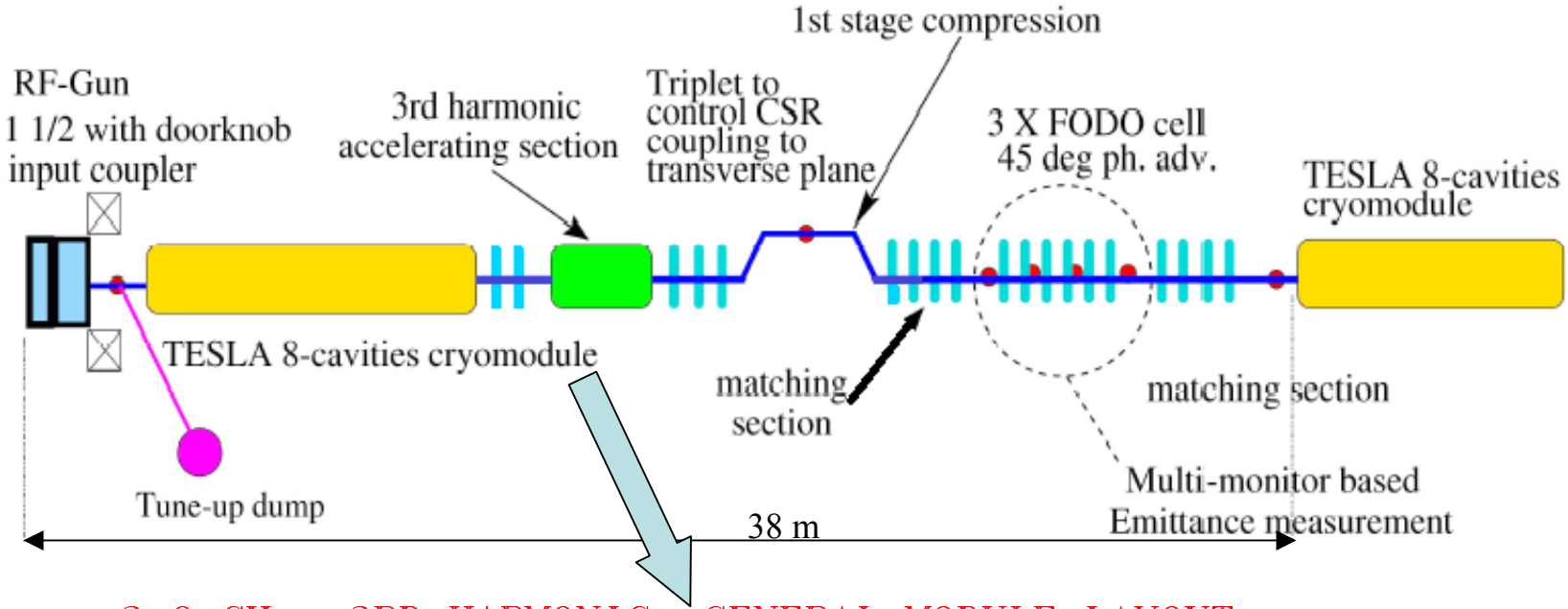
Hi Grad TESLA cavity- test long term operation with beam in"typical" environment (more flexibility of operation than at TTF). This is one of the 35 MV/m cavities.

CKM cavity operation- gain experience with beam & system integration, show that deflection is actually as expected

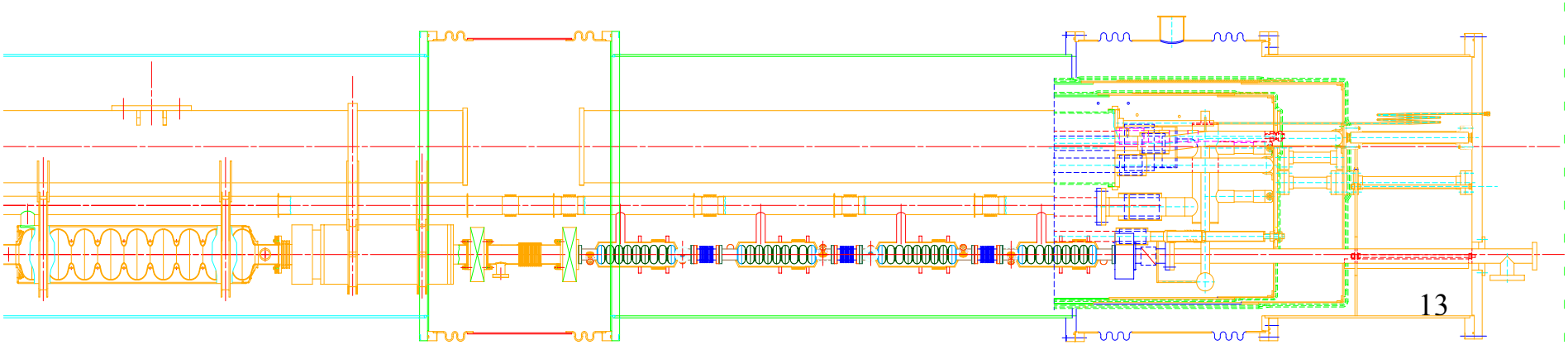
3rdHar cavity- allows for long beam bunches from gun to minimize space charge, then because the RF energy/time correlation has been linearized compression to short bunches should be possible. This R&D for the study of low emittance beams with direct application to FEL beams.

