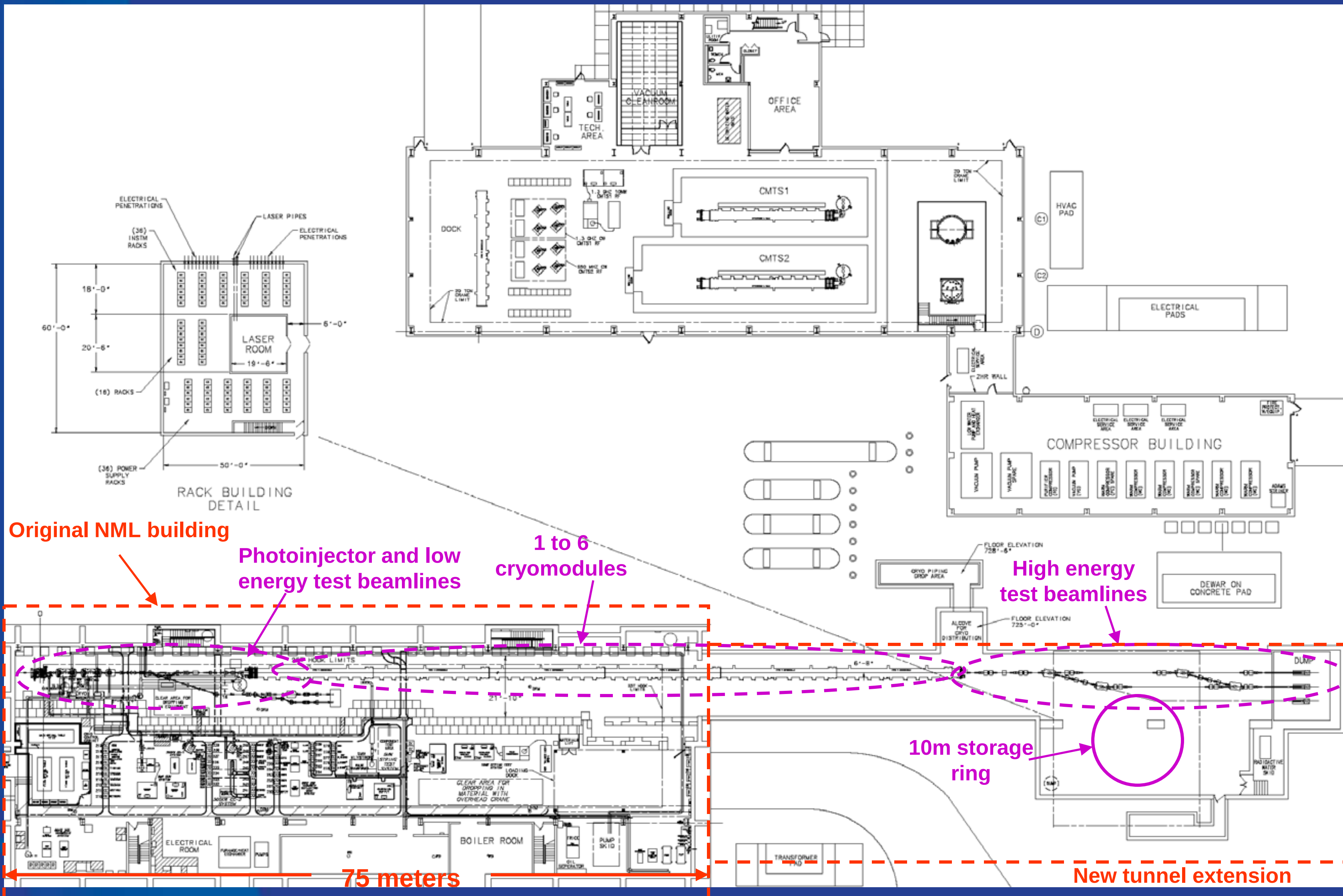
NML (ASTA) Status and Plans

(ASTA = Advanced Superconducting Test Accelerator)

