Status of the IASA Race Track Microtron Facility-the 10 MeV injector linac

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UoA & IASA - Greece

Layout of the talk

- Presenting IASA
- The 10 MeV injector linac
  - Accelerator structures – Diagnostics
  - Control – EPICS
  - Low – High power RF
  - HV & RF interlocking system
  - Cooling & tuning
  - Beam optics calculations – transport of the beam – energy analysis system
  - Experimental areas
- Future plans
  - Future experiments (Maquette building)
  - The new building
  - Other activities – IASA Publications

The Institute of Accelerating Systems and Applications (IASA)

An Autonomous Research Institute operating under the auspices of the Ministry of Education.

Participating Academic Units:

The National & Capodistrian University of Athens

- School of Medicine
- Department of Informatics
- Department of Physics

The National Technical University of Athens

- Department of Electrical & Computer Engineering
- Department of Chemical Engineering
- Department of General Science – Physics Division

Brief Historical Background

Aug – 94	IASA Founded
Jan – 95	First managerial structure established
Jul – 95	NIST RTM disassembled and shipped to GR
Sep - 95	1st International Technical review
Nov -95	Cascade Option chosen
Jan - 96	100 keV Injector Maquette Launched
Jun - 96	U. of Illinois RTM Equipment shipped to GR
Apr - 97	First Beam out of injector Maquette

Oct-97	Beneficial occupancy of "Maquette" Building
Oct-97	2nd International Technical review
Oct-98	100 keV Injector Maquette Completed
Nov-98	Plans for a 10 MeV linac
Sep-99	Beneficial Occupancy of an Exp. Hall
Oct-99	3rd International Technical review
Feb-01	Upgrade to 10 MeV Maquette Initiated

Mission of the Institute

To support Research and post graduate studies in all thematic areas where accelerators and related technologies play a role.

- Medicine
- Materials Science
- Informatics and Computer Science
- Instrumentation
- Nuclear & Particle Physics
- Archaeometry & Archaeological Preservation
- Food preservation
- Environmental Science

Open to researchers both Nationally and Internationally

Institutional and Geographical Setting

Facilities in Greece

- Several medical electron / proton Linacs
- The Tandem of "Demokritos"

Regional Facilities

- Nothing comparable in the Eastern Mediterranean Basin or the Balkan Peninsula
- Important facilities in Italy (Legnearo, Catania, Frascati)

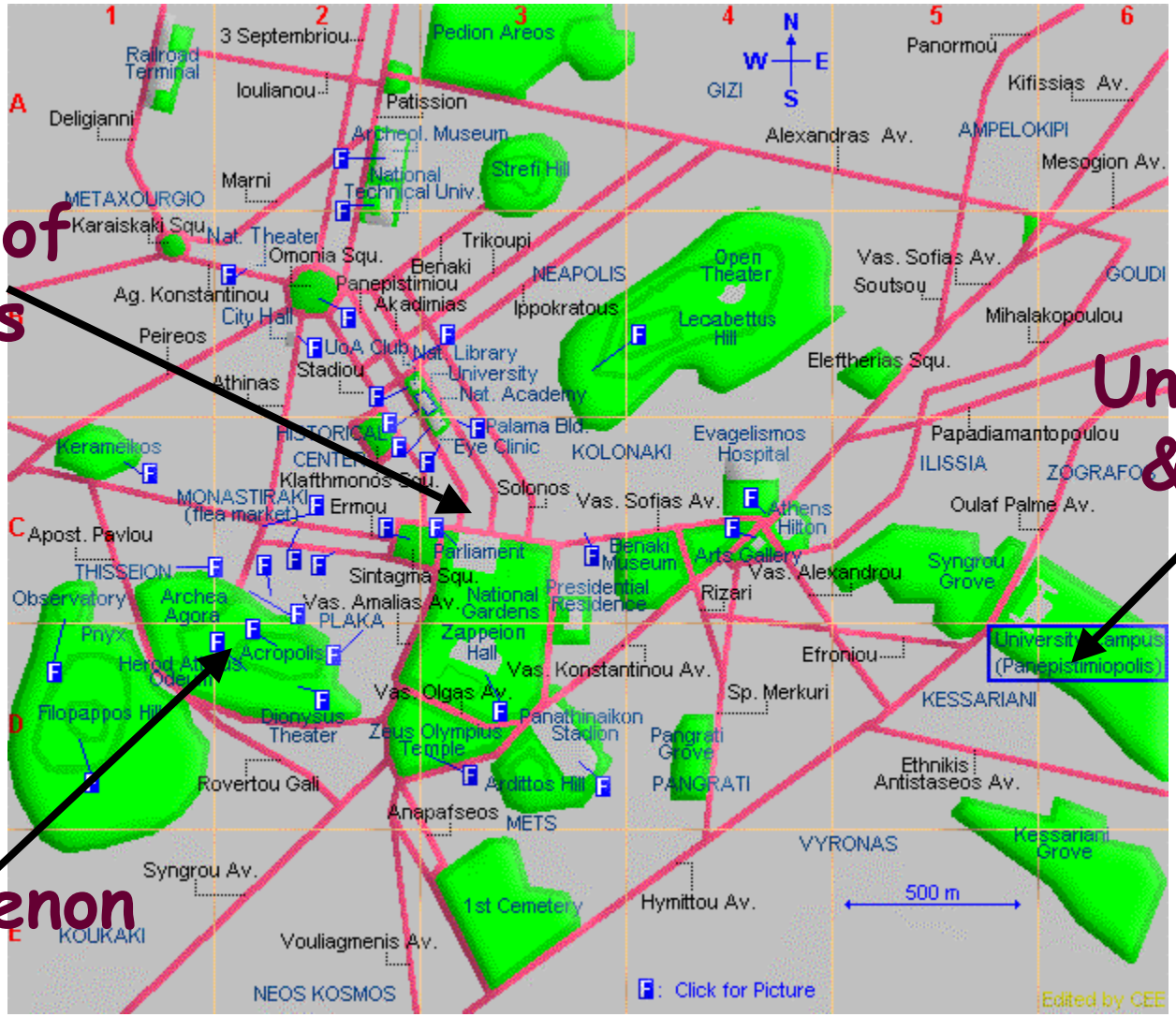
Europe


Iceland
Atlantic Ocean
Finland
Norway
Sweden
Estonia
North Sea
Baltic Sea
Latvia
Russia
Ireland
United Kingdom
Lithuania
Russia
Netherlands
Belarus
Belgium
Germany
Poland
Ukraine
Czech Rep
France
Slovakia
Switzerland
Austria
Moldova
Hungary
Caspian Sea
Slovenia
Croatia
Romania
Georgia
Bosnia
Black Sea
Azerbaijan
Portugal
Yugoslavia
Bulgaria
Armenia
Spain
Italy
Corsica, Sardinia (Italy)
Albania
FYROM
Iran
Madeira (Portugal)
Turkey
Gibralter Strait
Iraq
Ibiza, Mallorca, Menorca (Spain)
Canary Islands (Spain)
Sicily (Italy)
Greece
Syria
Morocco
Algeria
Cyprus
Malta
Lebanon
Tunisia
Crete (Greece)
Meditteranean Sea
Israel
Libya
Egypt

Greece

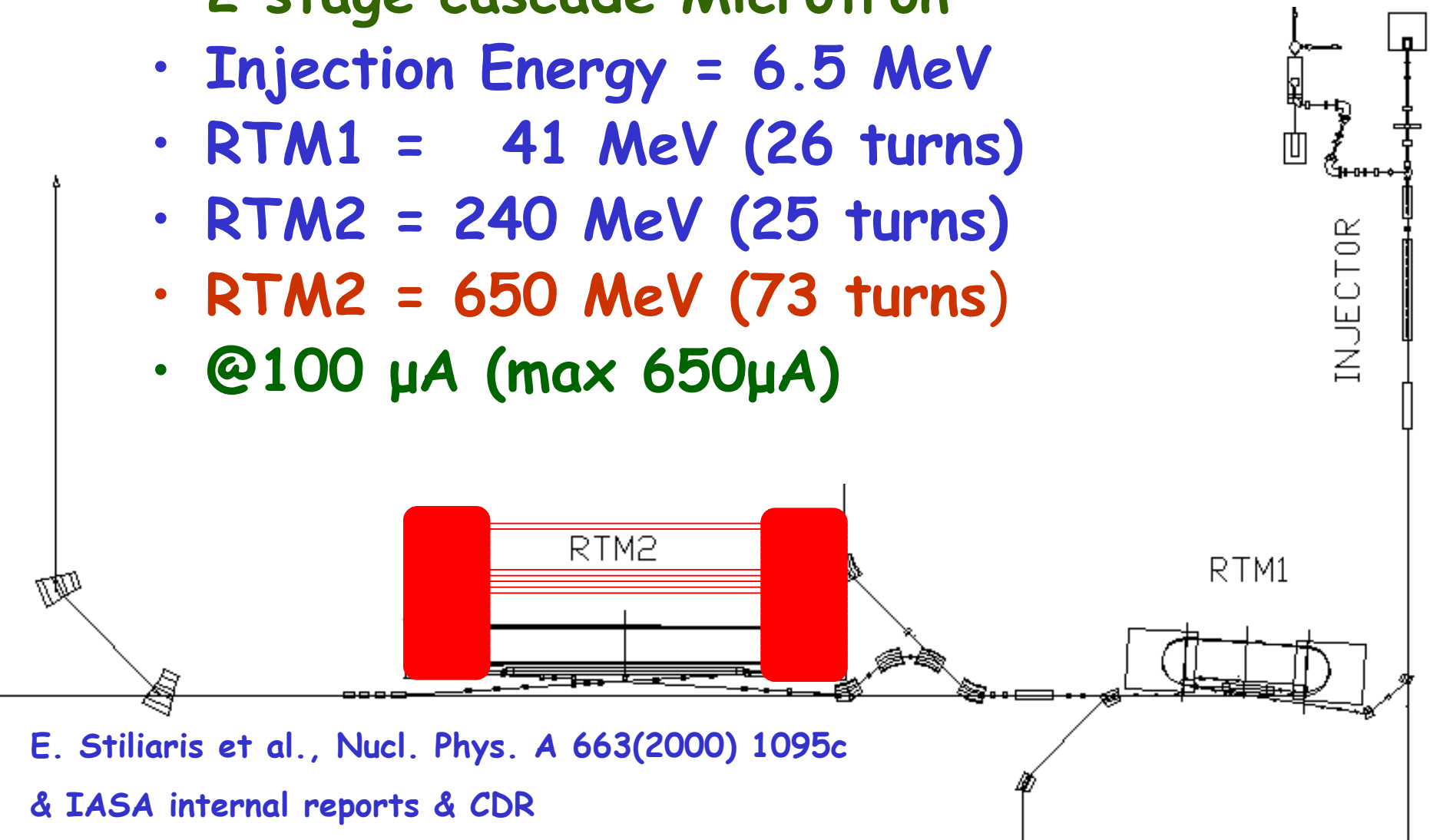

BULGARIA
F.Y.R.O.M.
ALBANIA
Alexandroúpolis
Kavála
Thessaloníki
Límnos
Ioánnina
Lárisa
Vólos
Kérkyra
Lésvos
TURKEY
Aegean Sea
Chalkís
Chíos
Pátrai
Elefsís
Peraiéfs
ATHENS
Sámos
Ionian Sea
Náxos
Kos
Rhodes
Sea of Crete
Mediterranean Sea
Irákleion
Crete
0 75 150km
0 75 150 mi

Map of Athens



One major task is building a cw RT Microtron machine

- 2 stage cascade Microtron
- Injection Energy = 6.5 MeV
- RTM1 = 41 MeV (26 turns)
- RTM2 = 240 MeV (25 turns)
- RTM2 = 650 MeV (73 turns)
- @100 μA (max 650μA)



E. Stiliaris et al., Nucl. Phys. A 663(2000) 1095c

& IASA internal reports & CDR

Emittance

Injection

$\varepsilon_x = \varepsilon_y < 2\pi$ mm mrad @ 100 keV measured
$\varepsilon_{tr} = 0.1\pi$ mm mrad @ 10 MeV
$\varepsilon_L = 6.5\pi$ keV deg

RTM1

Eigenellipse in output orbit

$\alpha = -1.02$

$\beta = 0.27$ deg/keV

$\gamma = 7.48$ keV/deg

RTM2

Eigenellipse in output orbit

$\alpha = -0.91$ (-0.91)

$\beta = 0.045$ (0.012) deg/keV

$\gamma = 40.2$ (88.4) keV/deg

The situation now…….

- **What we have**

- Linacs
- RF – Klystrons (2)
- End magnets (2 pairs)
- Diagnostics
- Magnets
- Power supplies
- Cooling

- **What we need**

- **Spectrometers**
- Polarize source
- More vacuum equipment, magnets, power supplies eTc
- Scattering chamber, cryogenics

And ……

- **A new Building!!**

In the meantime, we are building a 10 MeV injector. We do occupy now the so called

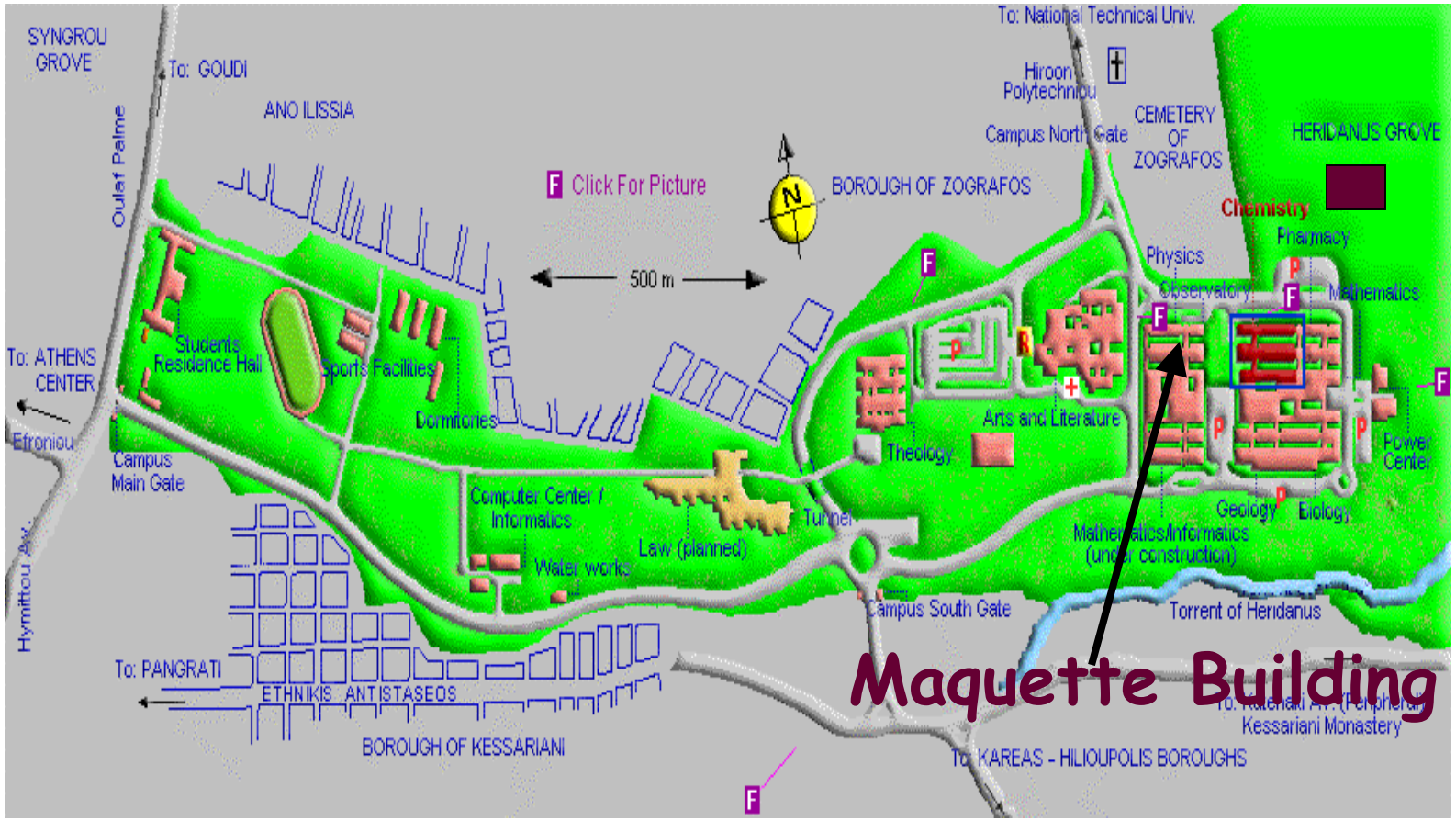
"Maquette" building

(~1000 m^2)