Step3 MOU(draft) with DESY-TTF Injector III with 3rd Harmonic Cavities

Demonstration of FNAL developing expertise in SRF



3.9 GHz, 3RD HARMONIC, GENERAL MODULE LAYOUT

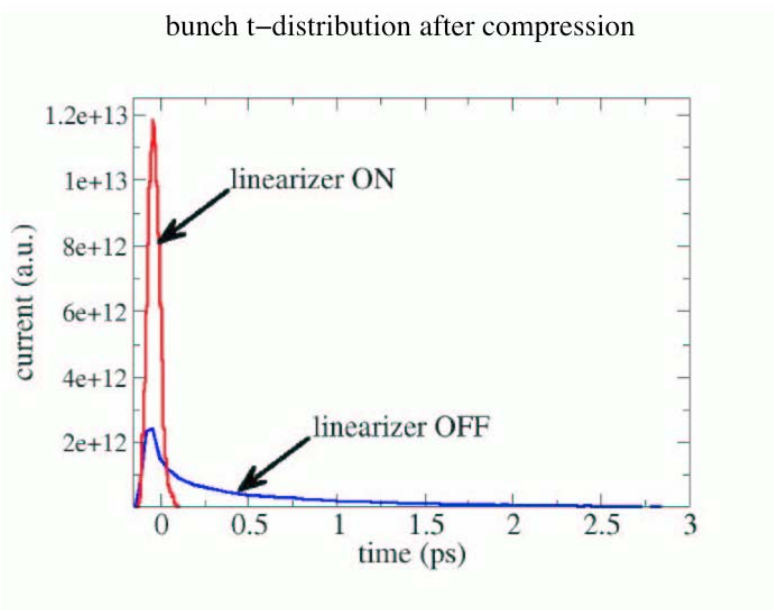


Step 3 Proposal for a TESLA Collaboration 4 cavity 3.9 GHz Module-

Once development of the cavity system has been accomplished for the FNPL photoinjector- Then a 4 cavity module could be built for TTFII.

This is VERY important for optimum operation of SASE
But it also gives FNAL experience with design and construction of a "module" and complete system

Other facilities are also interested in this development because of the potential for very high peak bunch currents



Evolution Plans & Steps- (2)continued

4) Further develop srf infrastructure for activities beyond the present capability. Specifically a 2K cryoplant is needed. Time scale is ~3 years from funding start.
Materials development and collaboration with materials experts (Univ Wisc) is also a goal.

5) Develop and implement a collaborative proposal for a srf test bed beyond the A0 capabilities. This test bed would attempt to integrate the needs of many US labs for proving state of the art srf performance, both high gradient and high Q in multi cavity modules with e beam energies > 100MeV. It in parallel provides beam for further beam emittance, diagnostics, and AARD (e.g. plasma, laser) studies.

Steps: -Can labs agree (unite) on need and a proposal (e.g. ANL, Cornell, JLab, LBL, SNS, MS…..)

-Can funding agencies agree across agencies & divisions (e.g. NSF, DOE-BES,NP,HEP

-Location is secondary to the above steps.

Collaboration

Collaboration is an extremely important aspect of the activities. It is what keeps us connected.

NIU/NICADD- FNPL Program, postdocs, funds
DESY TESLA TTF-srf, e injector, FEL applications, postdocs
Rochester- laser expertise, and students
UCLA- plasma acceleration, students
Chicago- student- flatbeam
LBL-LUX Much common R&D interest: flat beams, srf transverse mode, and acc mode 3.9GHz.
Argonne, MSU- srf infrastructure, chemistry
Cornell & JLab- srf, information, assistance,
Univ Wisc- basic surface studies
INFN, Saclay, Orsay IPN - cathode, modulator, cryostat(hi grad)
Georgia- diagnostics

FNPL Photoinjector Students, Postdocs, Fellows

Students:

Fry	Rochester
Fitch	Rochester
Colby	UCLA
Carneiro	Orsay-Paris
Fritzler	Darmstadt
Yin E Sun*	Chicago
Tikhoplav*	Rochester
Thompson*	UCLA
Bollinger*	NIU

Postdocs:

Colby	FNAL
Hartung	FNAL
Barov*	UCLA/NIU
Desler*	DESY
Mihalcea*	NIU

Peoples Fellows:

Piot*

Huening*

* In progress, present

Conclusions-SRF & Photoinjector

- The goals are to bring to FNAL connection with and experience in future concepts and technologies beyond its present program and to give opportunity for bright young people. (investment for future)

- Accelerator R&D bridges many end use applications and should not be closely confined by just what is perceived good for HEP. Its strength is in interplay of ideas irrespective of final application.

- The goals of this plan are (and should be) ambitious; resources are marginal at present though not insignificant. Considerable progress has been made. But resources would need to be increased to enlarge the effort.

- This is the time for aggressive Acc R&D programs - future projects are uncertain.

- I believe it is important to have the knowledge and competence- you can not just build components, you must use them with beam - you do not just go and buy accelerators, you must have the expertise to get what you want.