Mike Church

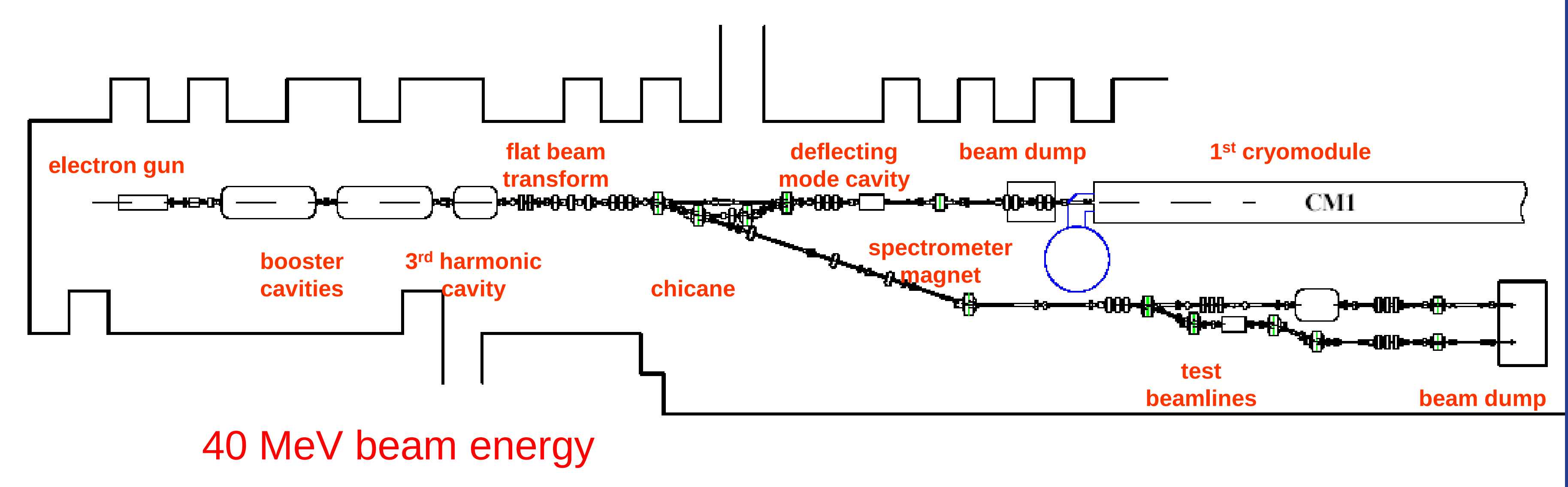
Accelerator Advisory Committee Meeting,
November 7 - 9, 2011

Facility Layout



Fermilab

Low Energy Beamlines



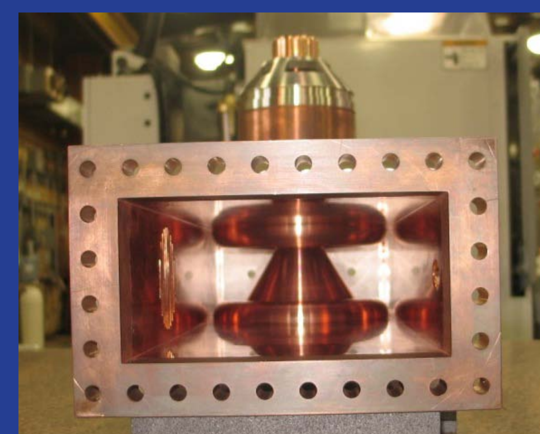
- 1.5 cell, 1.3 GHz electron gun with Cs_2Te photocathode; identical to DESY/PITZ design
- Two 9-cell 1.3 GHz superconducting booster cavities (one currently installed, one from A0PI)
- Superconducting 3.9 GHz cavity (eventually) for bunch linearization
- Three skew quadrupoles for flat beam transformation
- Chicane for bunch compression (R_{56} = 0.198)
- 3.9 GHz, normal conducting deflecting mode cavity for longitudinal beam diagnostics (from A0PI, or new)
- Vertical spectrometer dipole deflects beam 22.5° to dumps for beam energy measurement
- Test beamlines will be configured to suit experiments; example shown here is for emittance exchange

Electron Gun and Photocathode Chambers

- 1.3 GHz, normal conducting, 1.5 cell copper cavity (DESY/PITZ design)
- Up to 45 MV/m accelerating field at the cathode; requires 5 MW klystron; 20 KW average power at full ILC pulse length and repetition rate
- Cs_2Te photocathode excited by 263 nm UV laser
- 2 identical solenoids for emittance compensation
- Coaxial RF waveguide coupler
- 3 cavities have been fabricated; 1 additional under fabrication
    - 1 by DESY – completed and shipped to Fermilab; 1st spare
    - 3 by Fermilab – 1 completed and shipped to KEK; 1 completed and to be commissioned at NML; 1 almost complete as 2nd spare
- RF windows (from Thales) are currently being conditioned

gun cavity

Solenoids and PC transfer chamber



RF coupler

Laser Hut and Laser

- **IR fiber optic seed laser and amplifier have been purchased from Calmar Laser and commissioned at A0**
- **Will be moved to ASTA when the laser room has been fully outfitted (~Jan. 2012)**
- **A0 Ti:Sa will also be moved to ASTA; new higher bandwidth Ti:Sa laser will be installed at HBESL**
- **3rd optical table at ASTA will be reserved for laser R&D efforts**