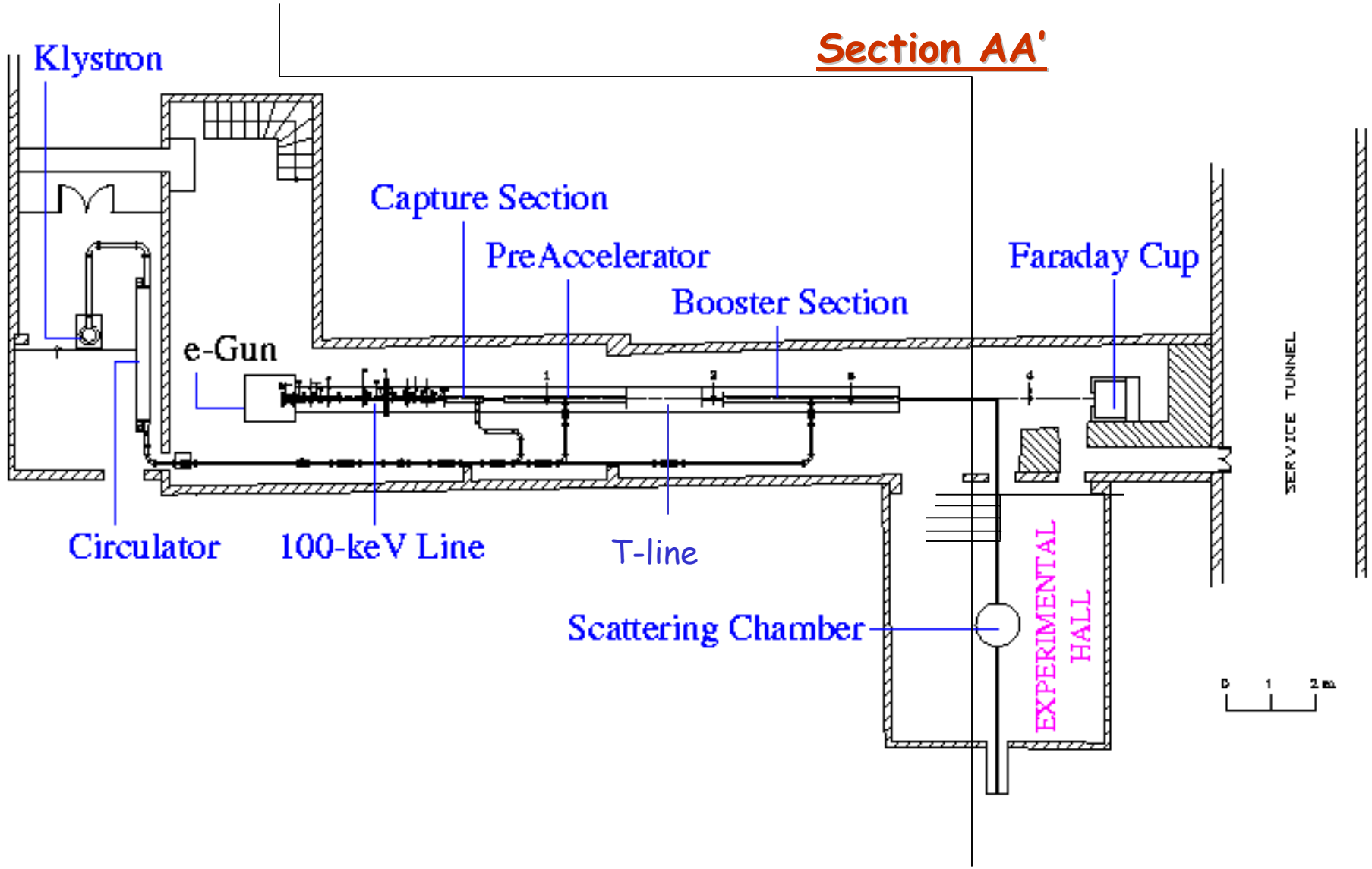
University Campus

1,5 km away from the center of Athens

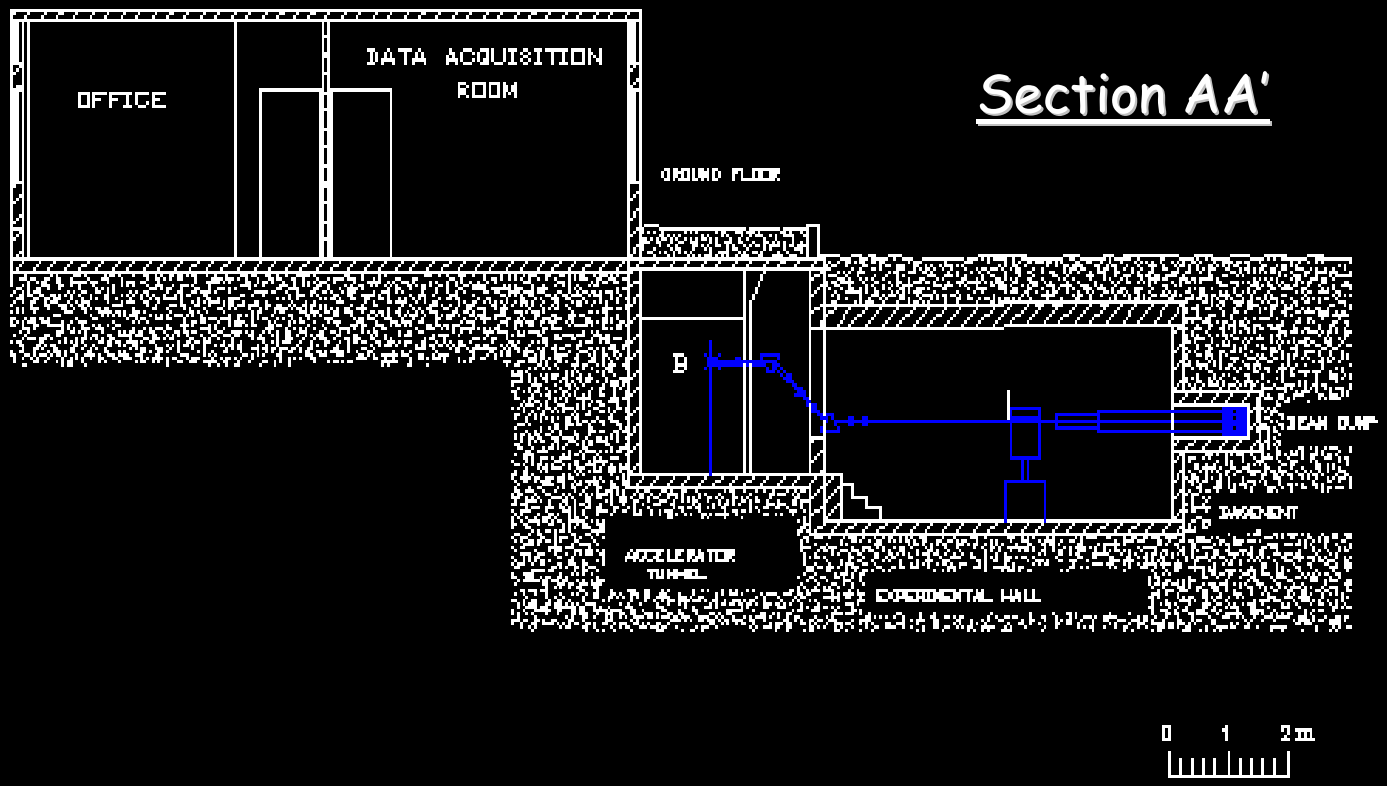
NTUA



10 MeV Linac Layout (Present Status)



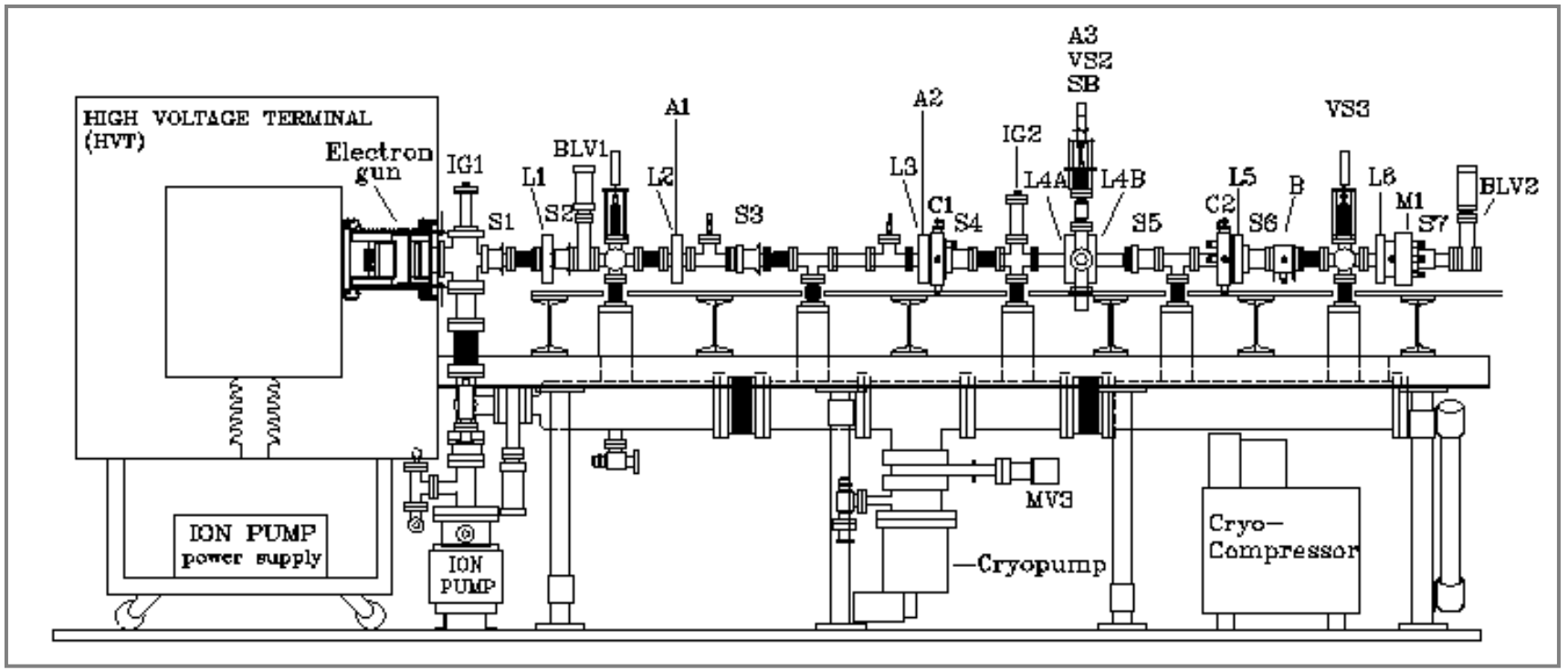
CROSS SECTION PP' OF ACCELERATOR TUNNEL & EXPERIMENTAL HALL



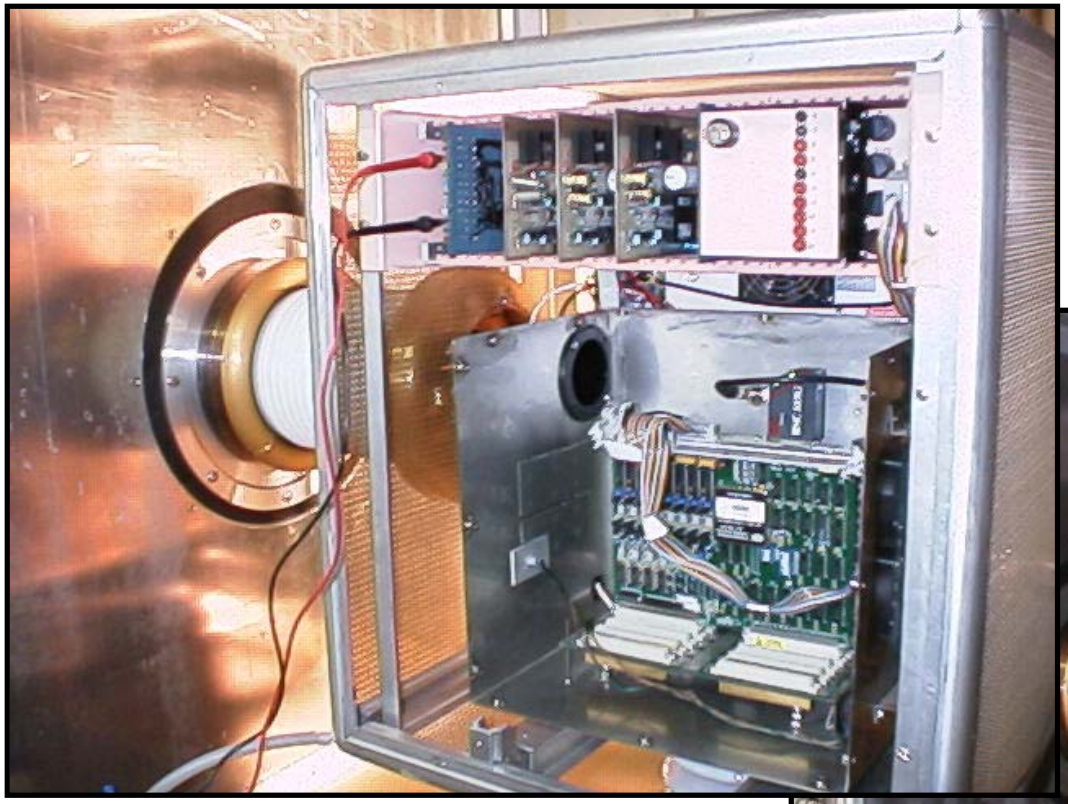
Section AA'

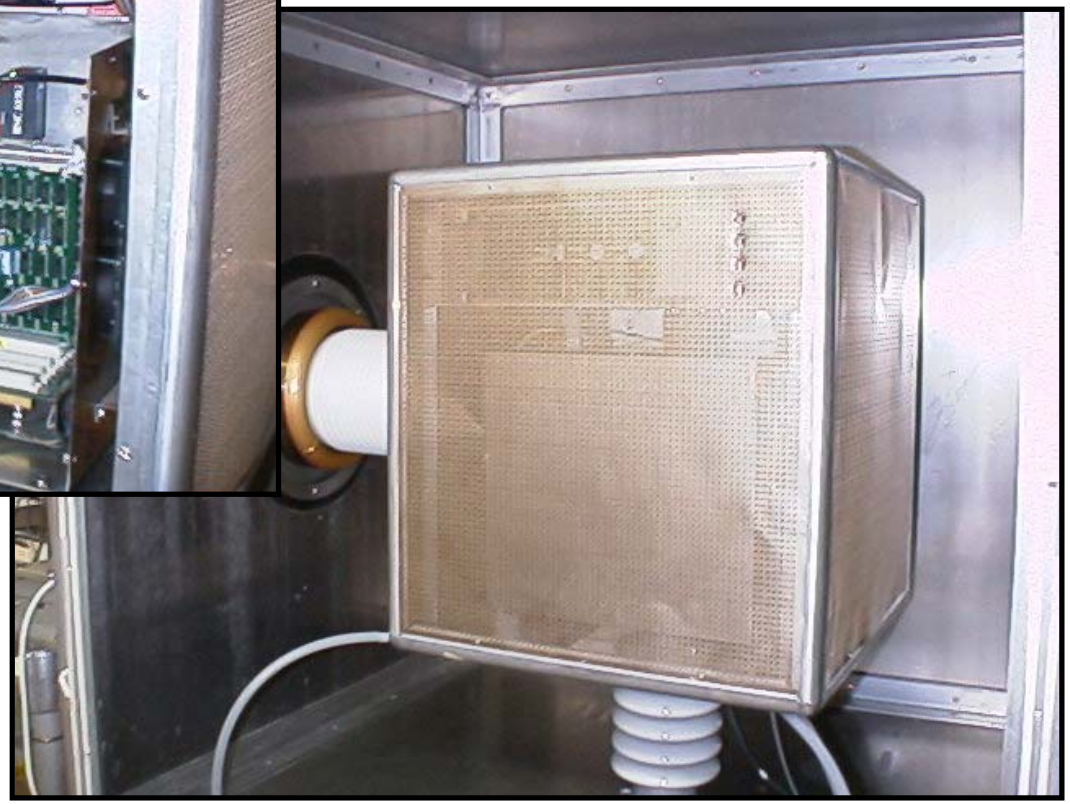
RTM Injector

- Thermionic Electron Gun [100keV (β=v/c=0.56)]
- Chopper - Buncher System
- Capture Section (β-graded) [1.5 MeV (β=0.95)]
- Pre-Accelerator (few MeV, β~1)
- Booster (4 m long → 10.5 MeV)



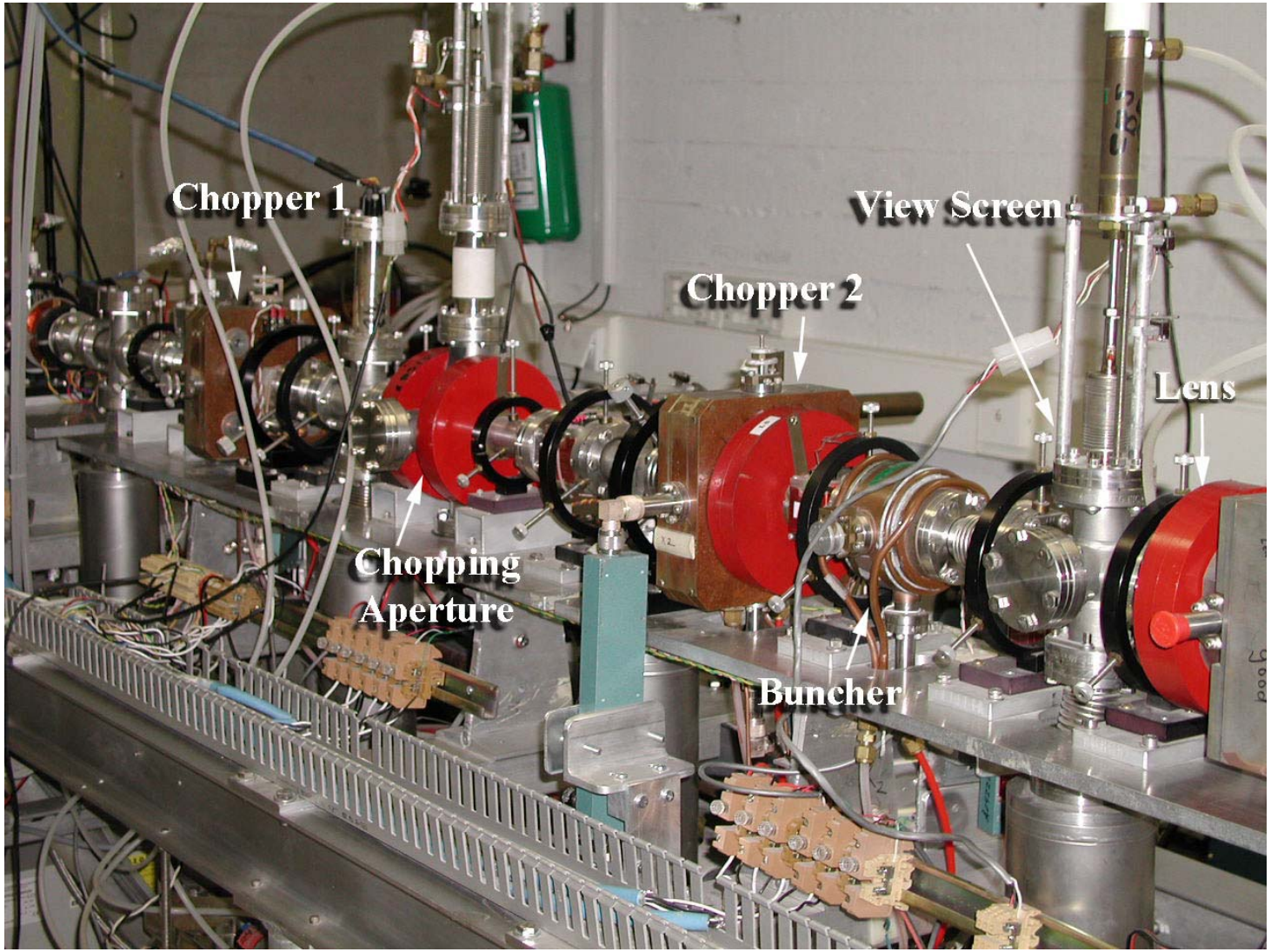
Electron Gun – Hermosa – 100keV



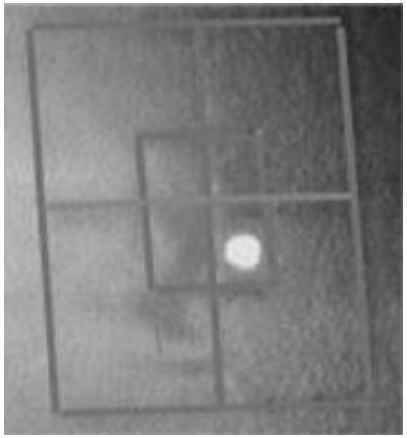
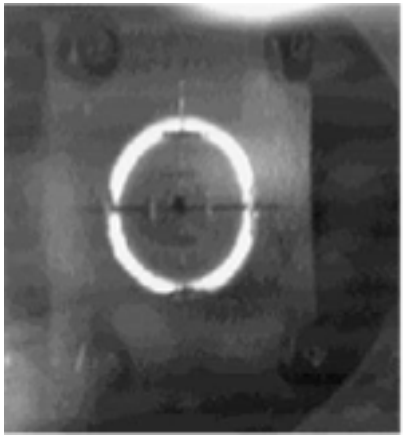
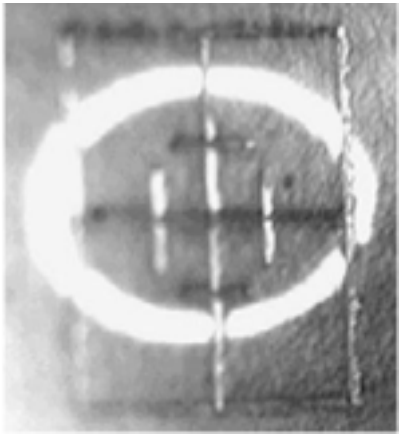
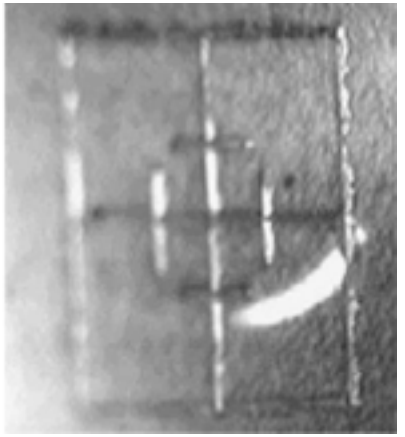