ASTA laser room

Seed laser test setup at A0

Booster Cavities

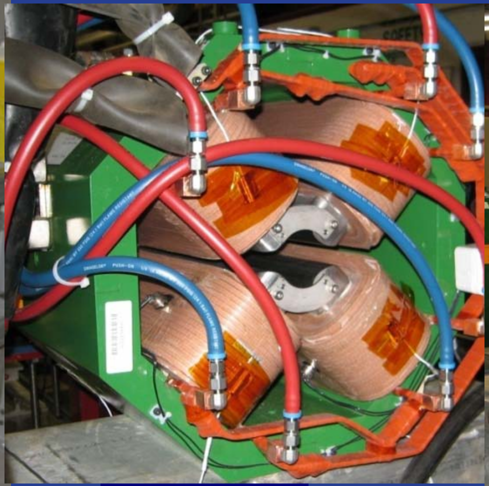
- 1 booster cavity ("CC2") installed and conditioned at ASTA -- 24 MeV/m
- 1 booster cavity ("CC1") at A0 photoinjector
  - Currently operates at 12 MV/m
  - Will be removed and refurbished (new cavity, new tuner, …) and installed at ASTA early next year
- Plans for installing the 3.9 GHz linearizing cavity are currently postponed
  - We are planning on installing 1 or 2 3.9 GHz deflecting mode cavities for longitudinal phase space diagnostics

2^{nd} Booster Cavity installed at ASTA

Beamline Magnets

- Gun solenoids – purchased , installed, and powered
- Low energy dipole correctors, quads, and dipoles – received; under test
- High energy dipole correctors and quads – received; under test
- High energy dipoles – delivery expected 11/11 – 2/12

LEQ and HECD on stands



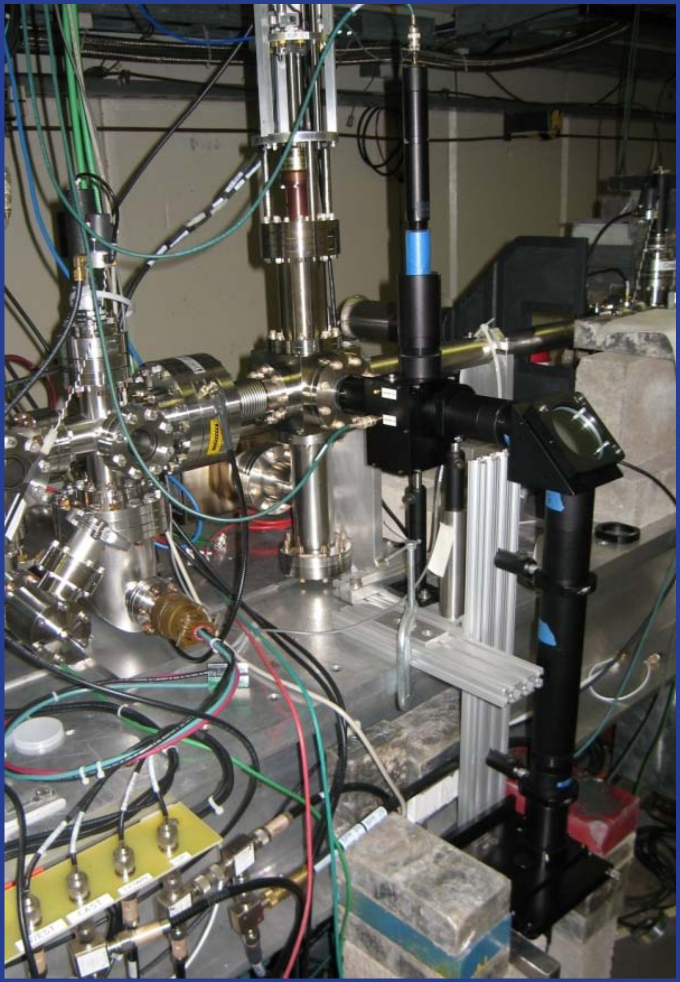
HEQ

LED

Instrumentation

- **Primary instrumentation consists of:**

- **Beam position -- button BPMs**
  - **< 25 μm single bunch resolution**
  - **Similar system tested at KEK ATF recently by M. Wendt**
- **Beam size -- instrumentation crosses (from Radiabeam)**
  - **Prototype tested at A0 – resolution ~18 μm**
  - **Combination of OTR, YAG:Ce, and LSO:Ce screens**
- **Beam current -- current transformers (from Bergoz)**
  - **Prototype tested at A0**
  - **Flanged, in-line device**

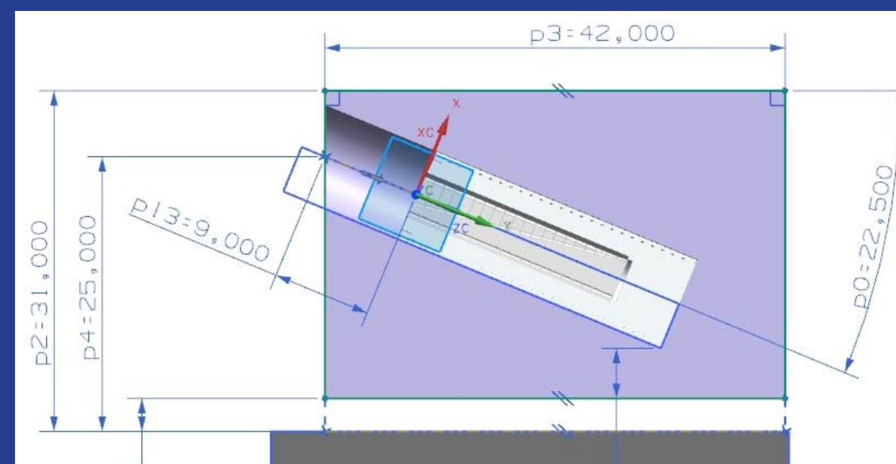


Bergoz ICT and Radiabeam Instrumentation Cross at A0

Beam Dumps

- **High energy beam dump designed for 100 KW beam power**
  - **Consists of graphite stack, surrounded by aluminum, steel, concrete**
  - **Water cooled and in inert environment**
- **Low energy beam dump designed for 2.5 KW beam power**
  - **Consists of graphite stack, surrounded by aluminum and concrete**
  - **Water cooled**

High Energy Beam Dump Core



Low Energy Dump Concept

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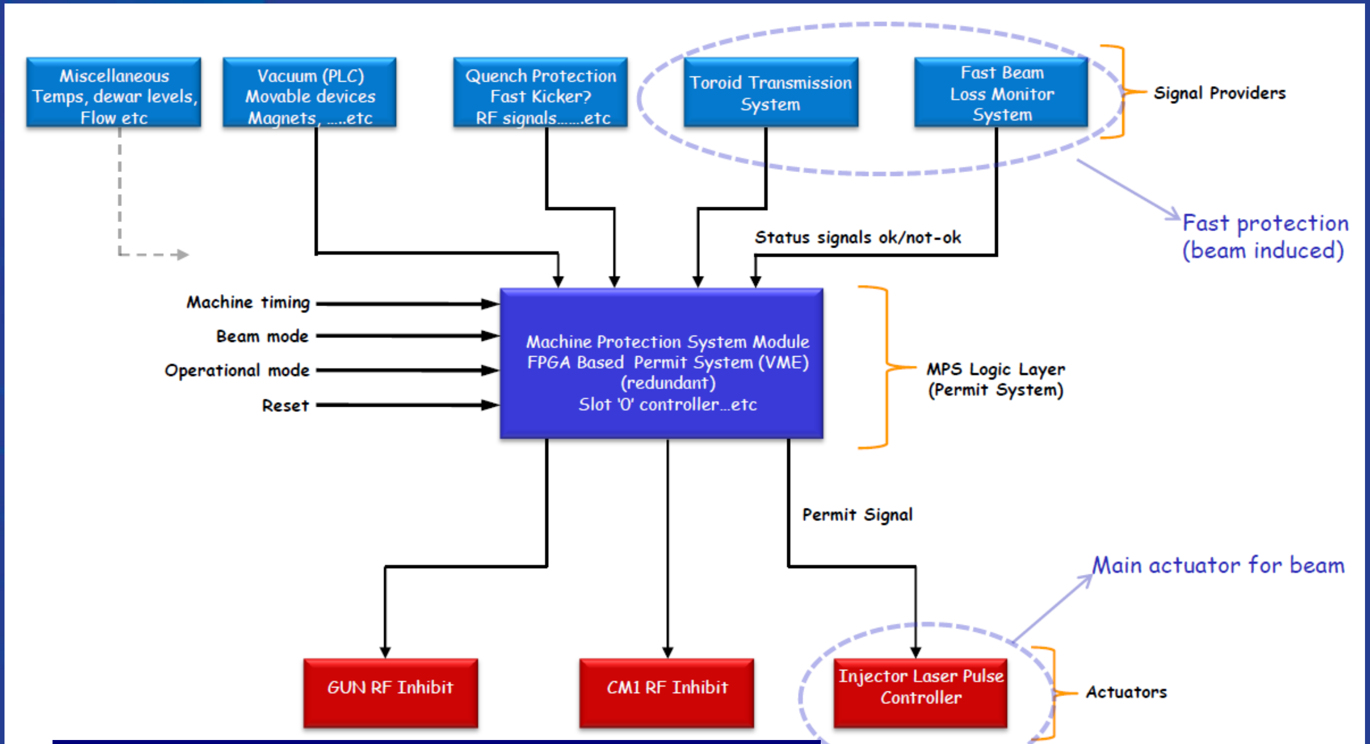
Cryomodules