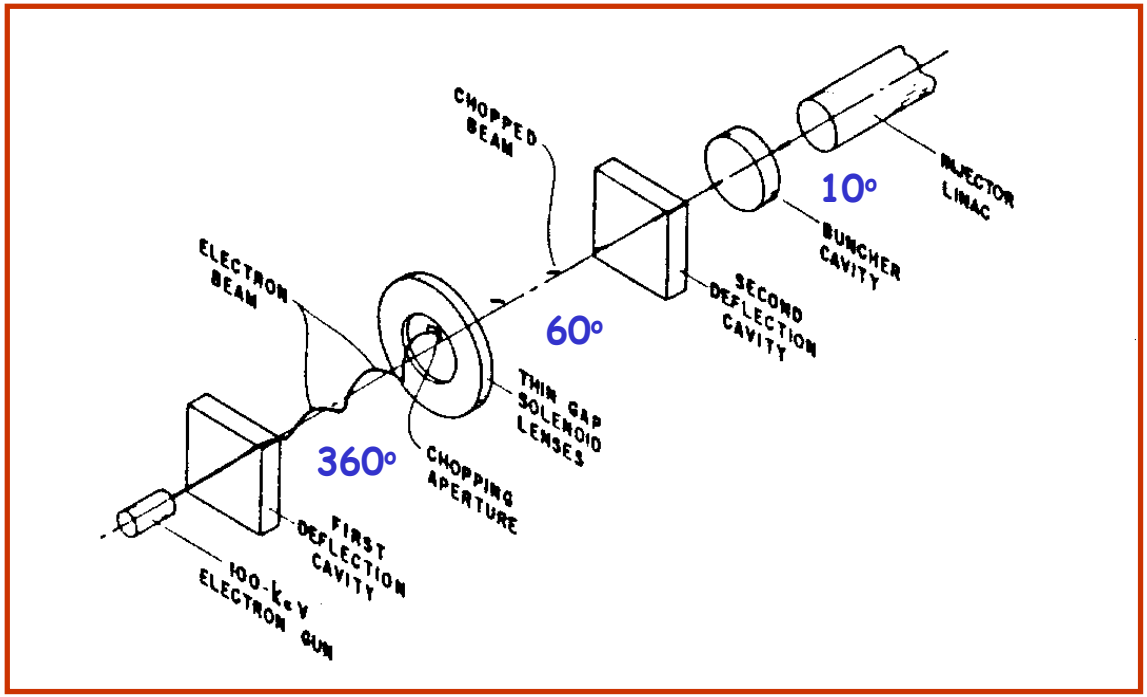
Adding a VME crate
& fiber optic link

100-keV (Chopper-Buncher) Line

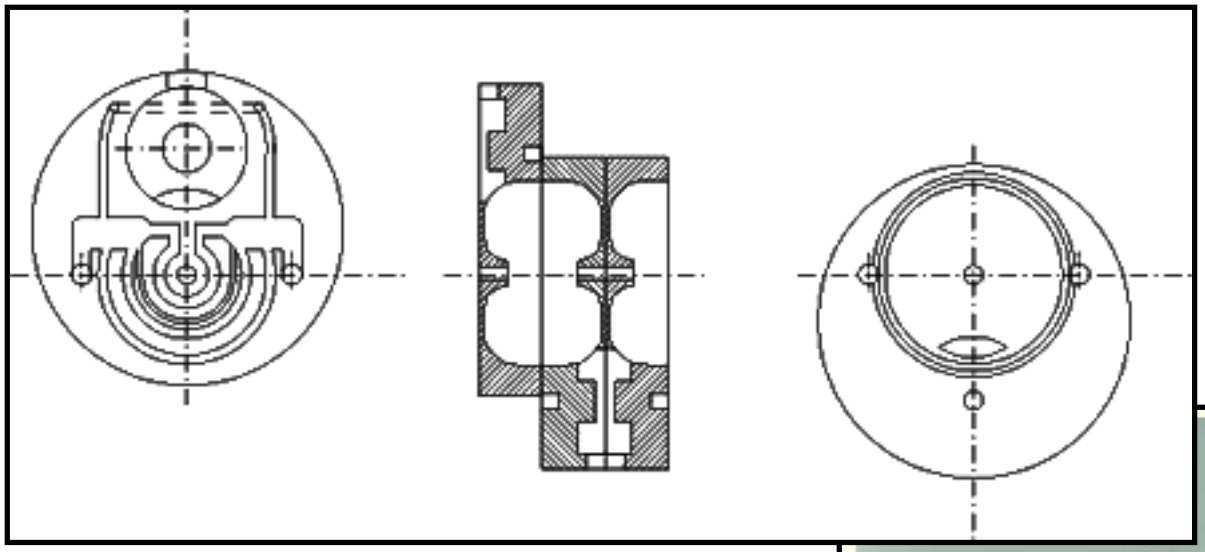


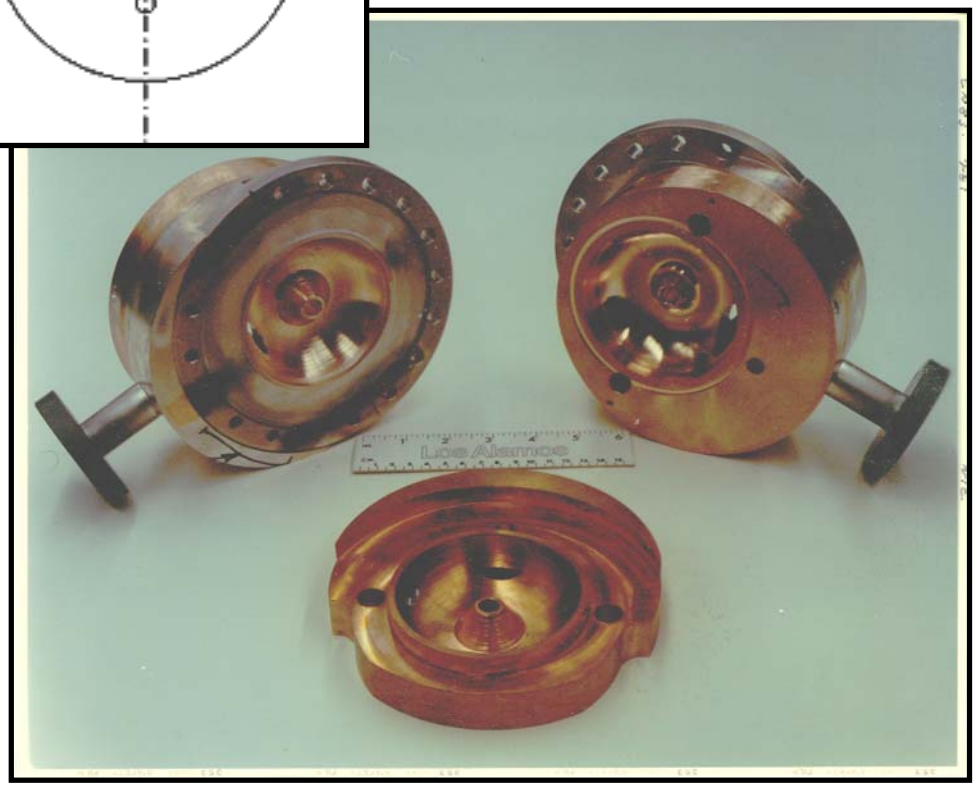
100-keV (Chopper-Buncher) Line



Capture Section & Pre-Accelerator

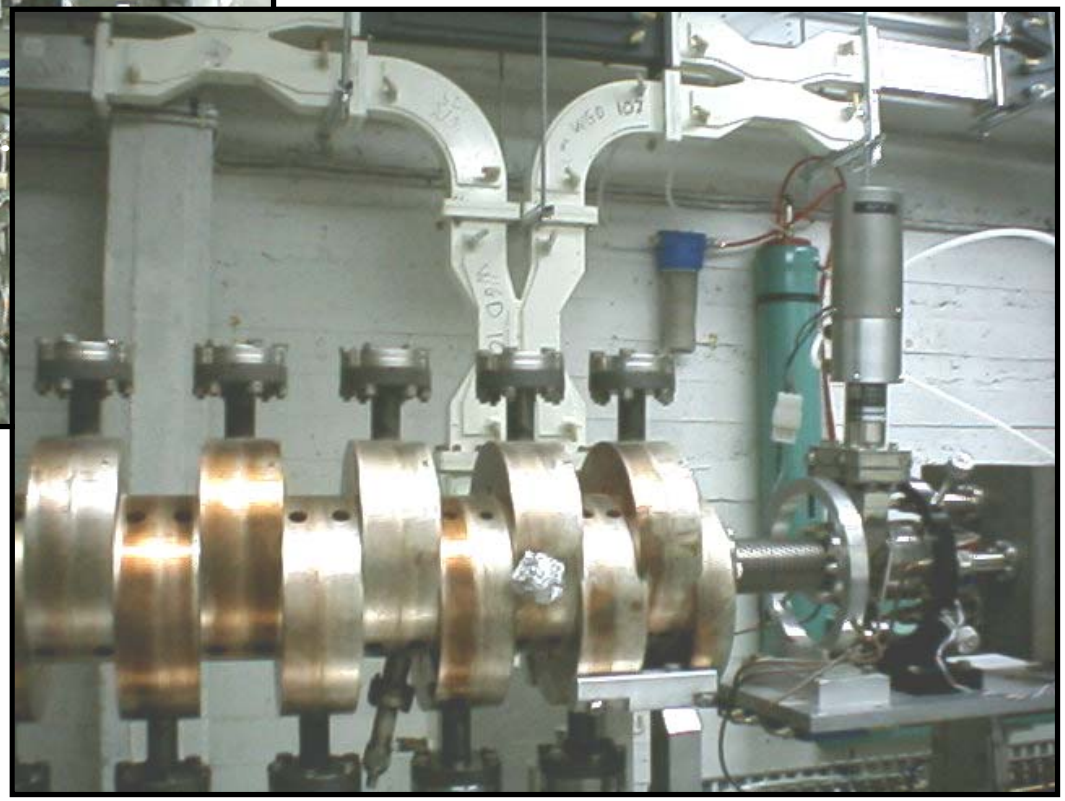




Los Alamos
Side coupled
structures

Capture Section & Pre-Accelerator

Preaccelerator :
2.7m, to 5 MeV
Eff. shunt imped.
82.5 MΩ/m



Capture :0.9m to 1.2 MeV, tapered β

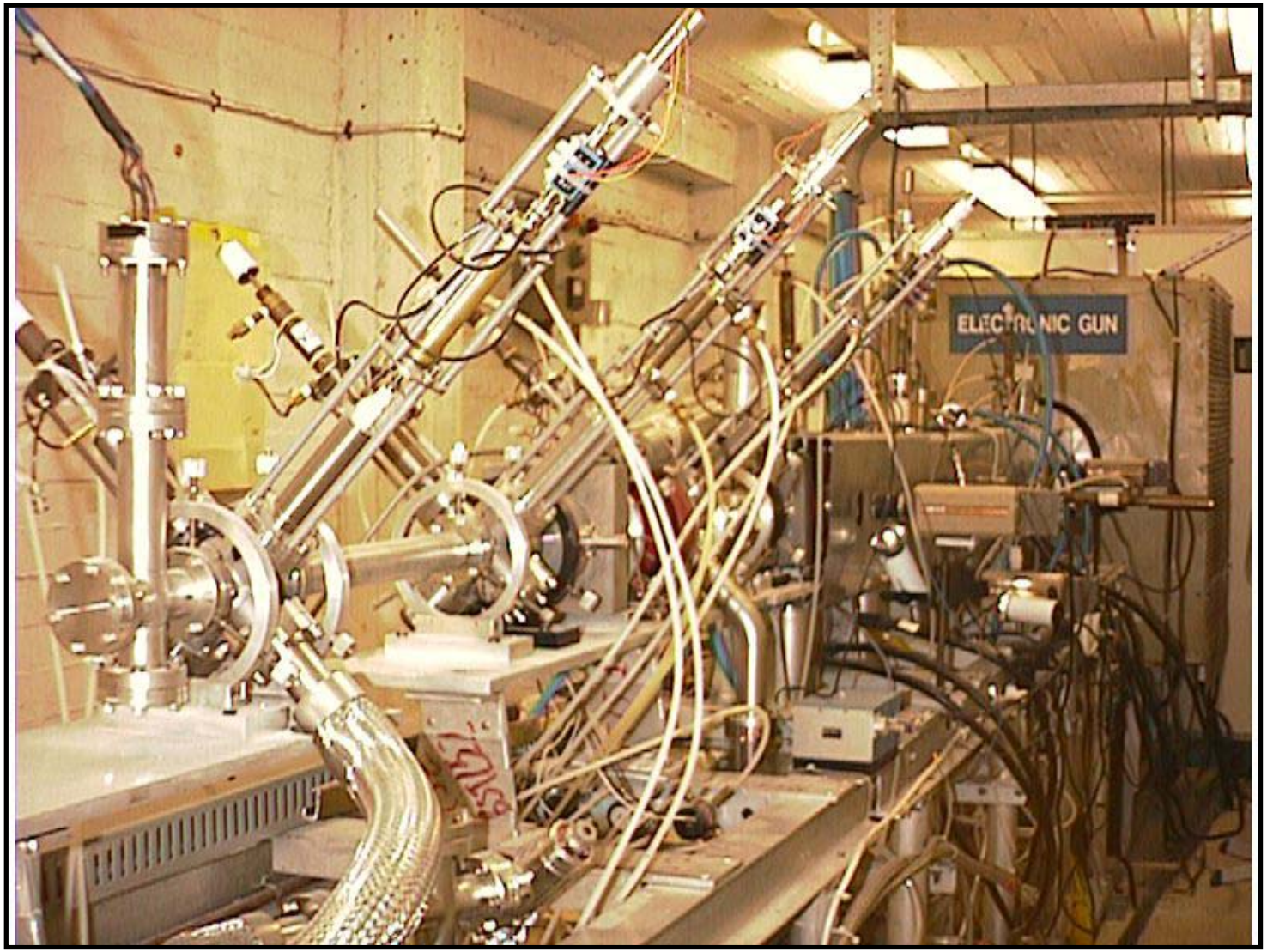
The 4m Booster

1,4MV/m
@
10.5 MeV

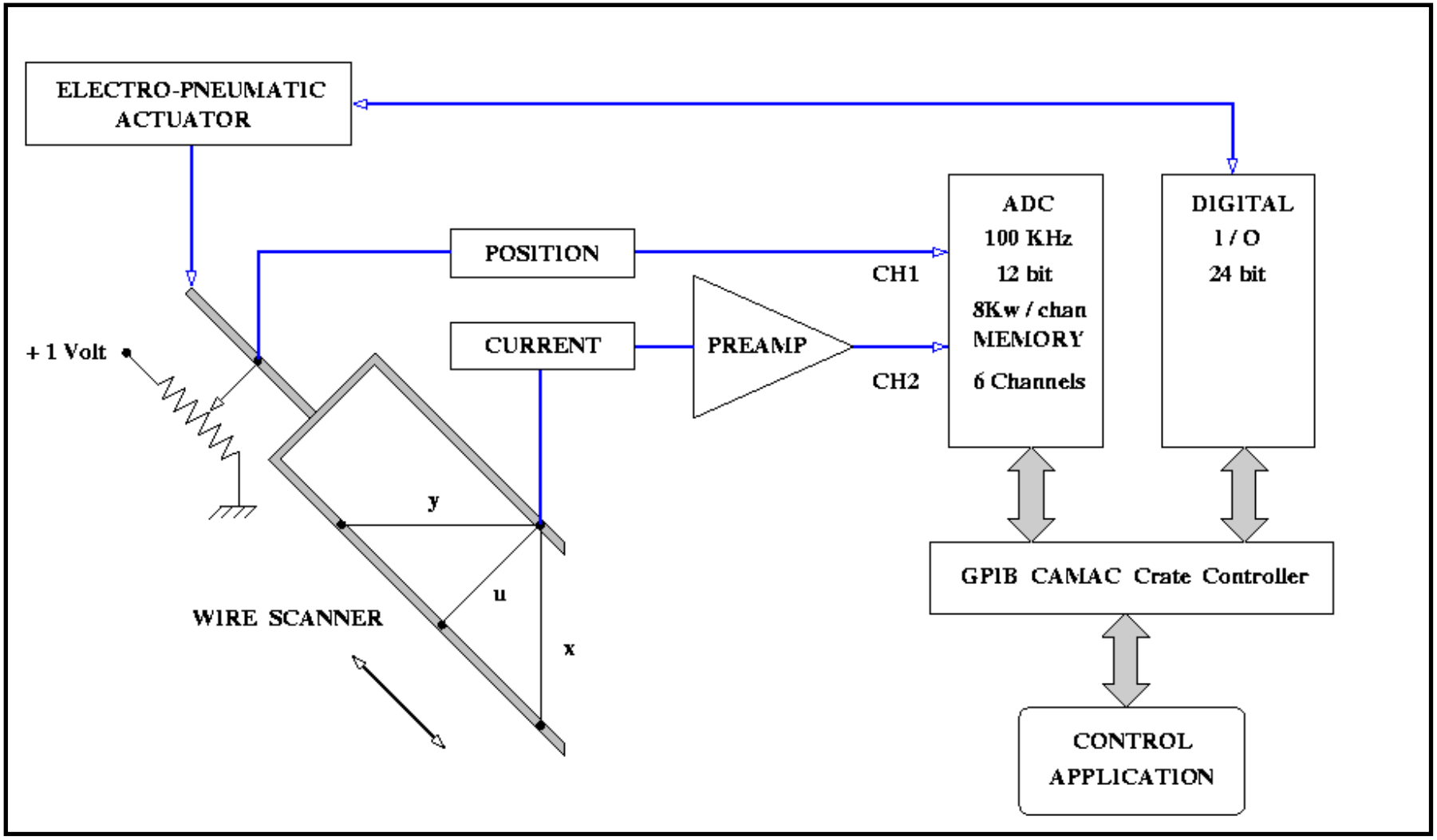
RF related parameters for the 10 MeV Maquette project

	Capture	Preaccel.	Booster
Length (m)	0.9	2.7	4
Gradient (MV/m)	1.6	1.4	1.4
Dissipated RF (kW)	27.9	64.1	95.0
Beam RF (kW)	0.14	0.38	0.54
TOTAL RF (kW)	**28**	**65**	**96**