- **Installation of cryomodule 1 started on Jan. 2010**
- **It has been conditioned and operated to an average accelerating gradient of >20 MeV/m with a 700 μs flattop pulse at 5 Hz**
    - **1 cavity has broken tuner and cannot be put on resonance with the other 7**
- **It is currently being used to develop, understand, and refine**
    - **Lorentz Force Detuning correction algorithms**
    - **Feedback algorithms**
    - **Phase and amplitude stability**
    - **Heat load and cryogenic operation**
- **Cryomodule 1 will be replaced with Cryomodule 2 starting in Jan. 2012**
    - **All cavities have reached gradients of 35 MV/m in the Vertical Test Stand**

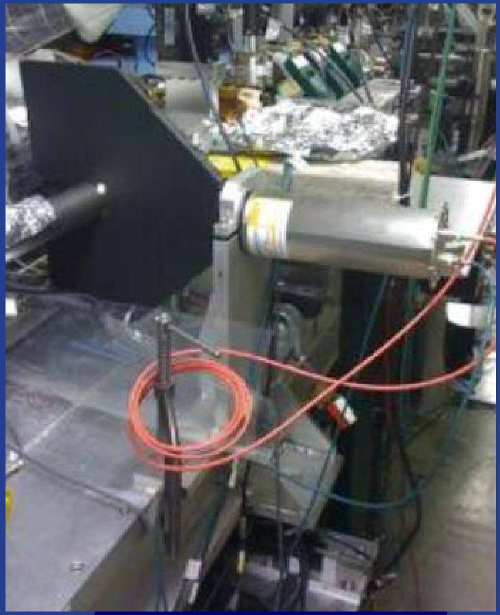
Cryomodule 1 Installed at ASTA

Machine Protection System

- 40 KW of beam power at ILC beam intensity and 900 MeV
  - Requires well-designed Machine Protection System
  - Must be able to shut down beam within 5 bunches
  - Beam losses in cryogenic sections must be <0.01%
  - Core of the fast response system is based on scintillator/PMT loss monitors