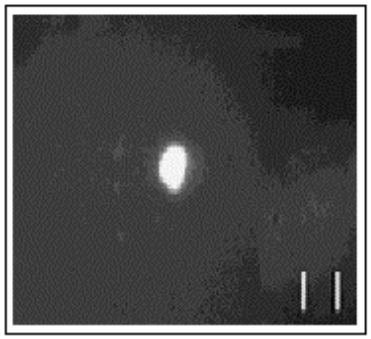
Beam diagnostics

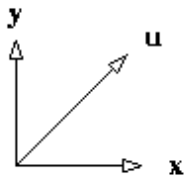


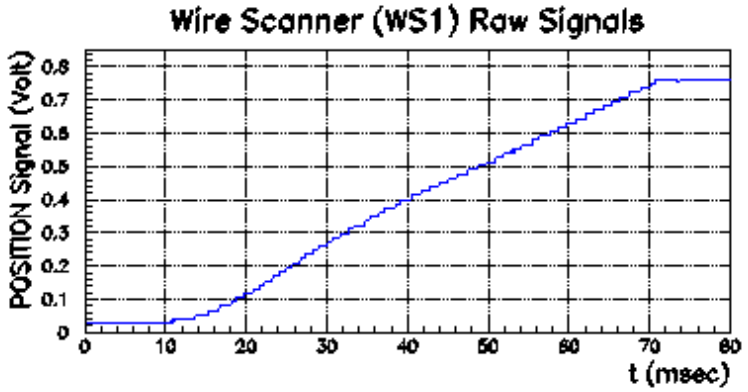
Wire Scanners

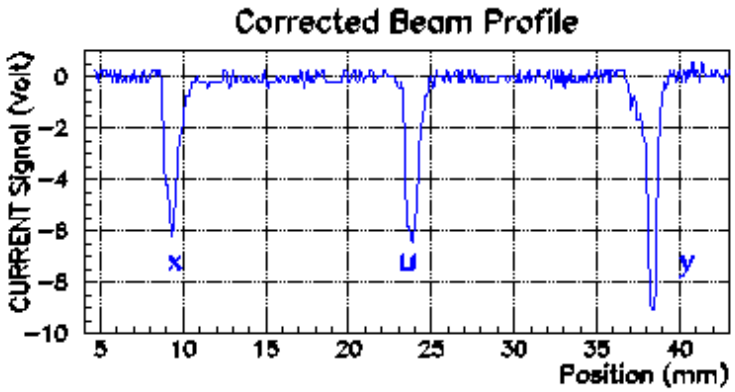


Wire Scanners



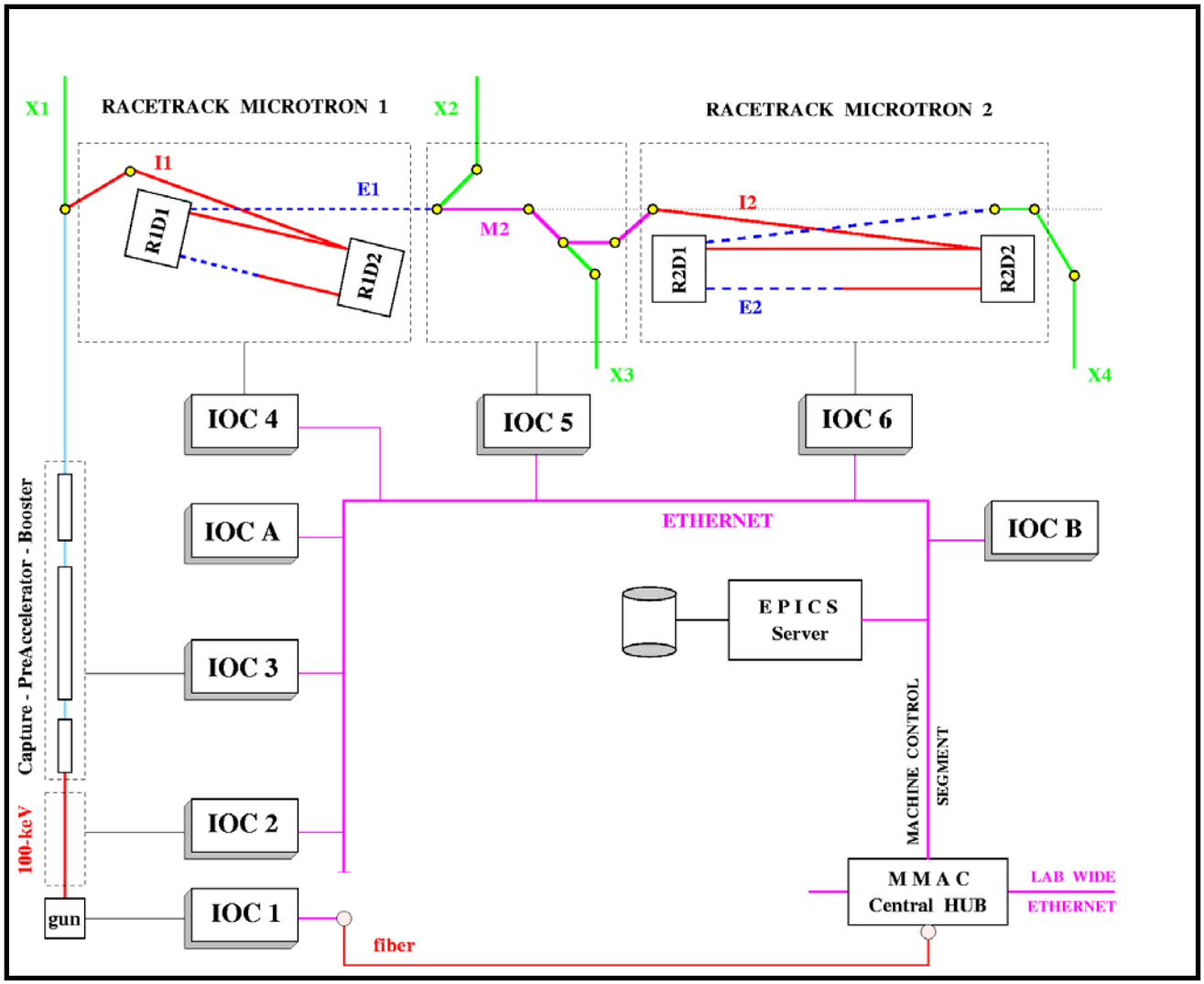






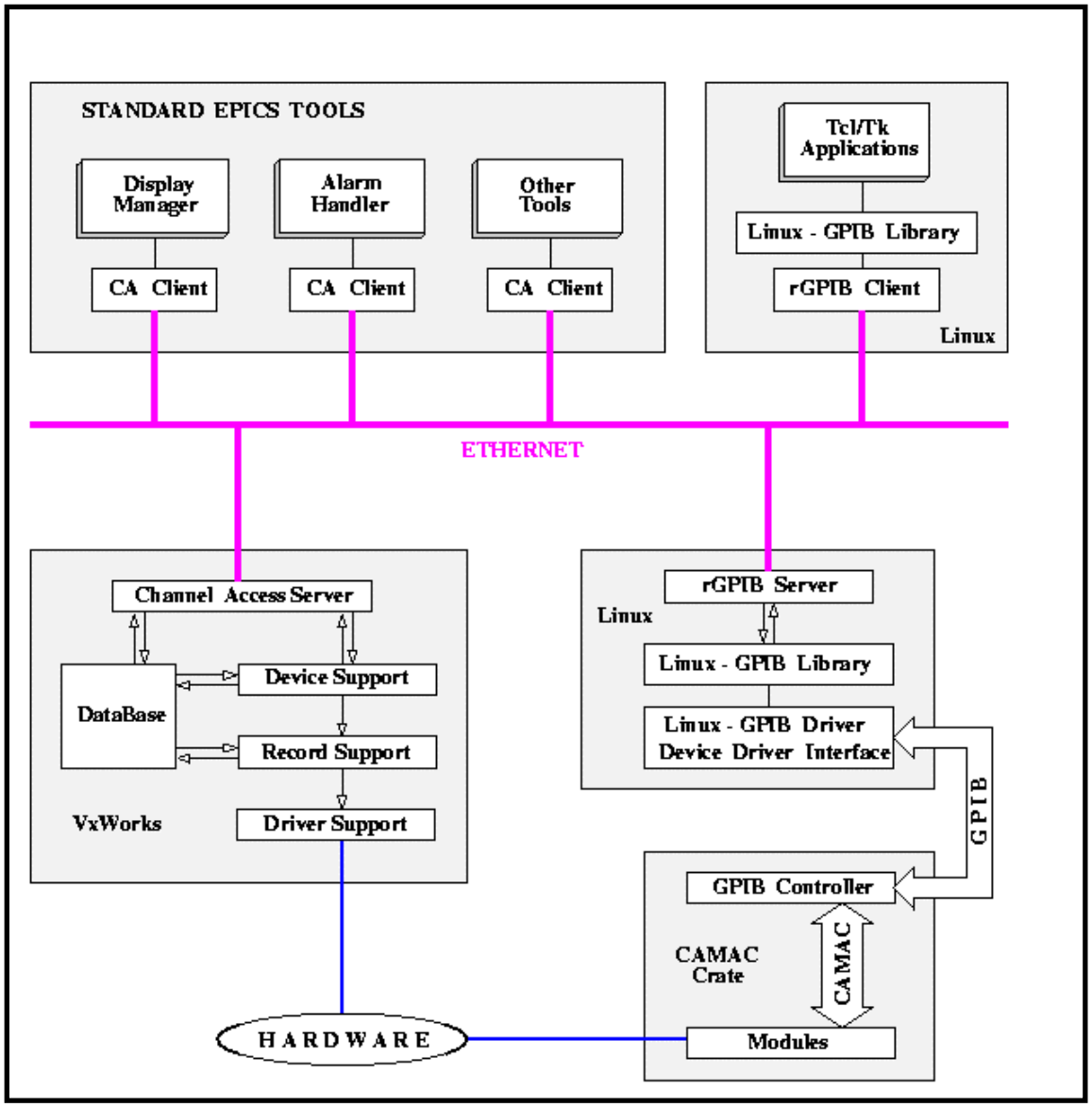
$s = s(t)$

RTM Control System Architecture

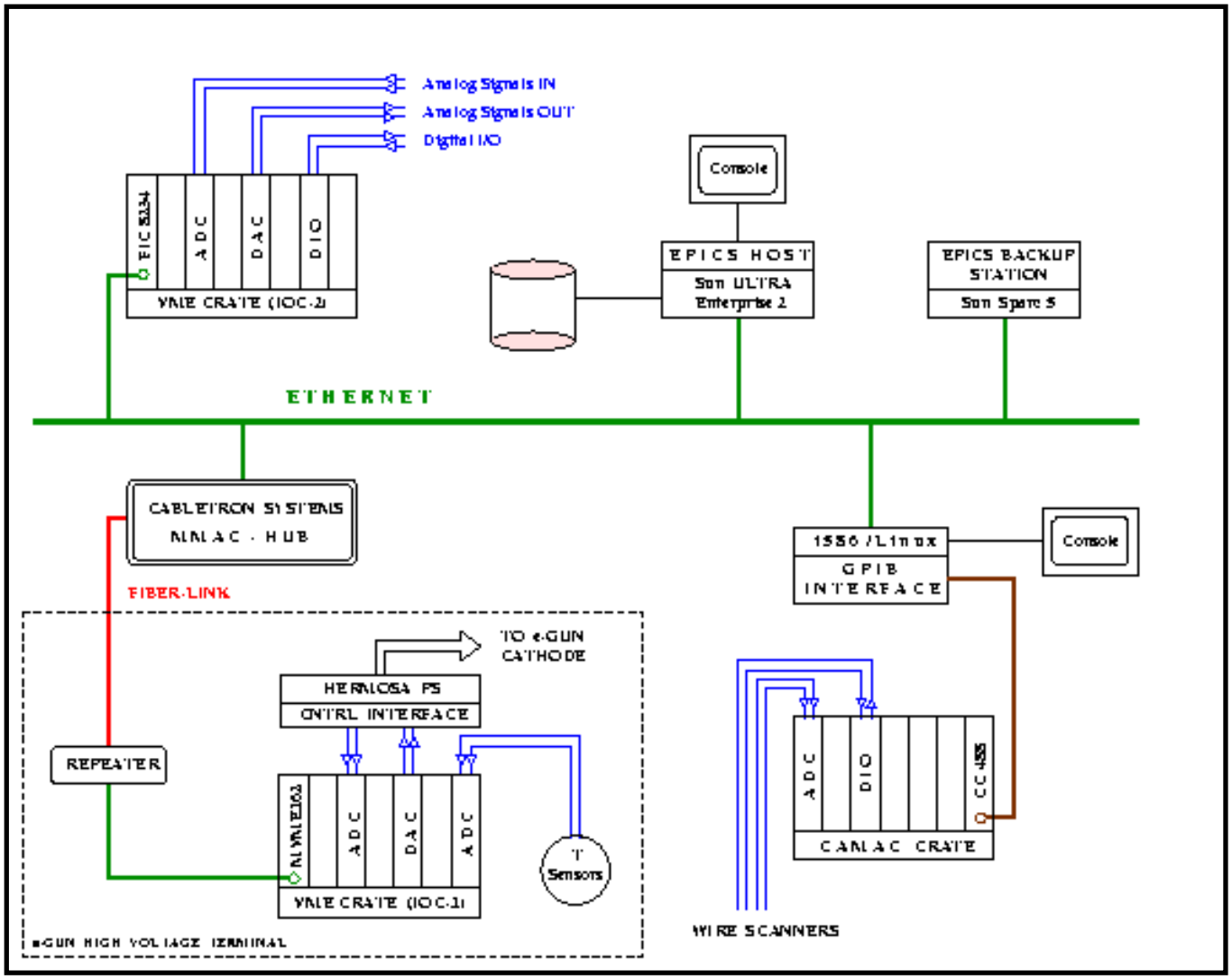


EPAC -98

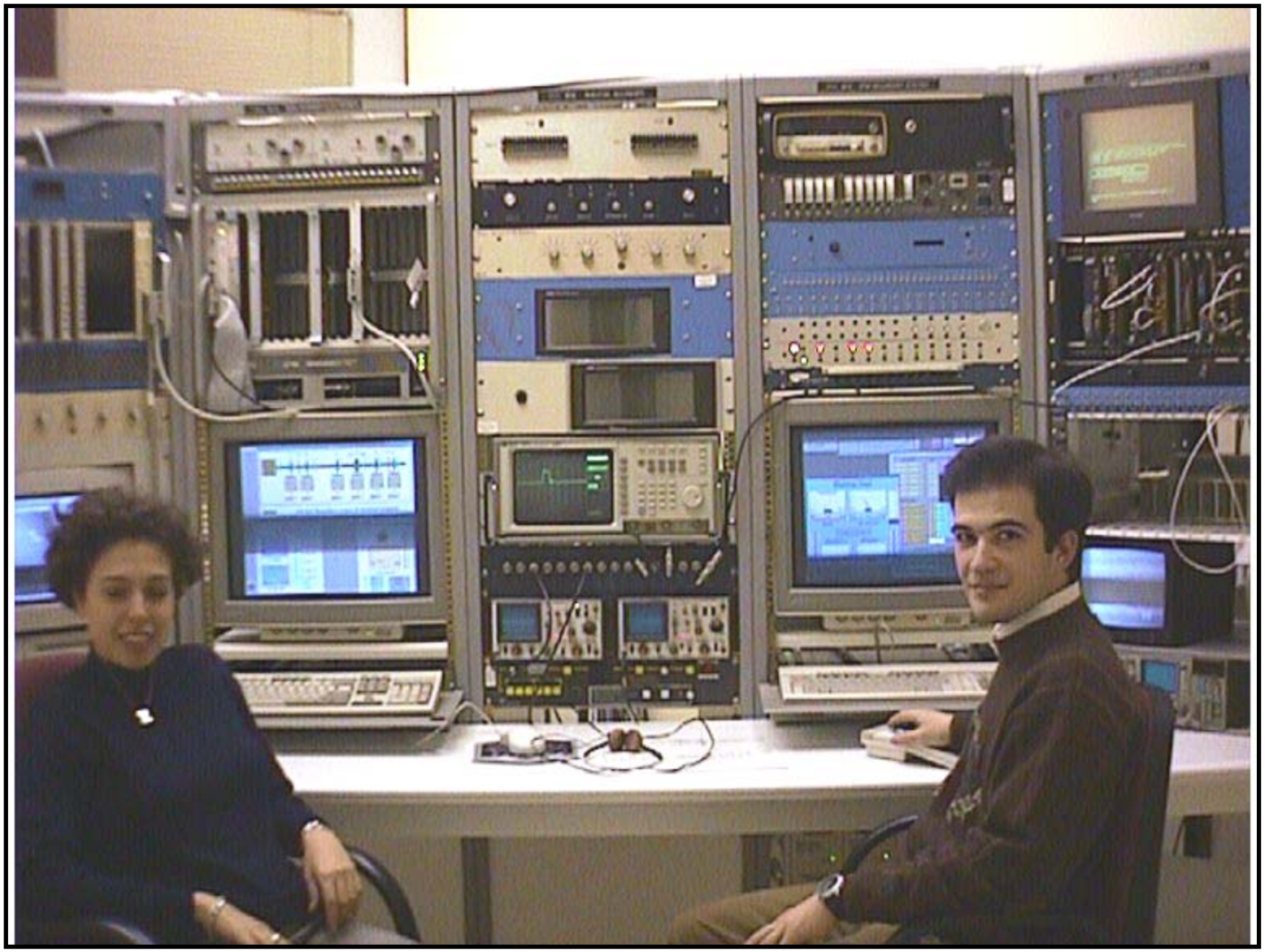
EPICS @ IASA

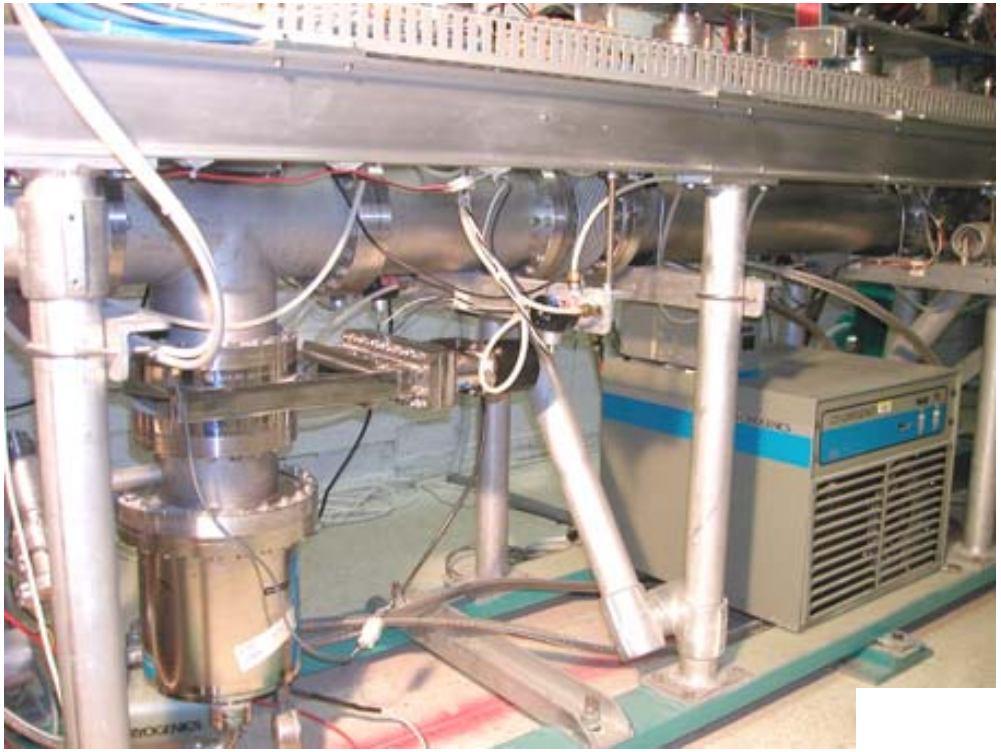

STANDARD EPICS TOOLS
Display Manager
Alarm Handler
Other Tools
CA Client
CA Client
CA Client
Tcl/Tk Applications
Linux - GPIB Library
rGPIB Client
Linux
ETHERNET
Channel Access Server
DataBase
Device Support
Record Support
Driver Support
VxWorks
rGPIB Server
Linux
Linux - GPIB Library
Linux - GPIB Driver
Device Driver Interface
GPIB
GPIB Controller
CAMAC Crate
CAMAC
Modules
HARDWARE

EPICS @ IASA

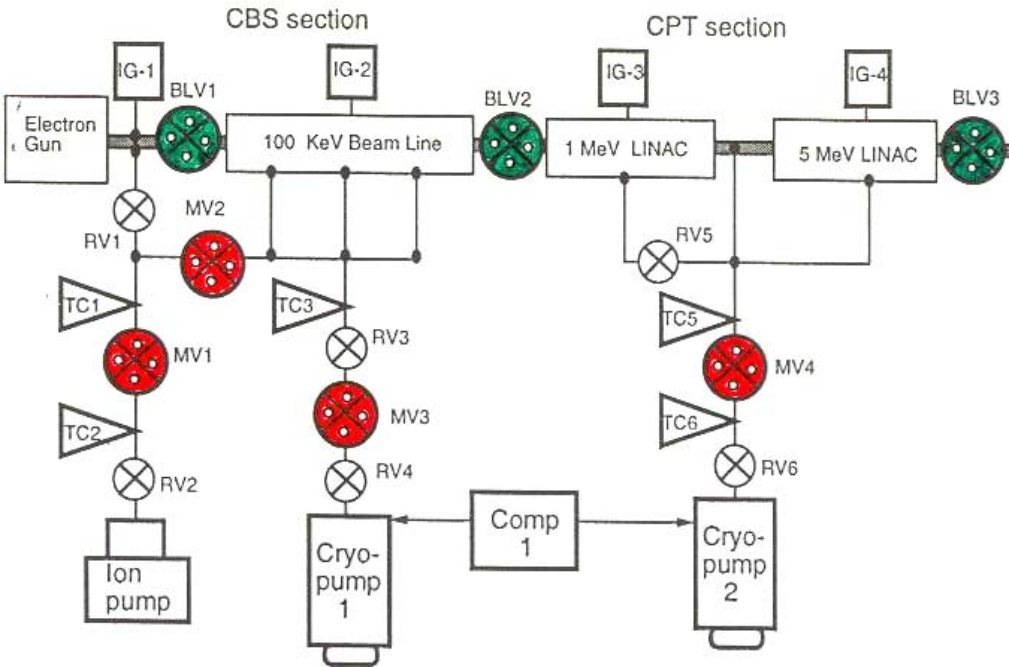

Analog Signals IN
Analog Signals OUT
Digital I/O
VME CRATE (IOC-2)
ADC
DAC
DIO
Console
EPICS HOST
Sun ULTRA Enterprise 2
EPICS BACKUP STATION
Sun Sparc 5
ETHERNET
CABLETRON SYSTEMS
MMAC - HUB
FIBER-LINK
1586 / Linux
GPIB INTERFACE
Console
TO e-GUN CATHODE
HERMOSA PS
CNTRL INTERFACE
REPEATER
VME CRATE (IOC-1)
ADC
DAC
ADC
T Sensors
e-GUN HIGH VOLTAGE TERMINAL
ADC
DIO
CAMAC CRATE
WIRE SCANNERS

EPICS @ IASA

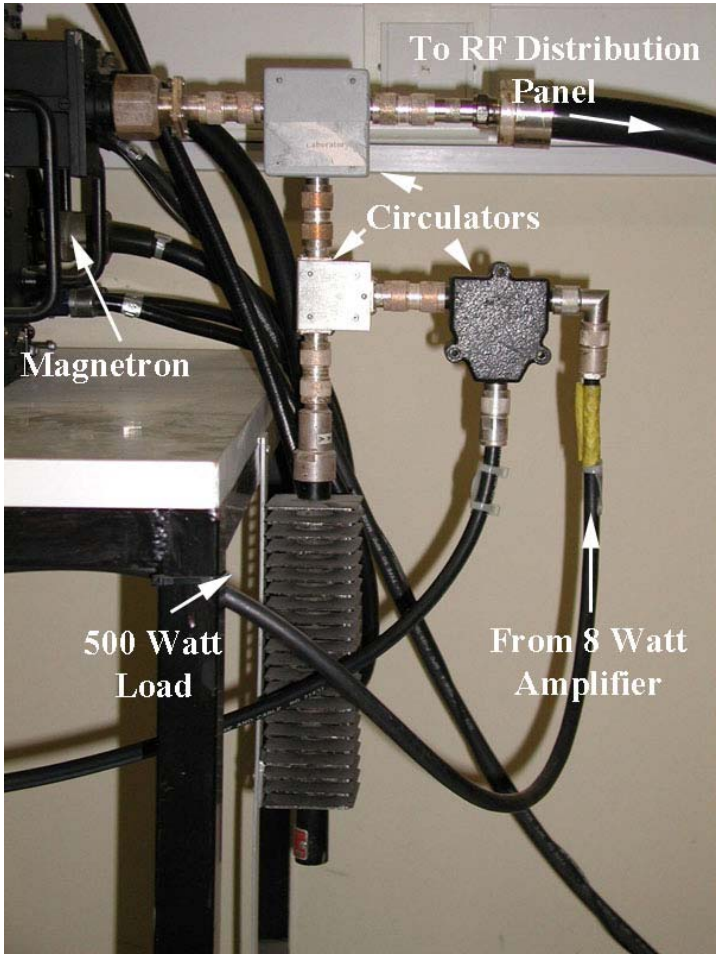




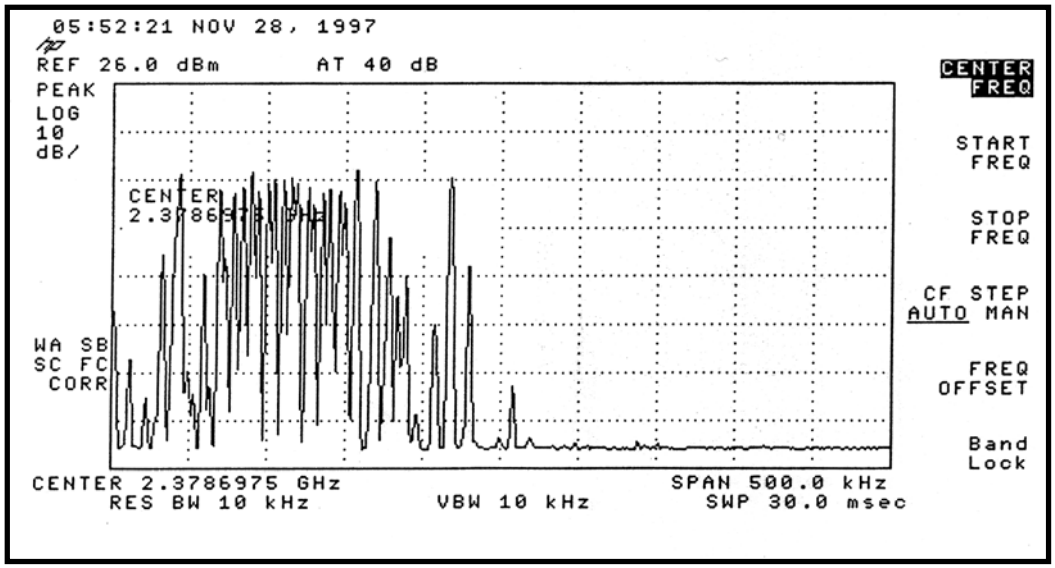
The vacuum system

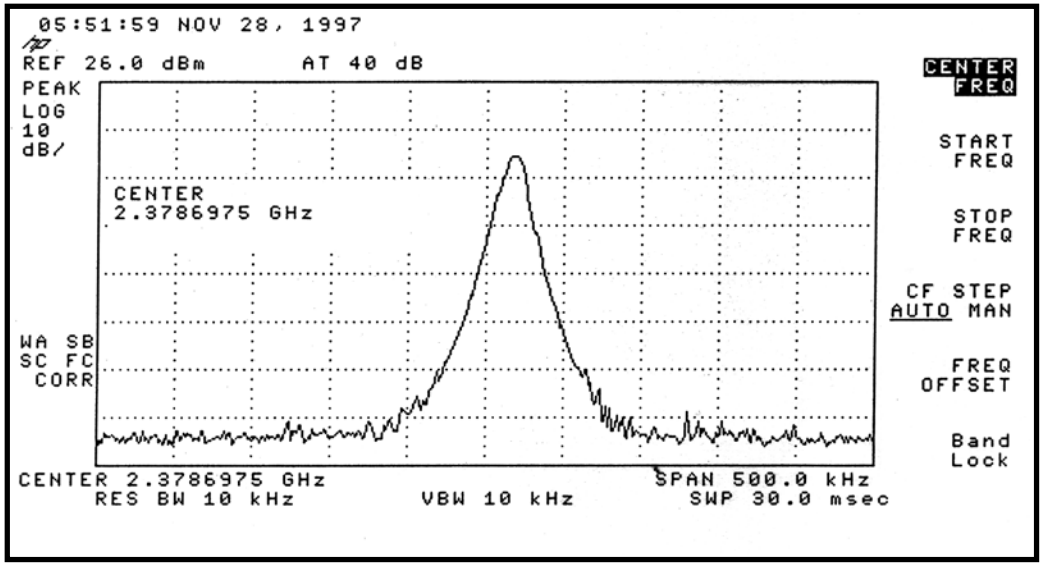


Low power RF for the 100 keV line



Low power RF @ IASA (230W Magnetron)