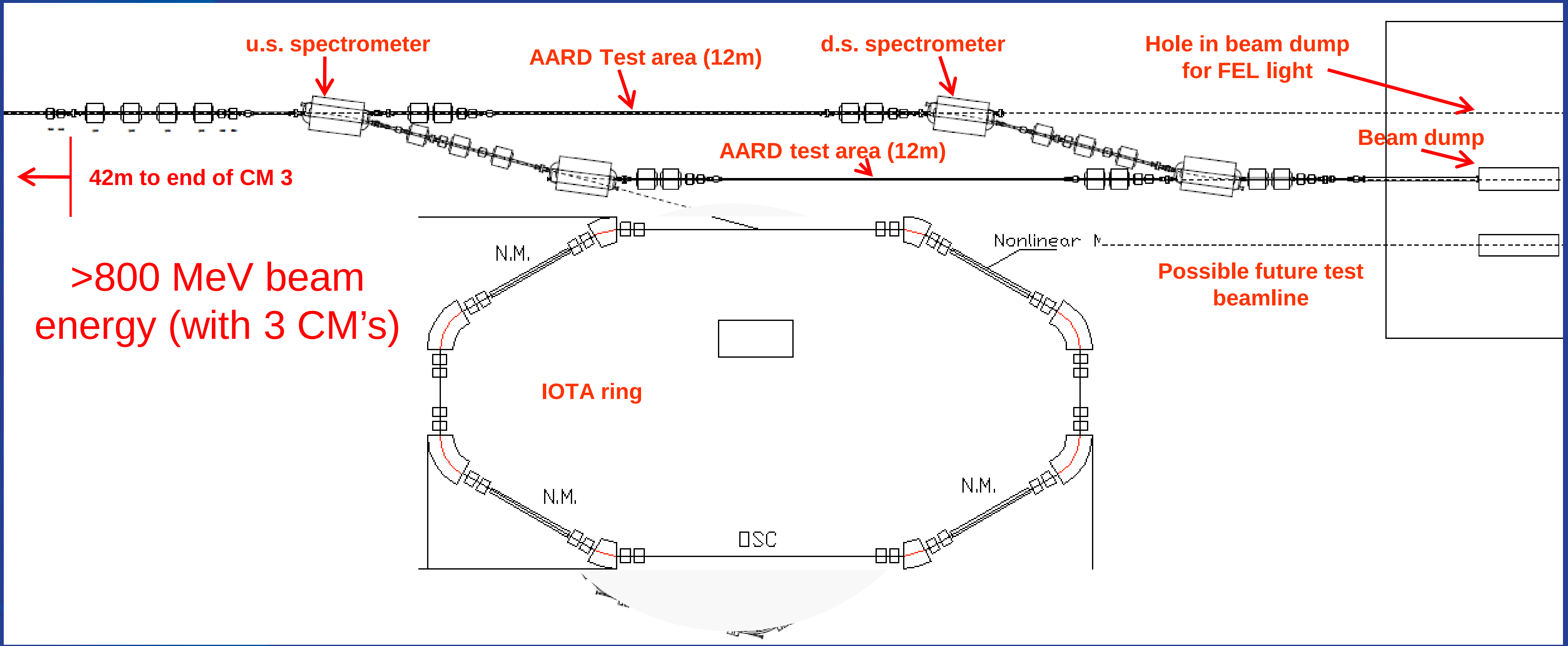


Simplified MPS Block Diagram (A. Warner)



Loss Monitor at A0

Downstream Beamline Layout



>800 MeV beam energy (with 3 CM's)

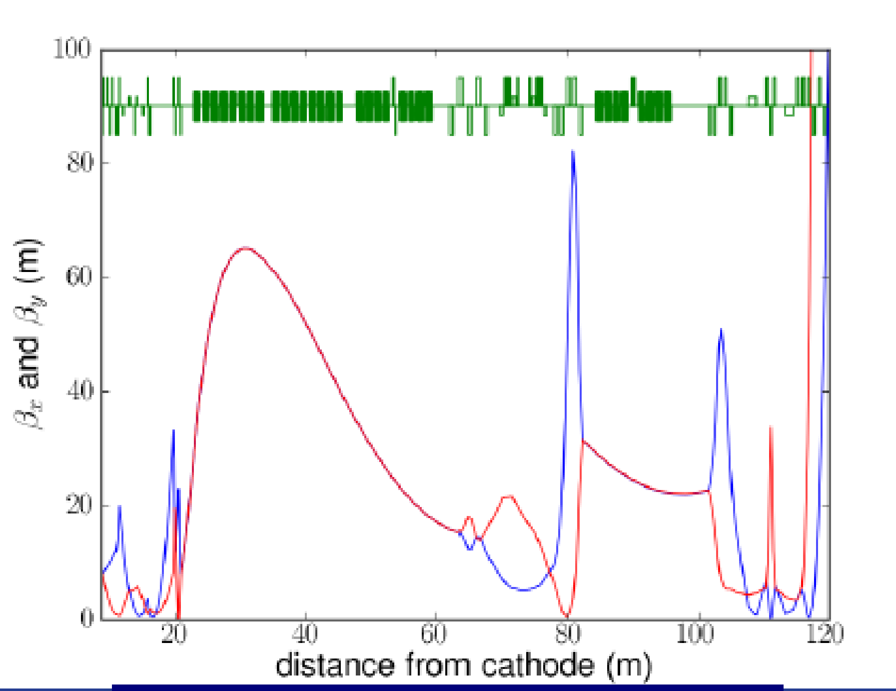
Beam Parameters

ASTA will be capable of operating with a wide range of beam parameters. As with all photoinjectors, many beam parameters are coupled, especially to the bunch intensity, due to space charge effects.

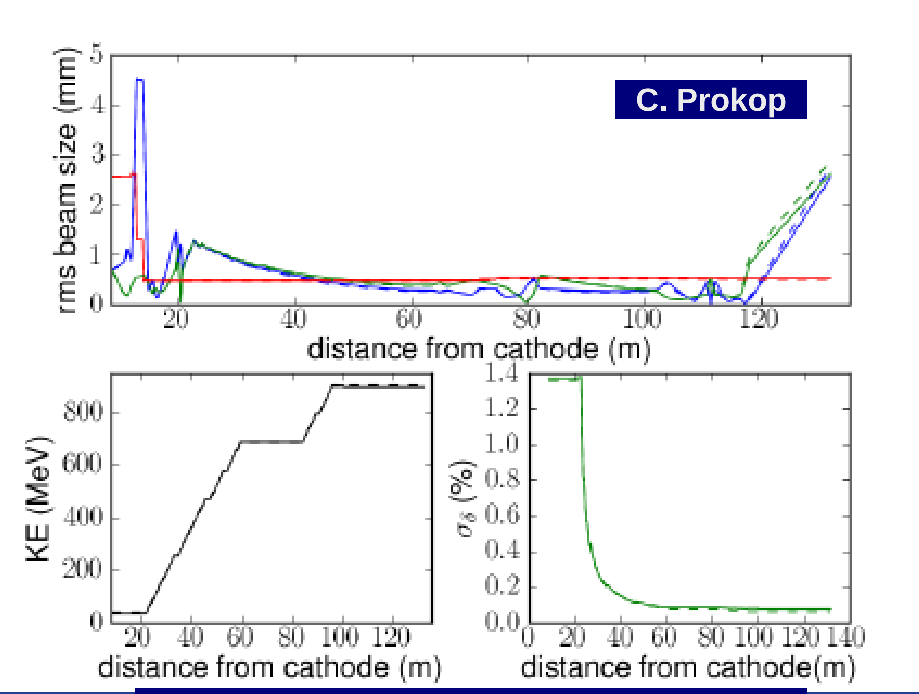
parameter	ILC RF unit test	range	comments
bunch charge	3.2 nC	10's of pC to >20 nC	minimum determined by diagnostics thresholds; maximum determined by cathode QE and laser power
bunch spacing	333 nsec	<10 nsec to 10 sec	lower laser power at minimum bunch spacing
bunch train length	1 msec	1 bunch to 1 msec	maximum limited by modulator and klystron power
bunch train repetition rate	5 Hz	0.1 Hz to 5 Hz	minimum may be determined by gun temperature regulation and other stability considerations
norm. transverse emittance	<20 mm-mrad	<1 mm-mrad to >100 mm-mrad	maximum limited by aperture and beam losses; without bunch compression emittance is ~5 mm-mrad @ 3.2 nC
RMS bunch length	1 ps	~10's of fs to ~10's of ps	minimum obtained with Ti:Sa laser; maximum obtained with laser pulse stacking
peak bunch current	1.3 kA	> 10 kA (?)	Impact-Z calculations indicate peak currents of 4 kA with bunch compression and no 3.9 GHz cavity
injection energy	40 MeV	5 MeV – 50 MeV	may be difficult to transport 5 MeV to the dump; maximum is determined by booster cavity gradients
high energy	810 MeV	40 MeV – 1500 MeV	radiation shielding issues limit the maximum

Simulations and Software

- **Software tools:**
  - **ASTRA (DESY) for tracking from gun through booster cavities**
  - **Elegant (ANL) for single particle lattice design**
  - **Impact-T/Z (SCIDAC) and CSRTrack (DESY) for multiparticle simulations**
  - **Tied together with Python scripts**
- **Most simulation work done by C. Prokop (NIU grad student) with contributions from P. Piot, M. Church, Y-E. Sun, and C. Thangaraj**