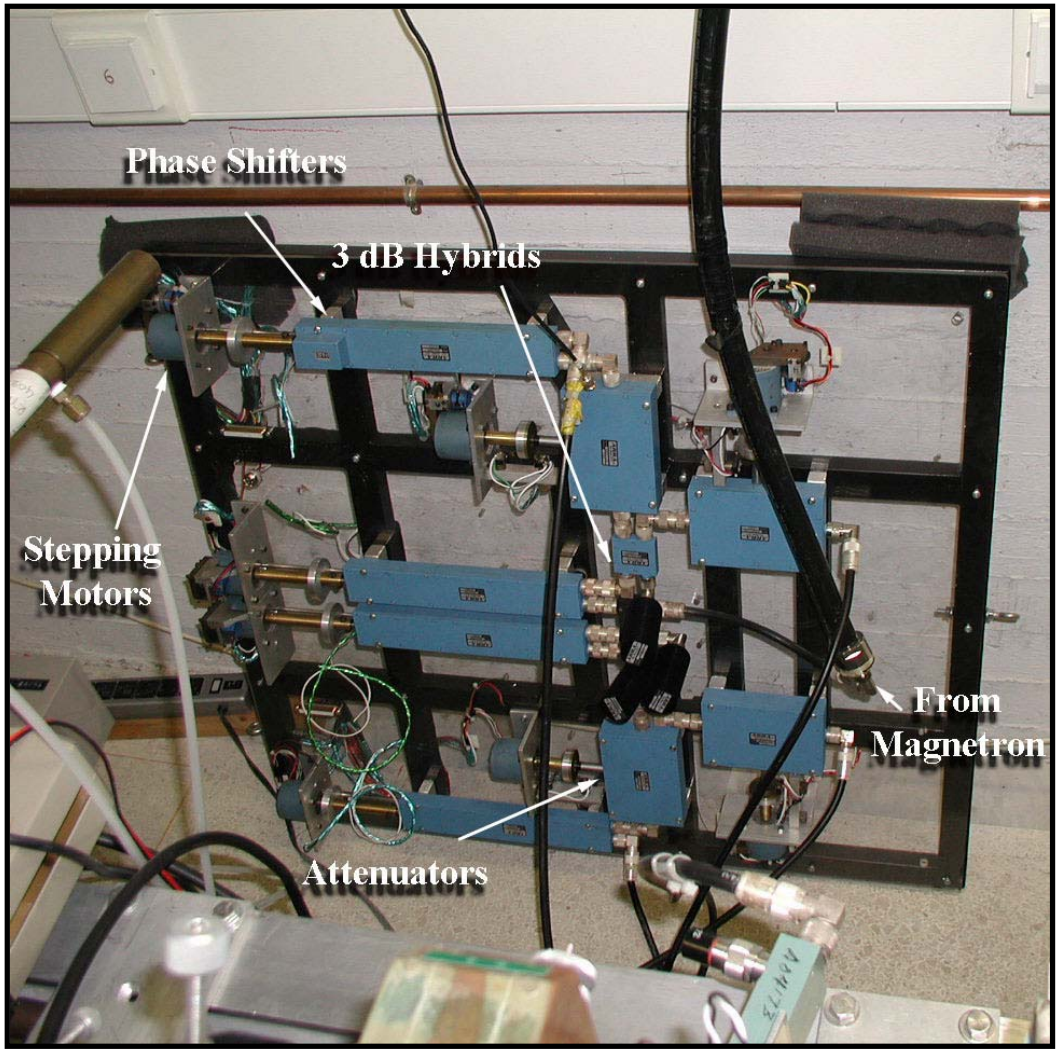




Injection locking

Low power RF – distribution for the two choppers and buncher

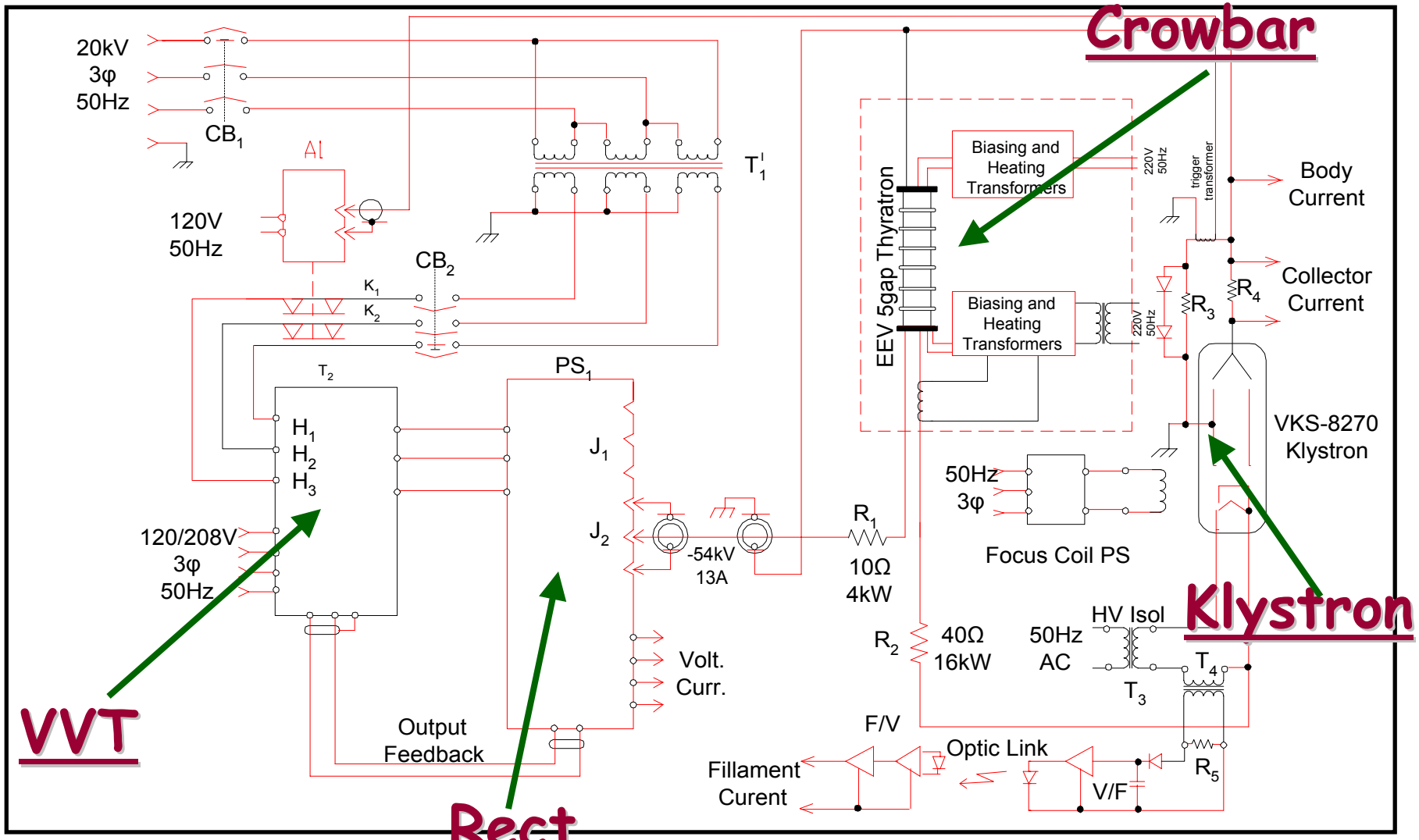
2380 MHz



High power RF @ IASA

500 kW CW

Klystron : HV & Crowbar schematic plan



A. Zolfaghari et al. Proc. of the PAC'99, NY 2000, MOP158

RF drive system

- Multigap thyratron – CX1194B by EEV
- Max voltage across each gap is 13kV –half the maximum spec. value.
- There is a 50 Ω series resistor (10+40)
- High side of crowbar connected to their intersection. The 40Ω in series with Klystron is much higher in impedance → diverts most of the charge from klystron
- Max peak current through crowbar 54kV/10Ω ~5,4kA
- The 10Ω+crowbar protects 40Ω+klystron

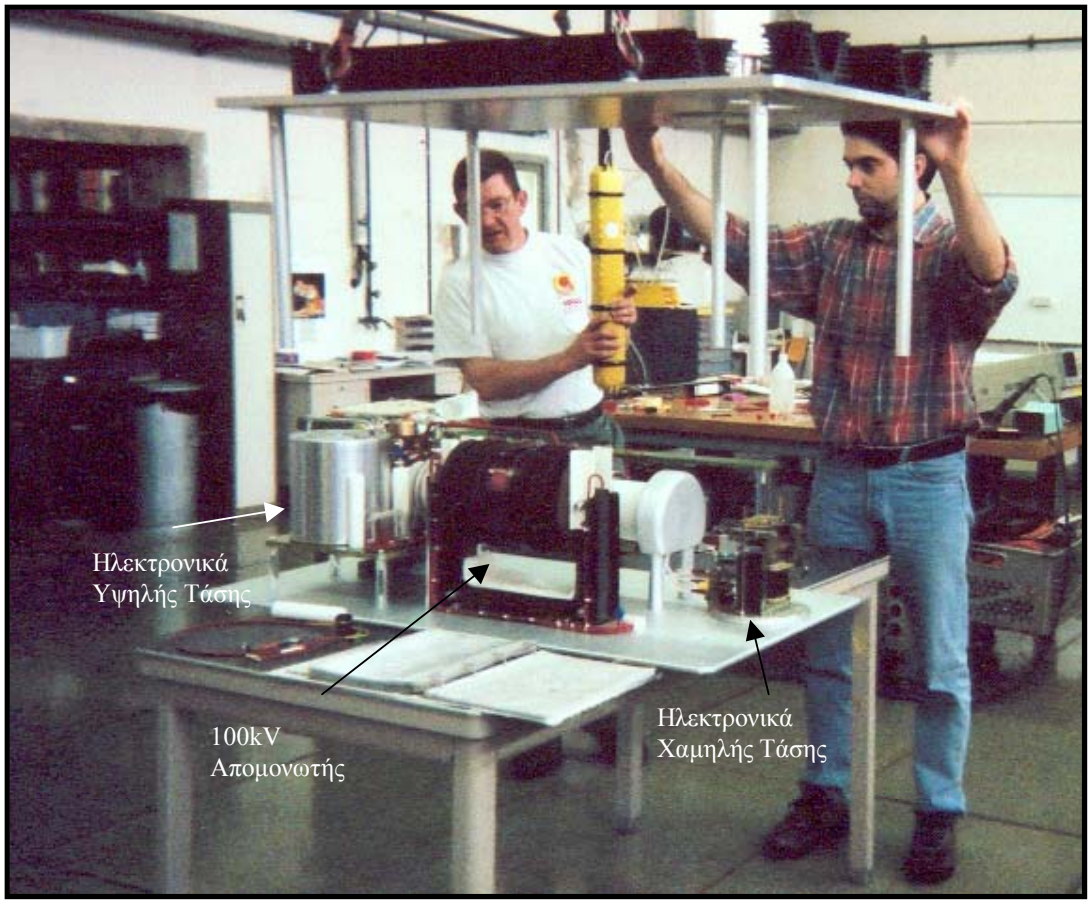
E. Stiliaris et al, Proc. of EPAC 2000, Vienna, Austria, p. 866

High-speed Main disconnect

- The 20kV circuit breaker too slow (3-5 cycles) →use of vacuum relays can achieve opening times in 2 ms (1/5 of cycle) → gives ½ cycle clearing time
- Relays (2 of them) from Ross Eng. HBF-51-NC.
- Driven open by output of a SCR-switched stored energy driver, HCB,A1

E. Stiliaris et al, Proc. of EPAC 2000, Vienna, Austria, p. 866

RF @ IASA: Crowbar tests



H.V. Interlocks

ANALOG SIGNALS

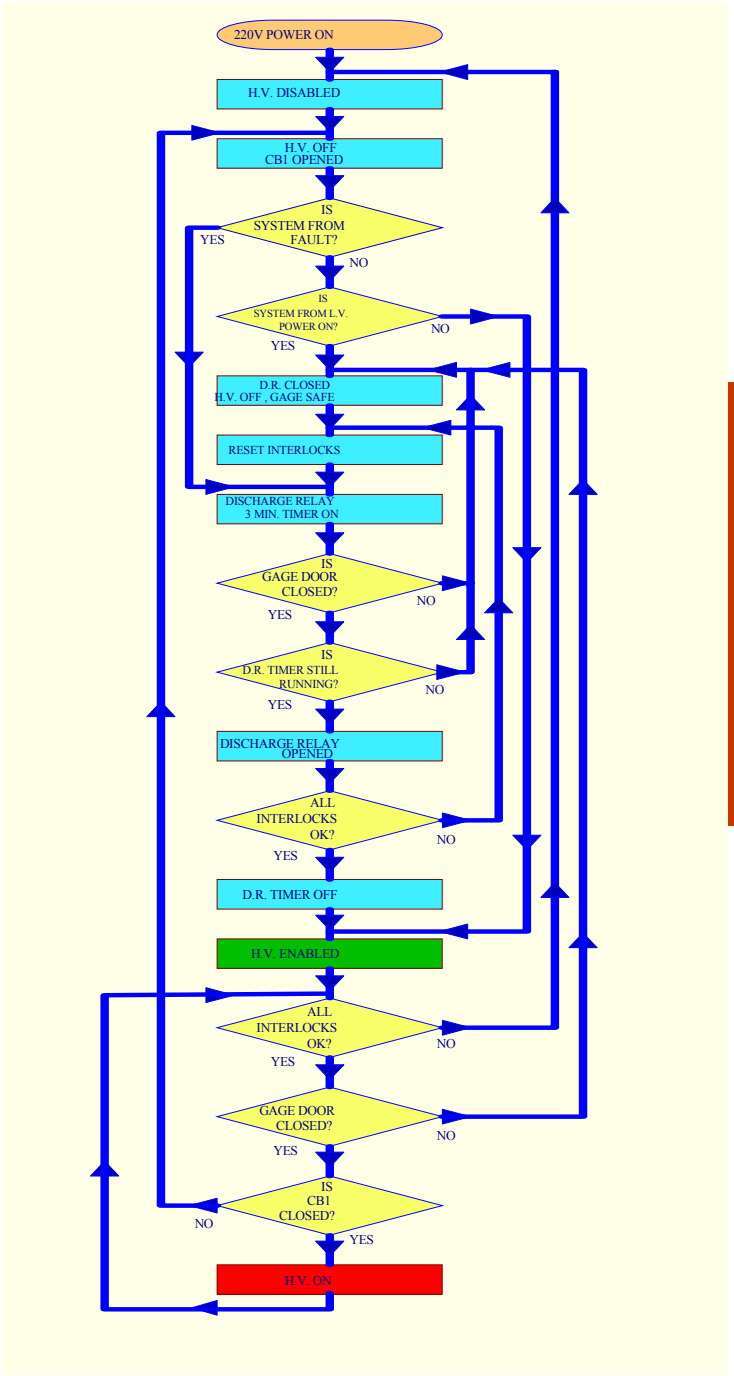
- BODY CURRENT
- BODY TEMPERATURE
- COLLECTOR CURRENT
- COLLECTOR TEMPERATURE
- KLYSTRON ION PUMP CURRENT

DIGITAL SIGNALS

- DISCHARGE RELAYS
- VACUUM CONTACTORS DRIVER READY
- COLLECTOR WATER FLOW
- BODY WATER FLOW
- FOCUSING CURRENT
- HEATER CURRENT (HIGH-LOW)
- KLYSTRON ION PUMP NOT POWERED
- H.V. CAGE DOOR
- WATER RESISTANCE
- X-RAYS OVER RADIATION

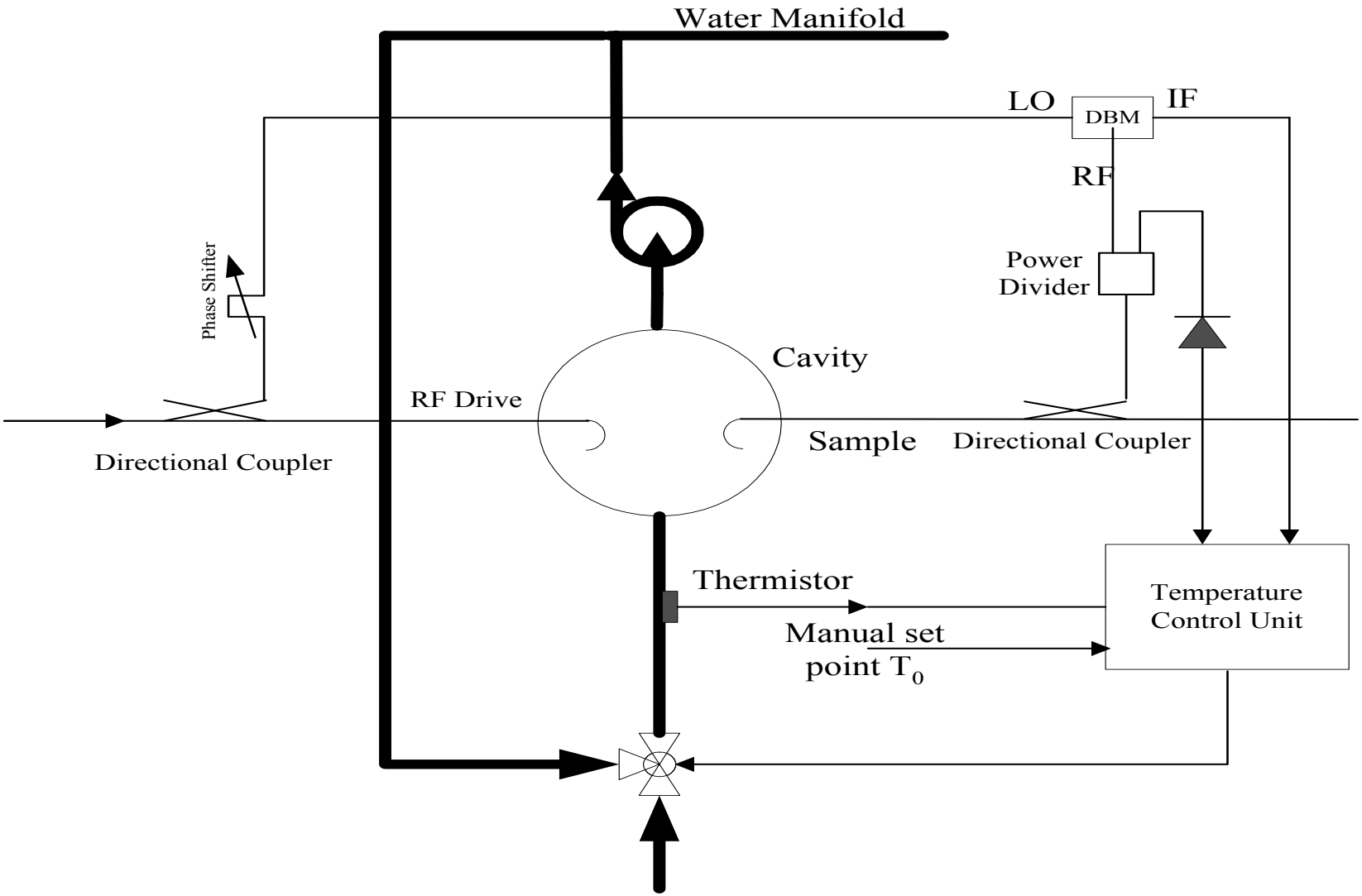
RF INTERLOCKS

- ANALOG SIGNALS
  - REFLECTED RF SIGNAL
  - WINDOW WATER TEMP.
  - CIRCULATOR WATER TEMP.
  - WAVEGUIDE WATER TEMP.
  - RF LOADS WATER TEMP
  - ARC DETECTOR SIGNAL
- DIGITAL SIGNALS
  - WINDOW WATER FLOW
  - CIRCULATOR WATER FLOW
  - WAVEGUIDE WATER FLOW
  - RF LOADS WATER FLOW



Trasmitter interlock flowchart

RF tuning (control of temperature)



Cooling System (560 kW)

De-ionized and sterilized water @ 5-6 MΩ/cm

Schematic plan of the cooling system

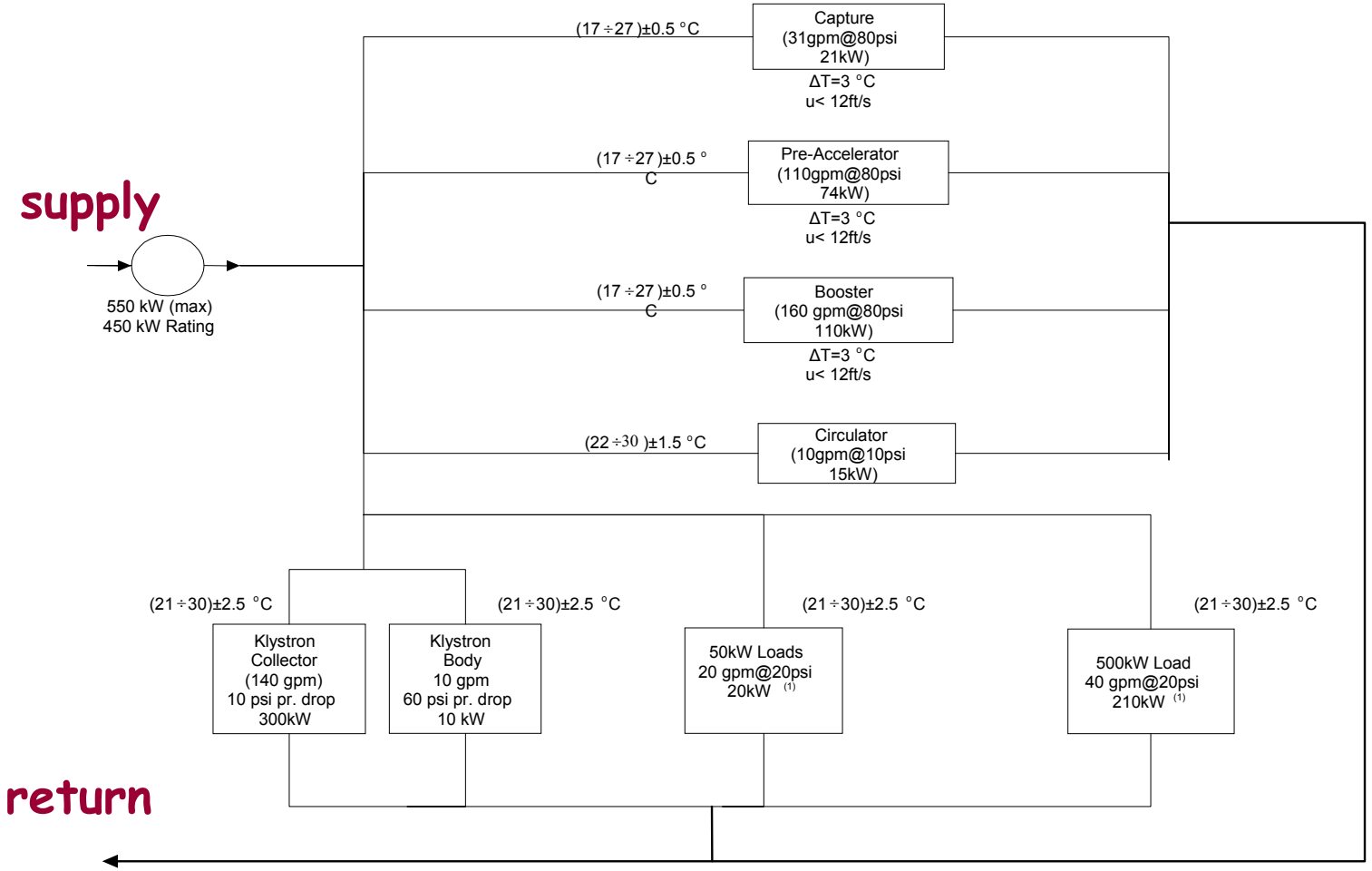
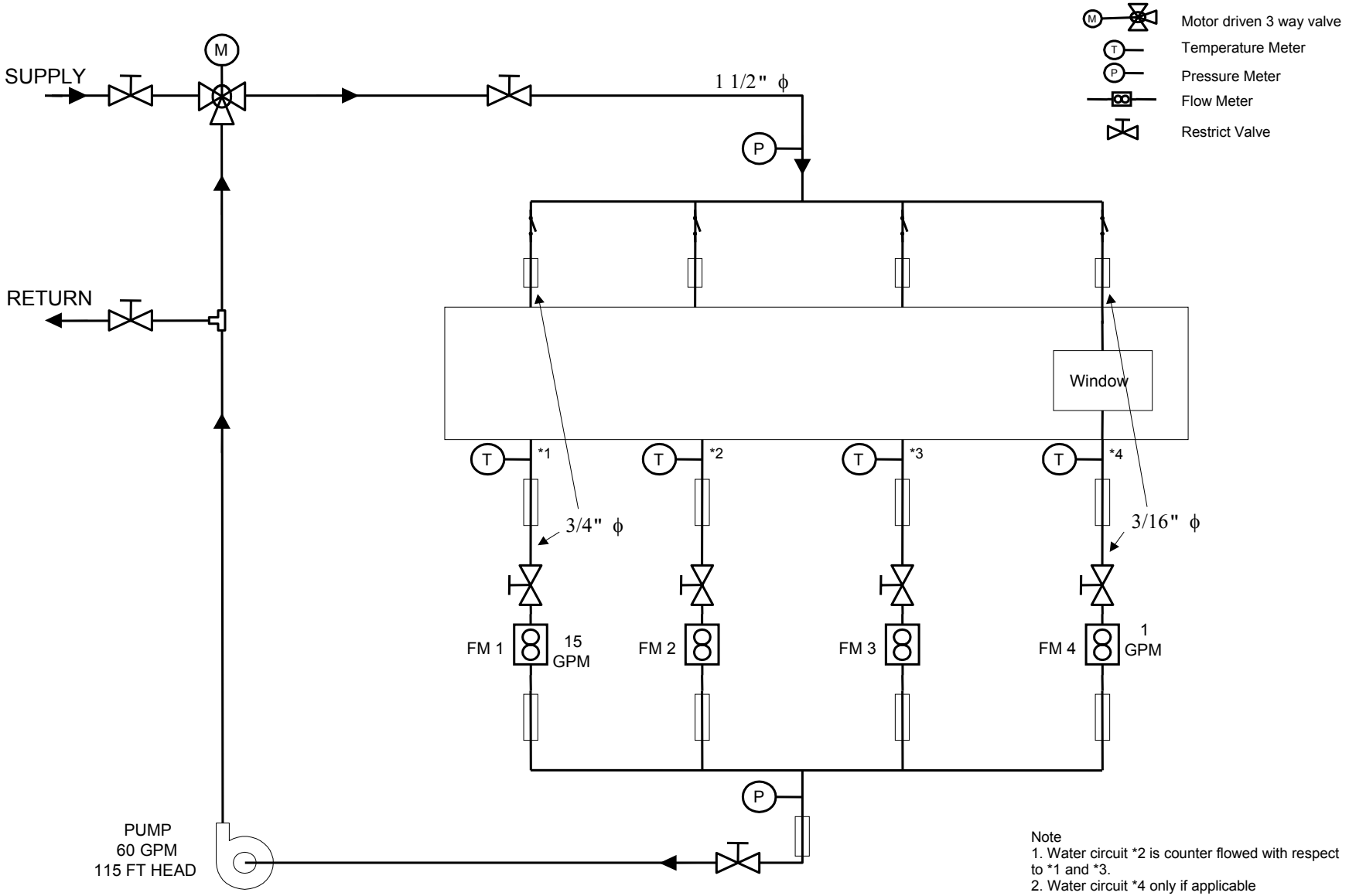


Figure 3

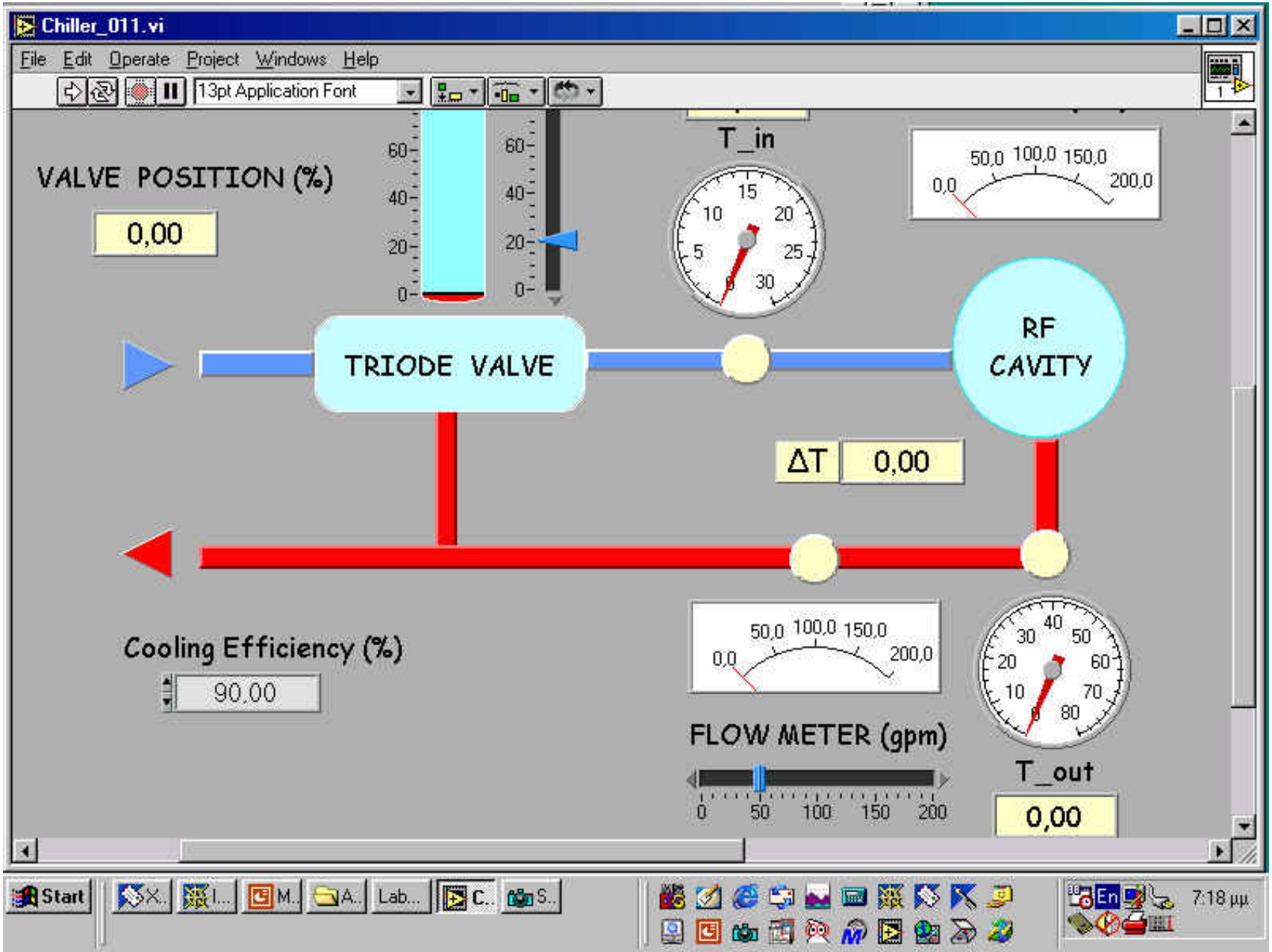
(1) max rating. Typical 10% of max rating

Detailed plan of the cooling system

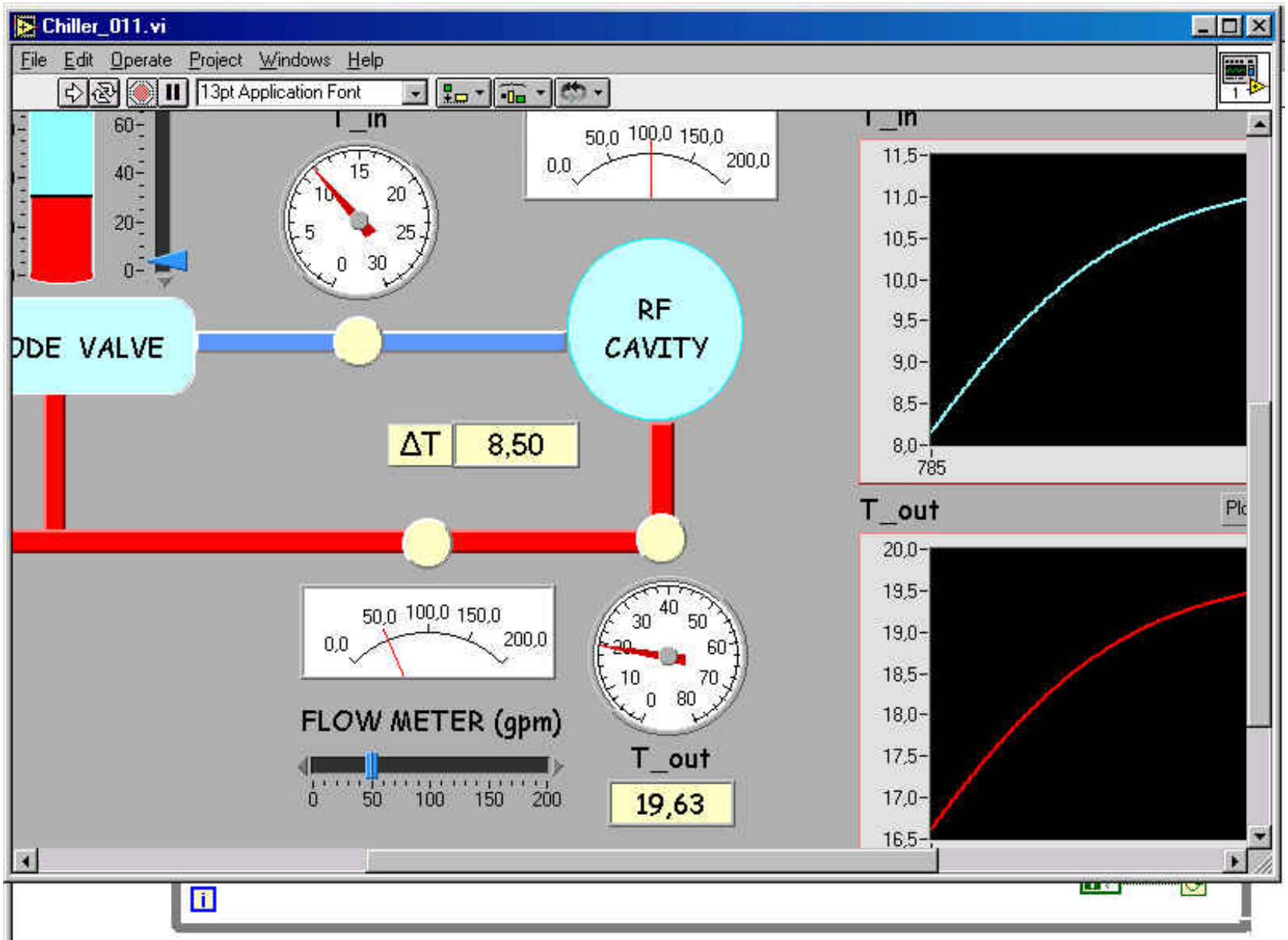


Note
1. Water circuit *2 is counter flowed with respect to *1 and *3.
2. Water circuit *4 only if applicable

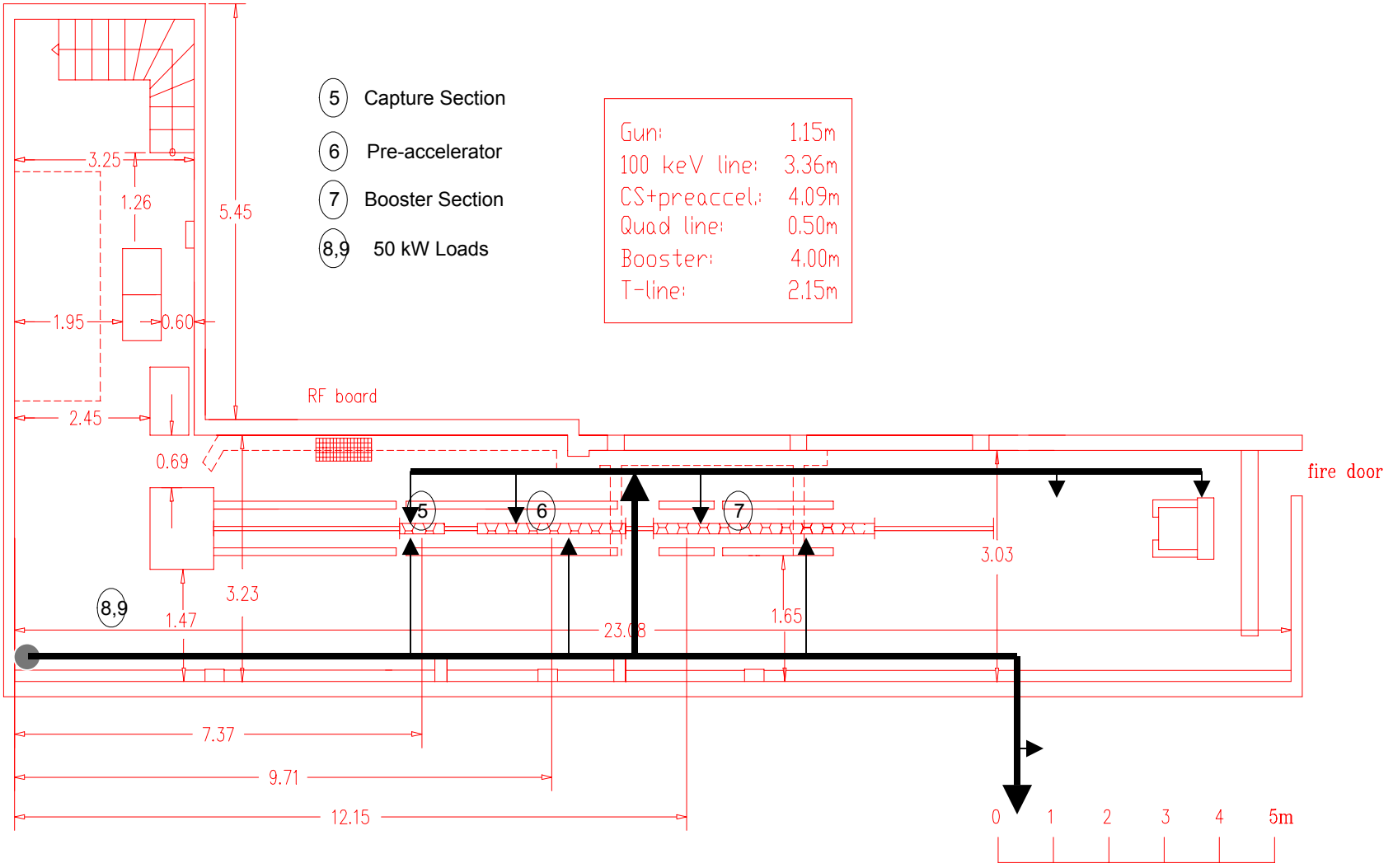
Control loop (labview)



e.g. 100 kW RF & 50 gpm



Injector floor



Cooling of the Klystron

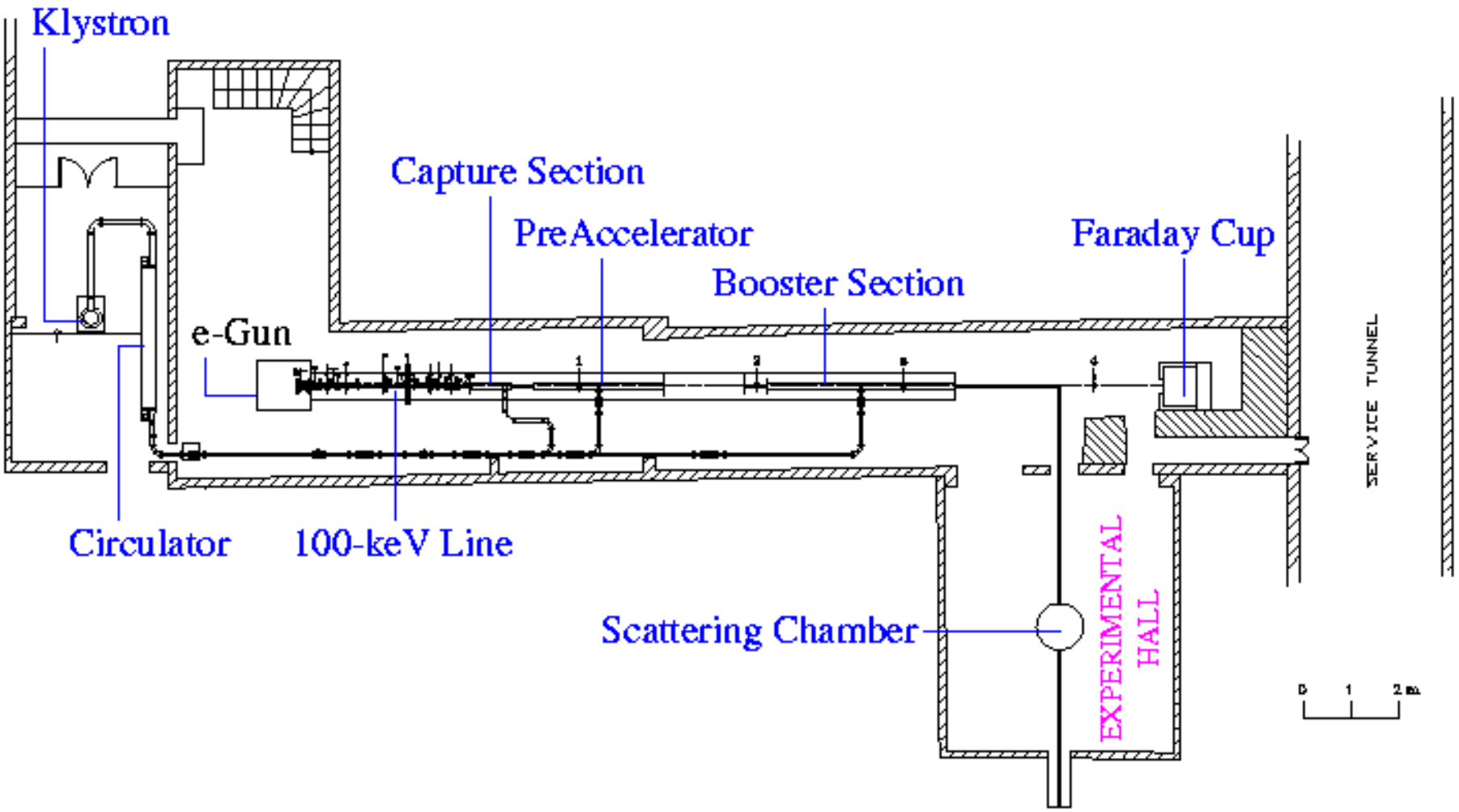
High Voltage tests

- Successful operation of the 20/11 kV transformer, alarms & interlocks
- Successful operation of the VVT
- Successful operation of the AC/DC Rectifier → 55kV DC