End-to-end lattice functions



End-to-end beam size, E, δE

Fermilab

Accomplishments to Date

- **Project was started in 2006**
- **Completion of civil construction of new electrical service building and tunnel**
- **Installation of a large amount of infrastructure – power, water, cryogenics, shielding, HVAC, RF, etc.**
- **Commissioning and operation of first full Fermilab-assembled cryomodule at high RF power**
  - **>20 MV/m average accelerating gradient @ 700 μsec flattop pulse length**
- **Commissioning of SC booster cavity (“CC2”) @ 24 MeV/m**
- **Commissioning of cathode preparation chamber**

Overall Goals

- 2012
  - replace cryomodule 1 with cryomodule 2
  - establish 1st beam operation from gun to HE dump with a single cryomodule
- 2013
  - establish high intensity, stable operation with a single cryomodule
  - install 2 more cryomodules
  - commission new refrigerator
  - start 1st AARD experiment (X-ray production from crystal)
  - start installation of IOTA
- 2014
  - establish high intensity, stable operation with 3 cryomodules; start ILC string test
  - IOTA operation
- 2015
  - continue (complete?) ILC RF string test
  - start installation of double emittance exchange experiment
- 2016 ---
  - directions to be determined … -- reconfiguration for FEL? addition of 2nd bunch compressor and 4th cryomodule ? addition of 3 more cryomodules ? future AARD experiments ?

FY12 Plans

- **Complete high power tests and feedback studies with CM1**
- **Install and commission new photocathode laser (1st complete laser hut)**
- **Complete high power conditioning of gun RF windows; finish installation of gun RF system; install gun; commission gun**
- **Replace CM1 with CM2 and recommission**
- **Remove 9-cell booster cavity from A0 (CC1); refurbish; install at ASTA; commission to high power**
- **Finish installation of high energy dump and RAW system**
- **Finish design and installation of low energy dump and RAW system**
- **Install beamline components – magnets, instrumentation, vacuum components, …**
- **Reconfigure shielding for beam transport to the high energy dump**
- **Develop suite of application programs for basic operations**
- **Complete radiation shielding assessment and SAD**
- **Install Machine Protection System**
- **Start beam commissioning – 1st 2 Faraday cup downstream of gun, then to 40 MeV dump, then to high energy dump**

ILC RF Unit Test at ASTA

- ILC RF Unit ≡ 26 Cavities <V> = 31.5 MV/m, 10 MW L-band RF power, 9 mA / 1ms beam
  - *Demonstrated full current, stable acceleration 2001*
- Gradient, RF Power, Utility, Cryogenic, linac length and controls overhead margins to be specified and tested
  - Includes test of gradient ‘spread’ (+/-20%)
- *Primary Goal of System Test → COST*
  - *ILC Project cost contained by best-effort evaluation of baseline cost ←→ performance relationship*

M. Ross

Resources and Operations

- The vast majority of resources for this project come via SCRF Program funds
  - see R. Kephart's talk
- FY12:
  - NML buildout has been allotted 2.5 M$ M&S; requests from task leaders amount to 4.4 M$; this has been prioritized so that 3.0 M$ is being requested for FY12
- Future operations:
  - Although ASTA is a stand-alone facility, we expect to develop operational procedures fully compatible with Main Control Room operations
  - A department of 10 people has been formed in AD (SRF Electron Test Facility Dept.). I believe this is adequate to operate ASTA.
    - 3 ex-crew chiefs, 3 scientists with extensive operational experience, 2 staff with extensive A0PI experience, 2 staff with extensive installation experience
  - I estimate an additional 5 FTE's from support groups will be required to keep the facility operating reliably.
  - This estimate does not include effort for building/installing specific AARD experiments

Risks

- **Primarily schedule risks**
  - **Installation, RF cavity conditioning, cryo commissioning, and beam operation conflicts may slow down overall progress**
  - **Gun may take longer to commission than anticipated**
  - **Shortfall in M&S funds may delay beam startup**
- **Technical risks**
  - **Beam energy may be limited by cavity gradients**
  - **Beam intensity may be limited by beam losses, dark current, and radiation**
  - **Beam quality may be limited by problems with the gun**

Summary/Outlook

- We have made good progress on all technical fronts
- Our schedule to deliver beam is optimistic but plausible
- The major risk is to schedule
- The next few years will see a gradual transitioning from installation to operation
- A strong group has been formed to move ASTA forward into operations
- We are reaching out to the accelerator community at large to develop a strong AARD program
- We are open to your suggestions