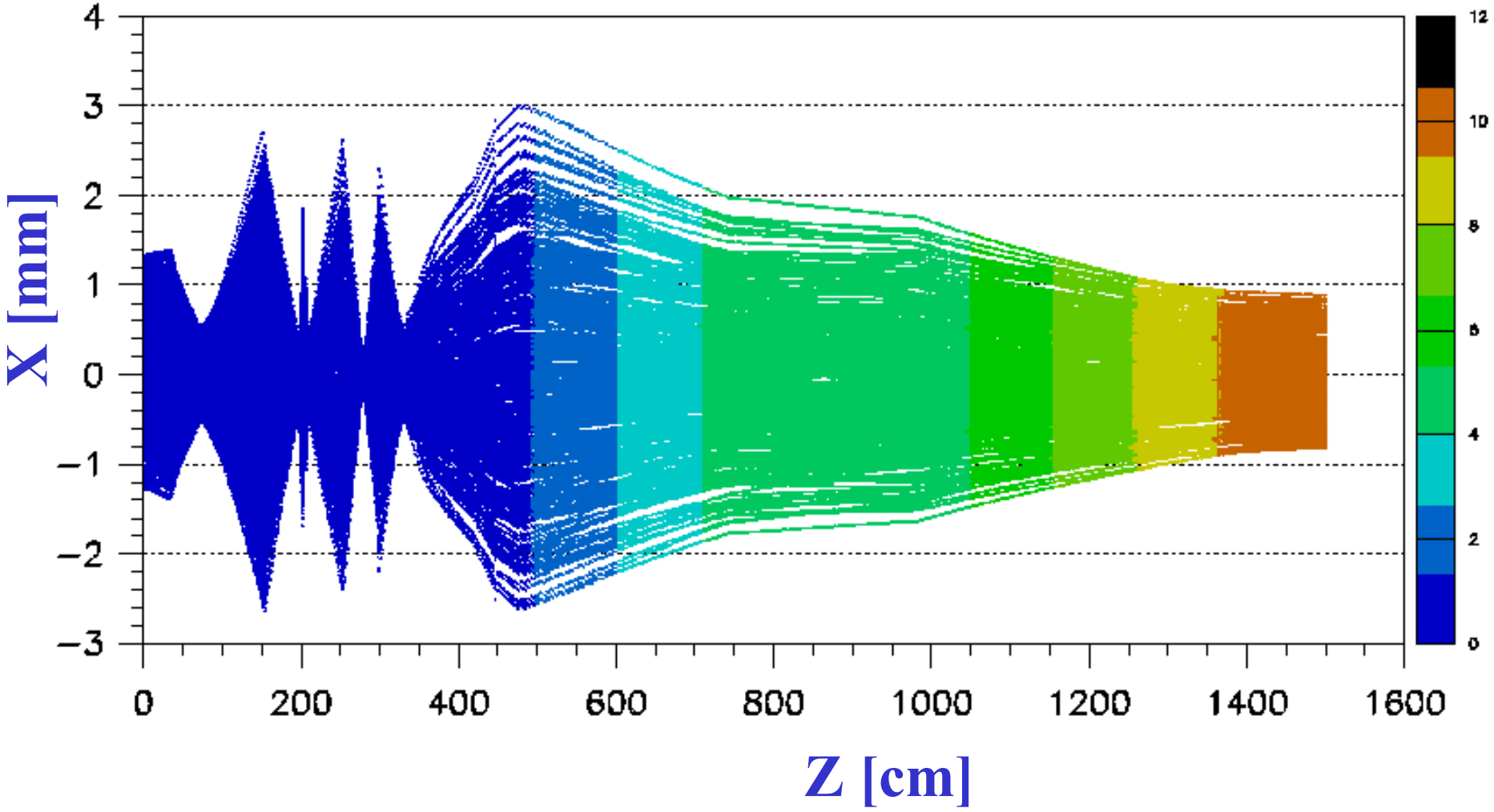
Beam Transport to the Experimental Area

- Beam Optics Calculations (ptrace / Omen and Transport codes)
- Two Brown systems (horizontal – 270° and vertical)

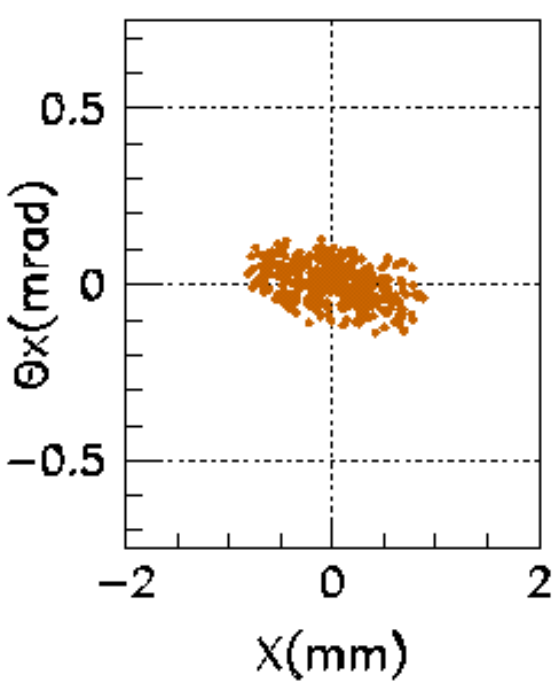
10 MeV Linac Layout (Present Status)

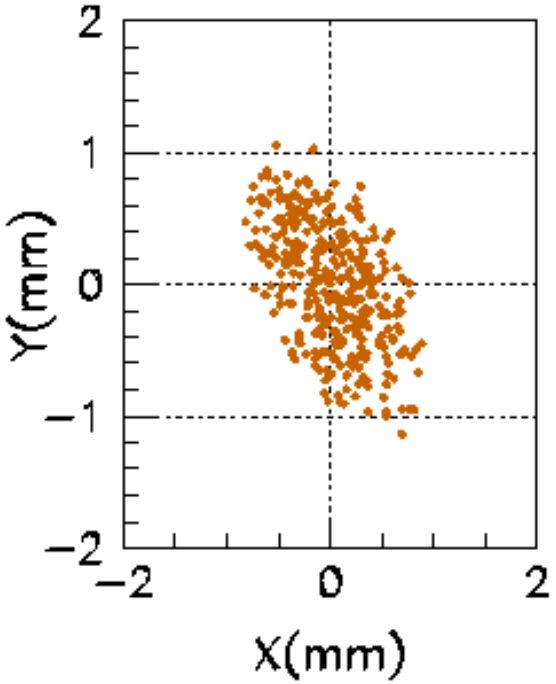


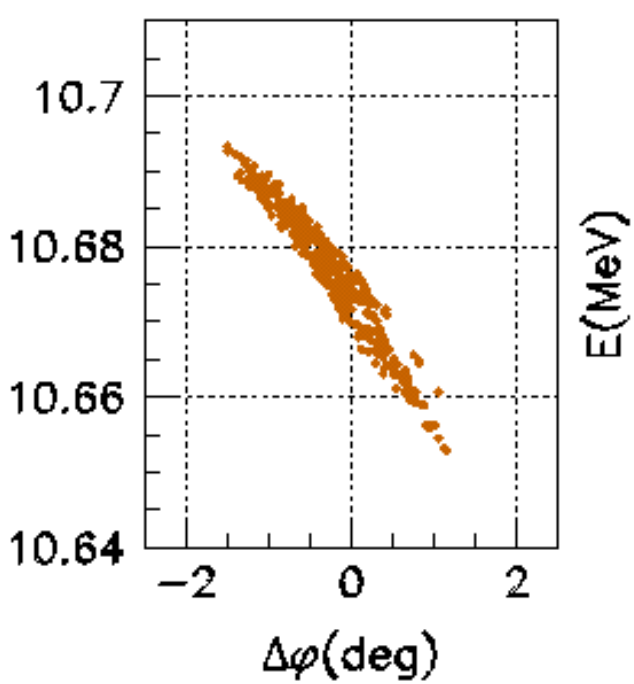
10 MeV CW-Linac (Beam Profile)
Parmela simulation



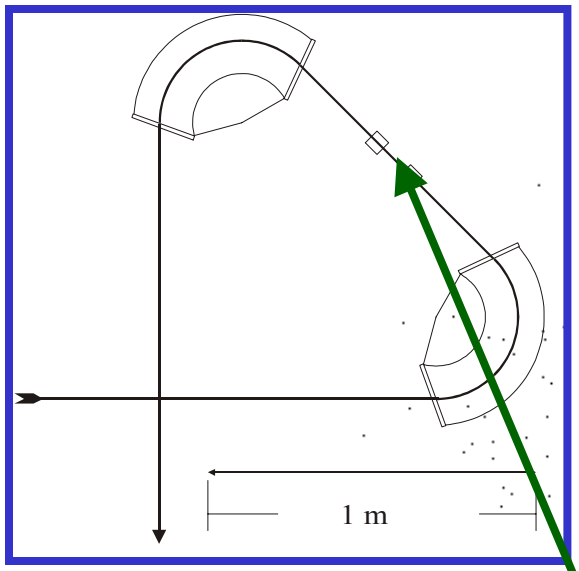
10 MeV CW-Linac (Emittance)

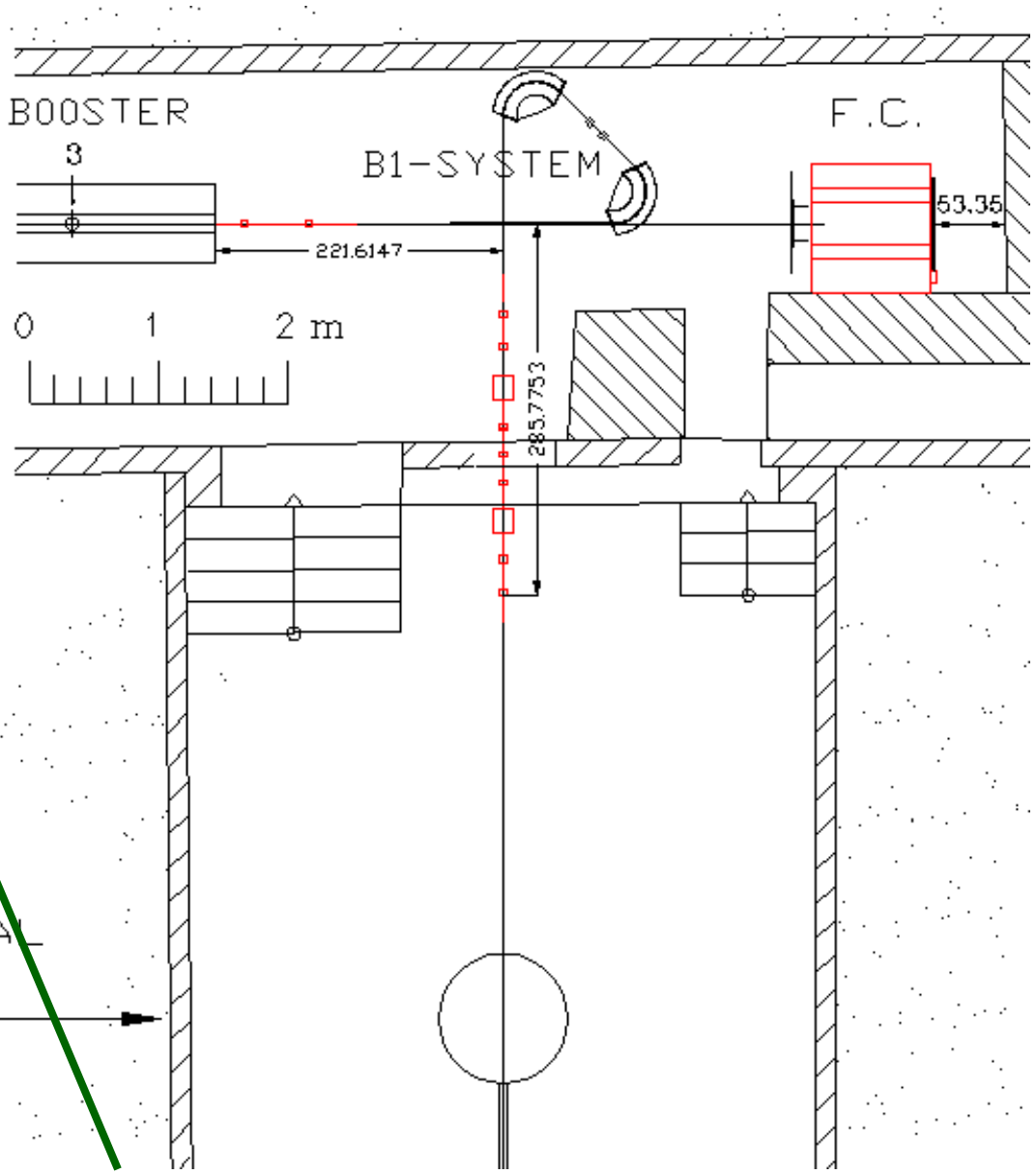






Transport System



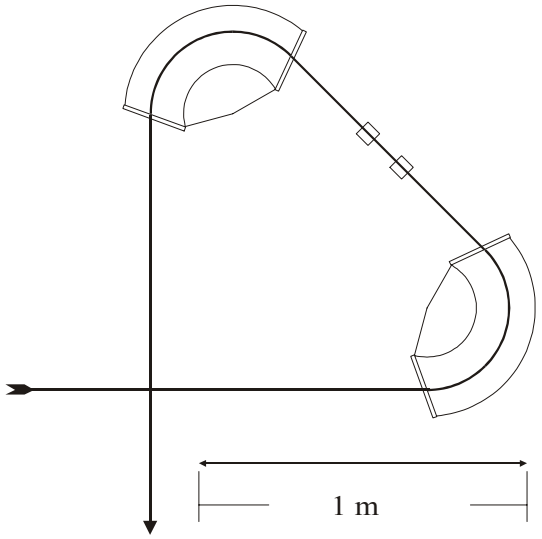


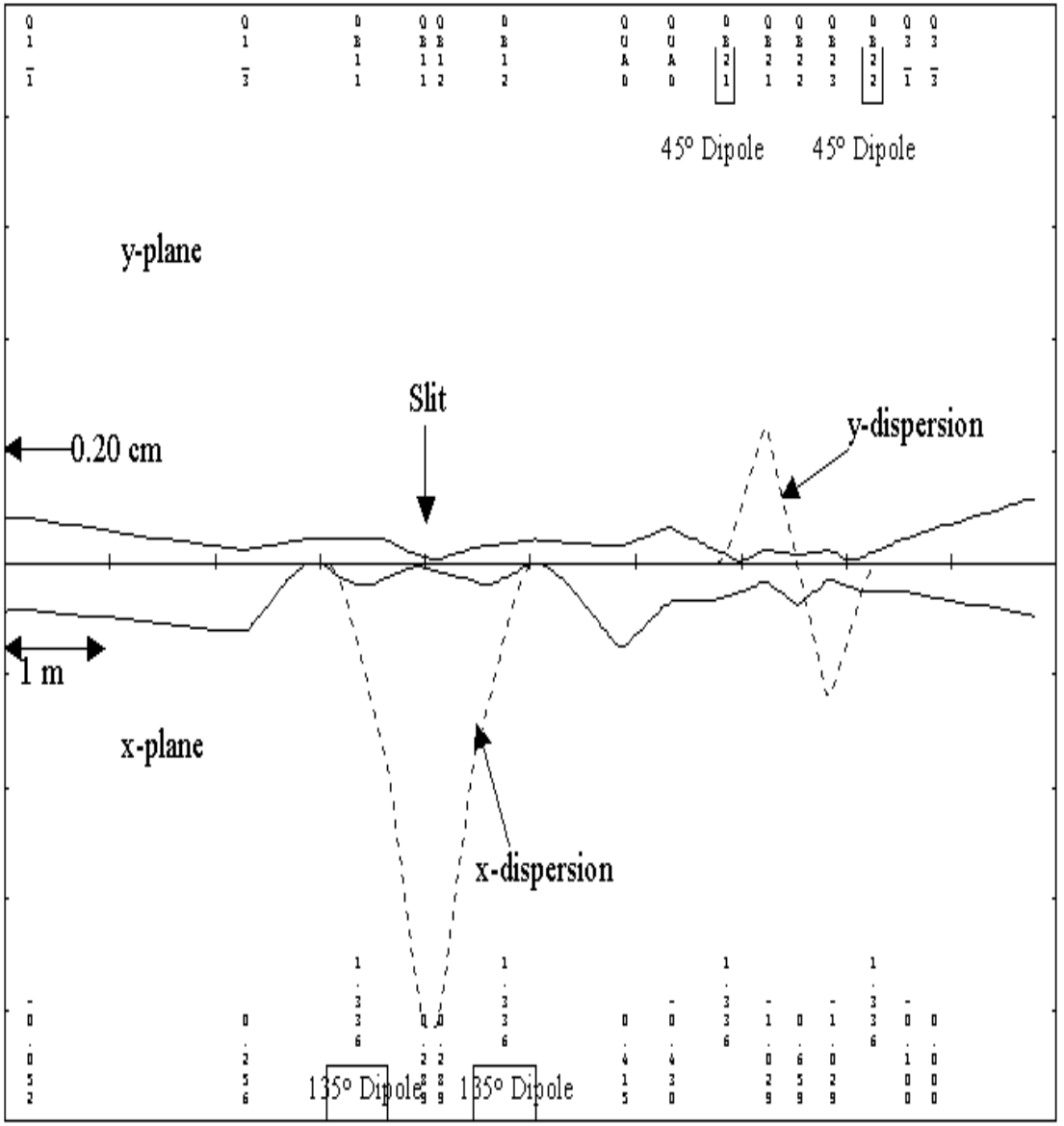
Two 135° dipoles

Energy analysis system

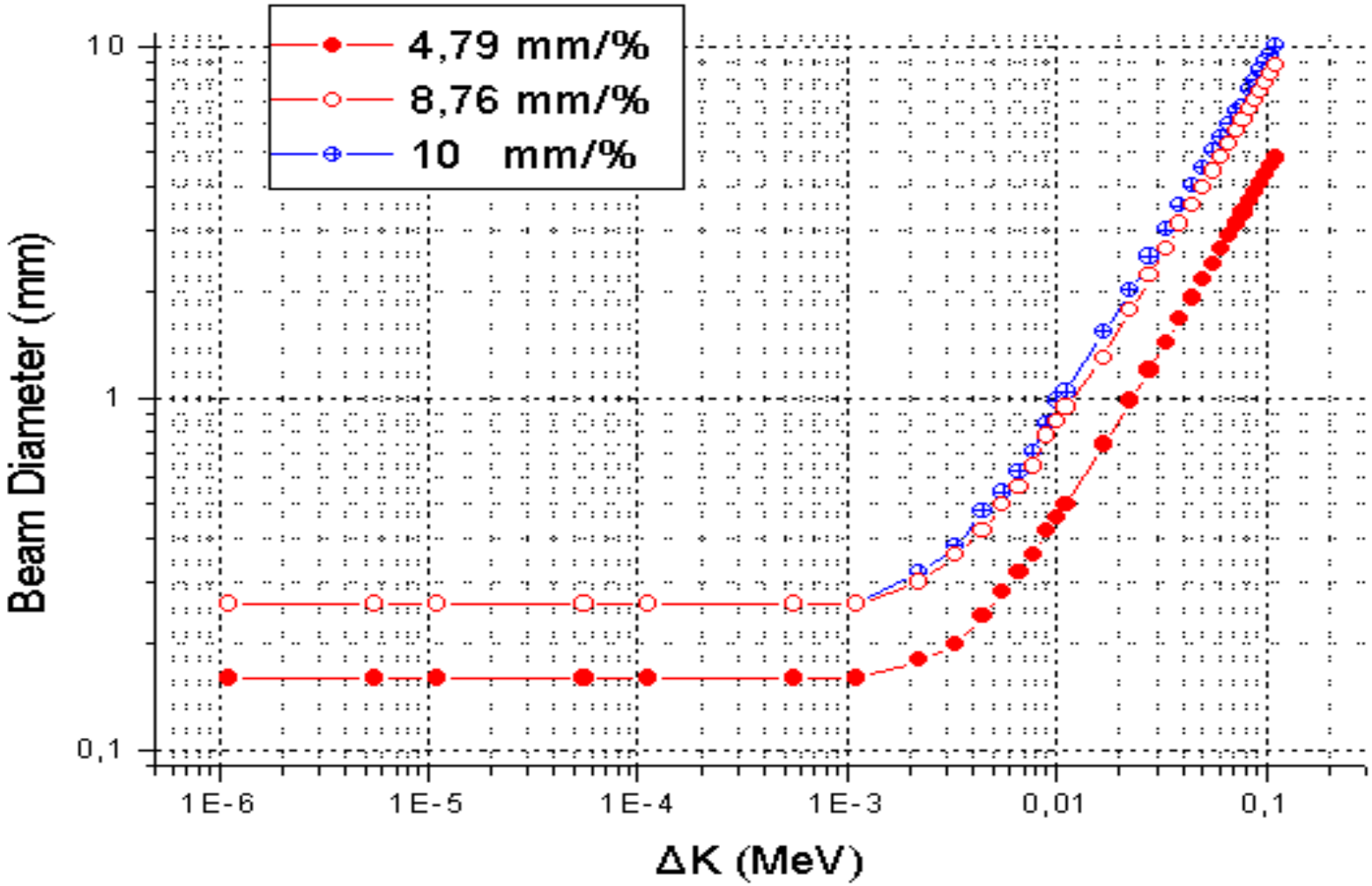
Energy analysis system

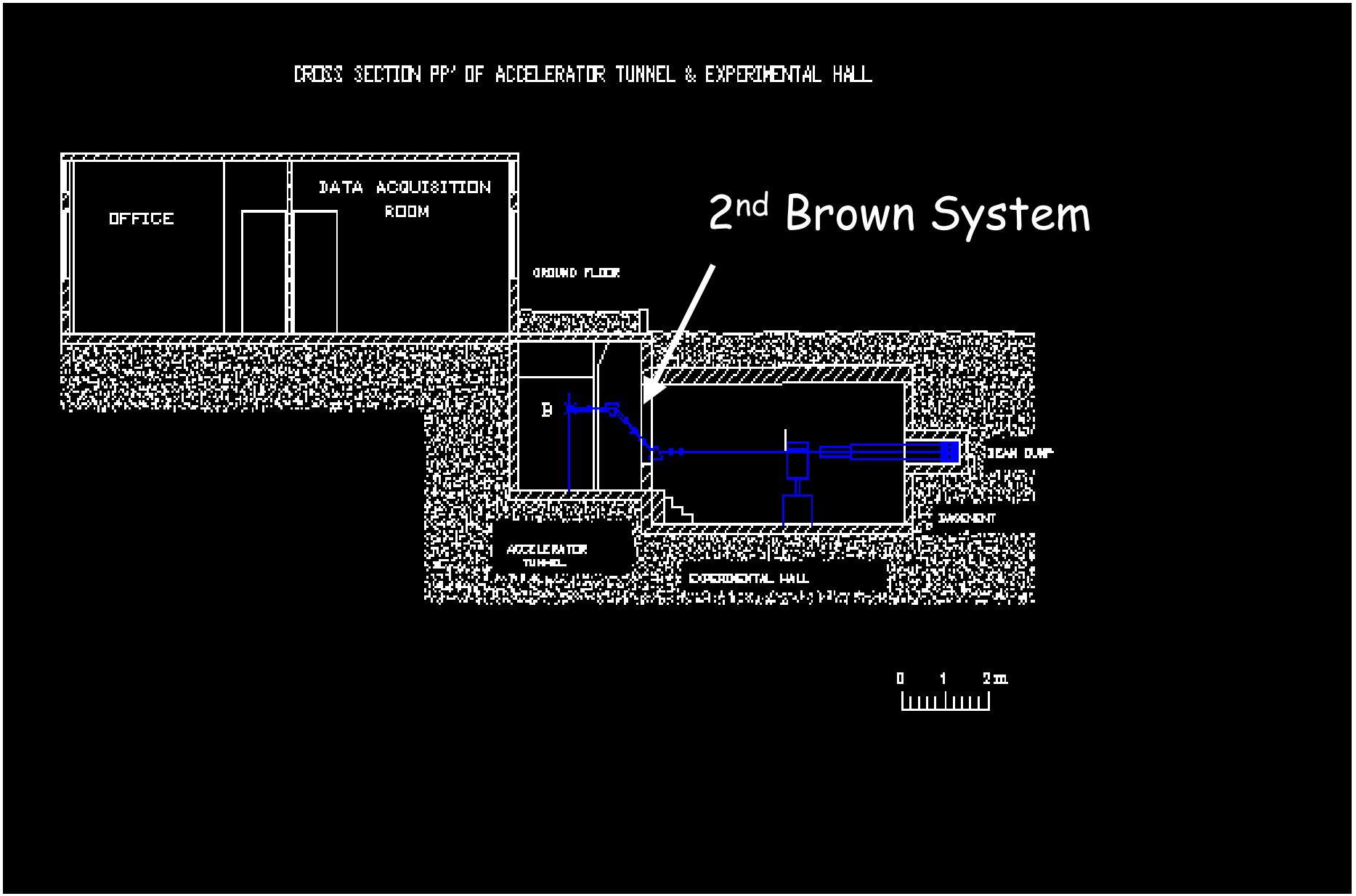
Dispersion **8.76mm/%** in the first Brown system using **135°** magnets and internal angles of **20.43°.**



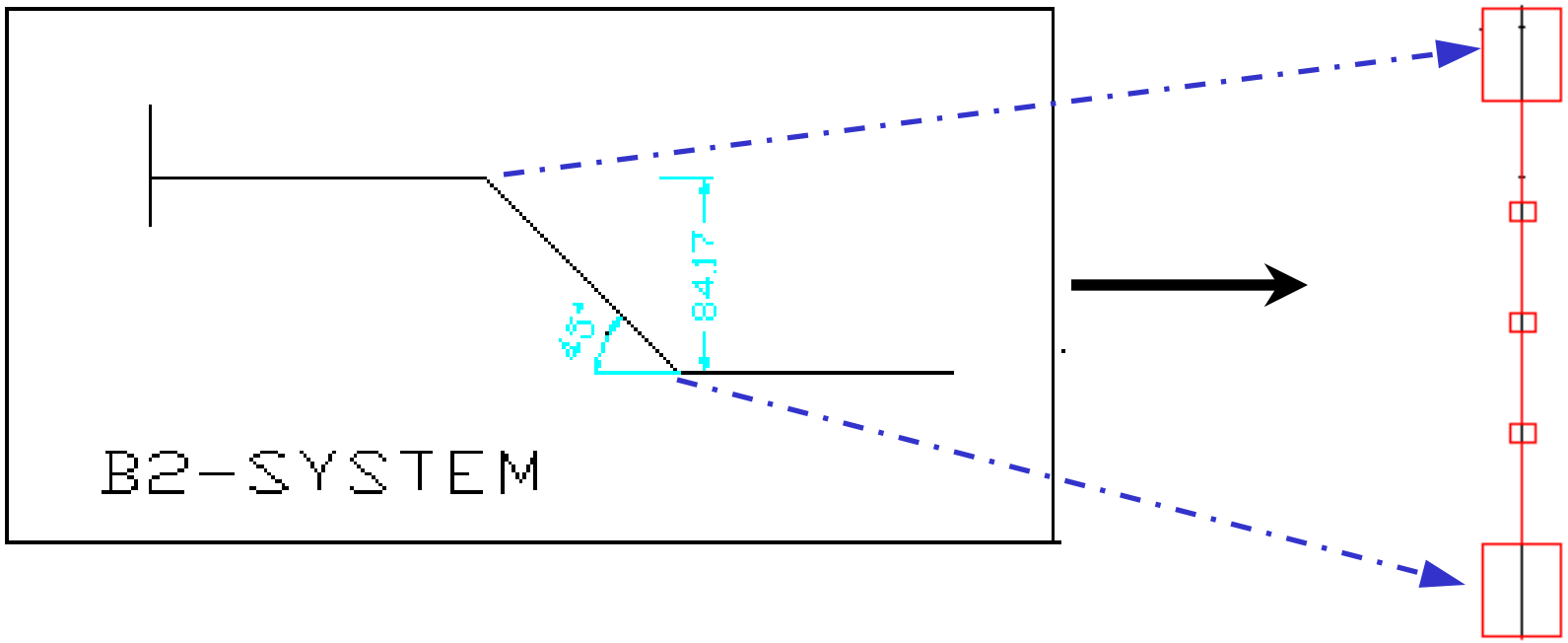


Beam size (diameter) as a function of energy shift



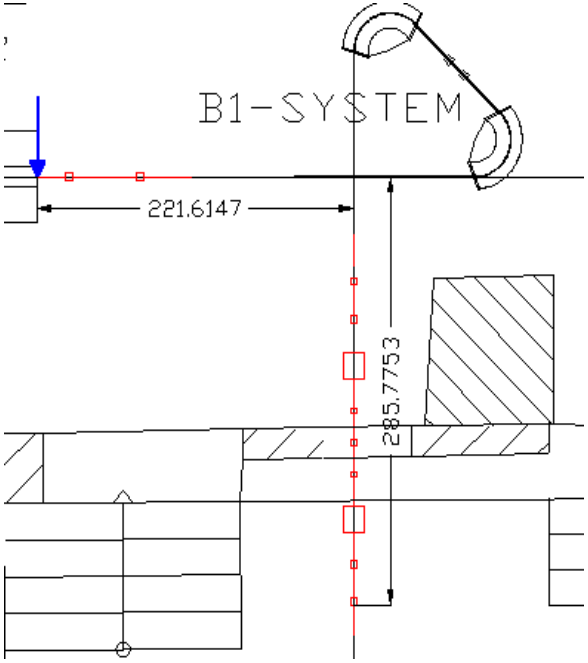

CROSS SECTION PP' OF ACCELERATOR TUNNEL & EXPERIMENTAL HALL
OFFICE
DATA ACQUISITION ROOM
GROUND FLOOR
2nd Brown System
B
BEAM DUMP
MAGNET
ACCELERATOR TUNNEL
EXPERIMENTAL HALL
0 1 2m

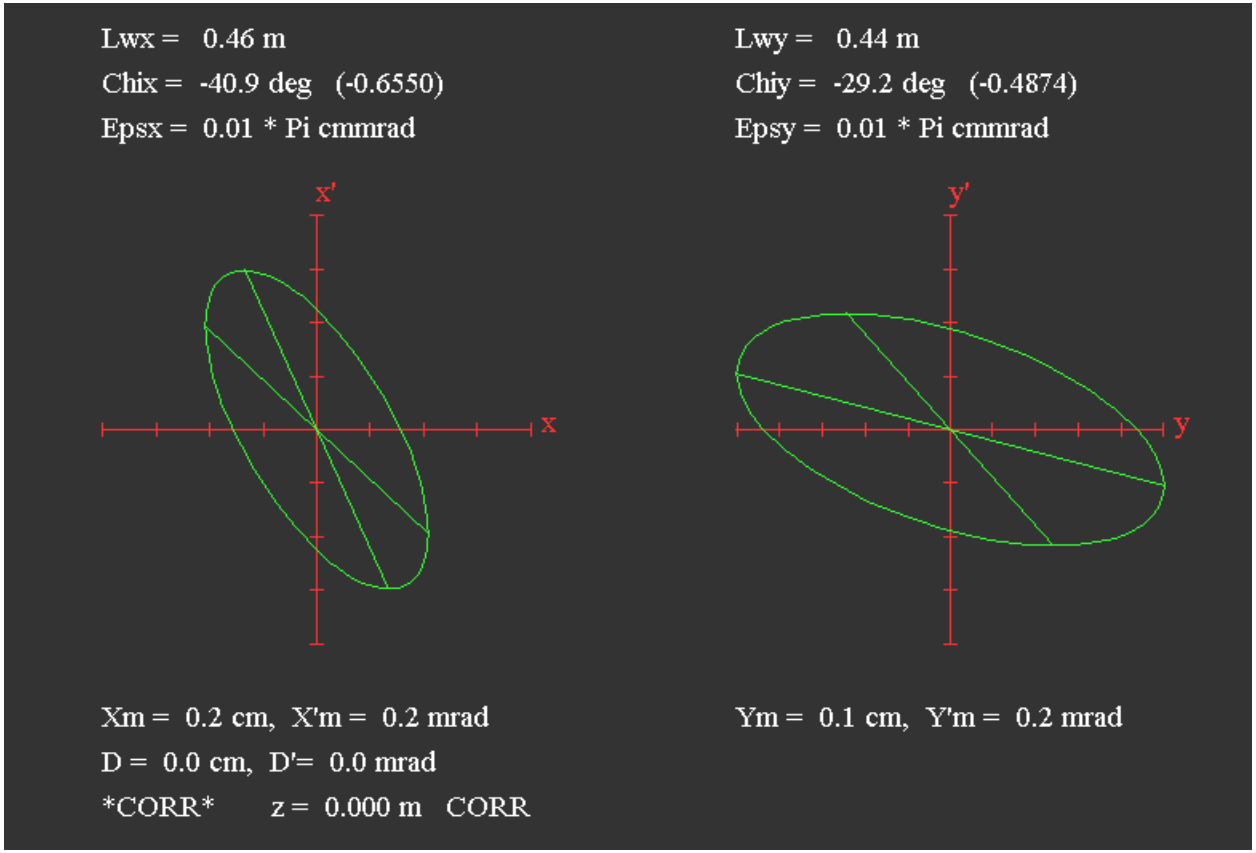
Vertical Brown system

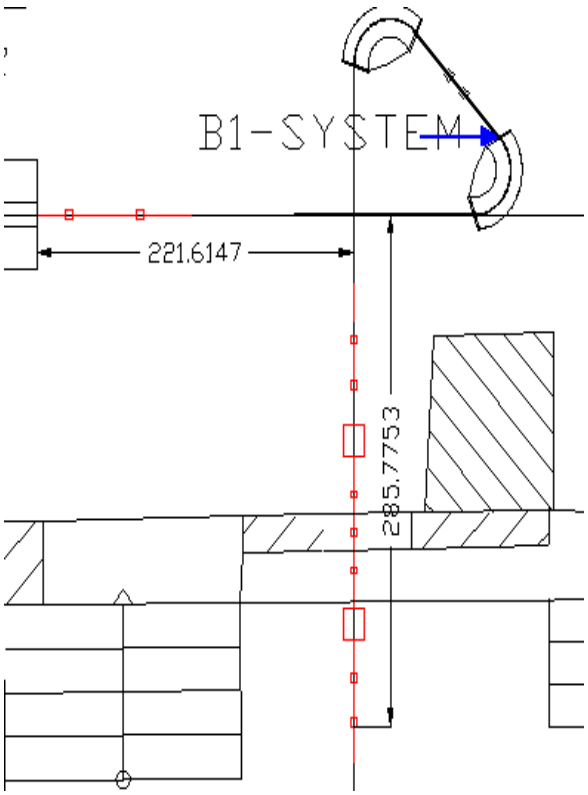


Optics of the beam transport system

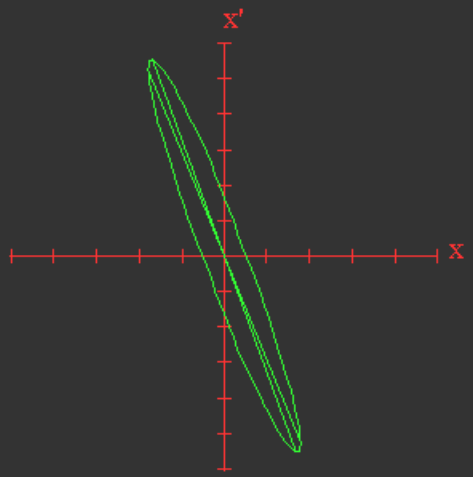
10 MeV Exit line



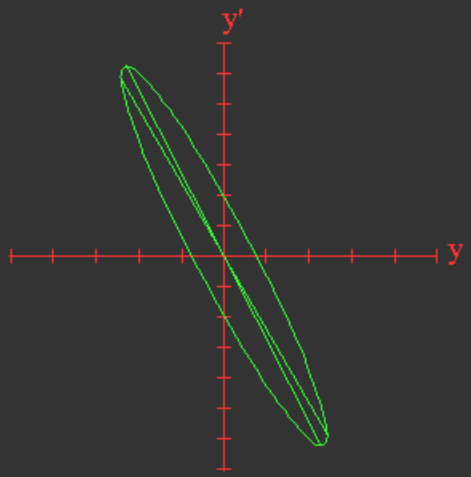




Lwx = 0.03 m
Chix = -72.5 deg (-0.9537)
Epsx = 0.01 * Pi cmmrad

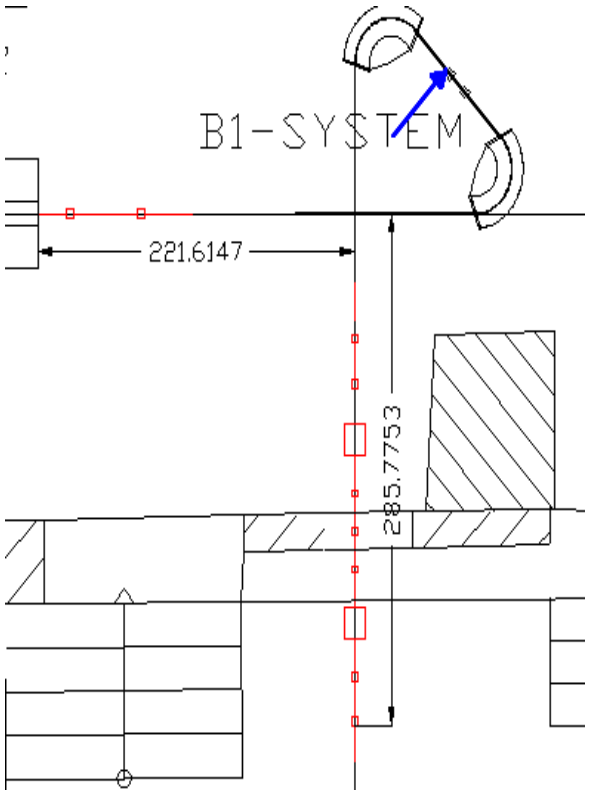


Lwy = 0.07 m
Chiy = -71.5 deg (-0.9482)
Epsy = 0.01 * Pi cmmrad

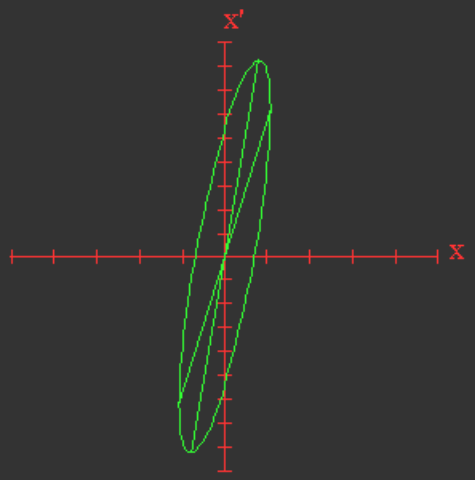


Xm = 0.1 cm, X'm = 1.2 mrad
D = 0.0 cm, D'= 0.0 mrad
ROTAT z = 3.639 m

Ym = 0.1 cm, Y'm = 0.7 mrad

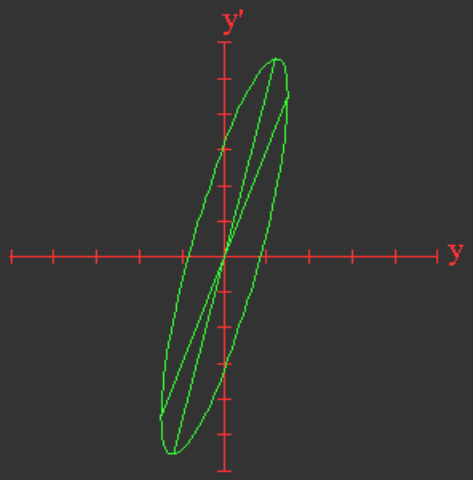


Lwx = -0.02 m
Chix = 49.2 deg (0.7568)
Epsx = 0.01 * Pi cmmrad

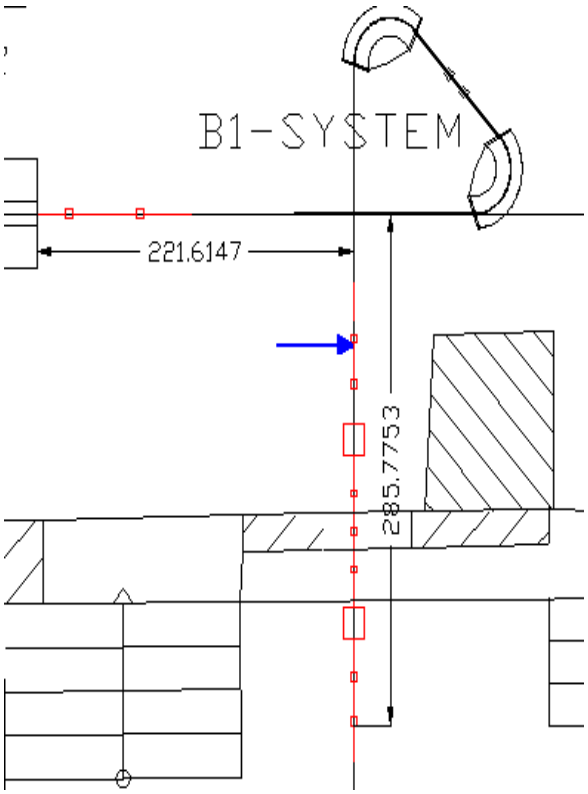


Xm = 0.1 cm, X'm = 0.9 mrad
D = 0.0 cm, D'= 0.0 mrad
QUAD z = 4.149 m QB12

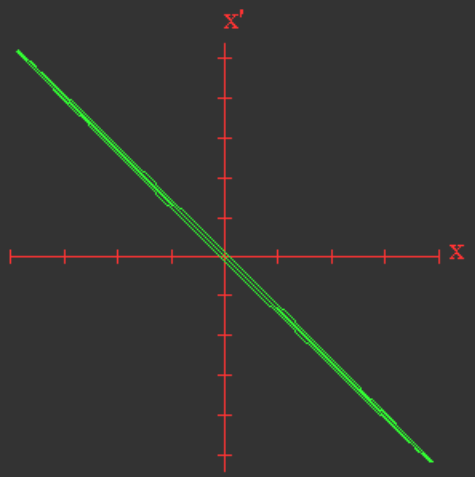
Lwy = -0.04 m
Chiy = 55.0 deg (0.8194)
Epsy = 0.01 * Pi cmmrad



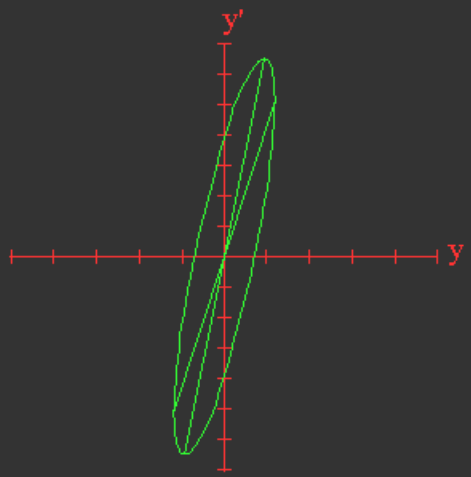
Ym = 0.1 cm, Y'm = 0.6 mrad



Lwx = 0.07 m
Chix = -88.7 deg (-0.9997)
Epsx = 0.01 * Pi cmmrad

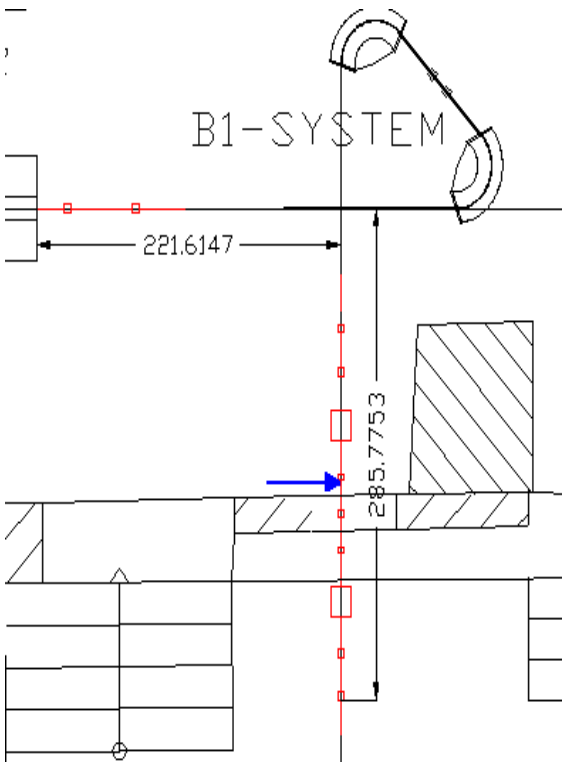


Lwy = -0.03 m
Chiy = 52.8 deg (0.7967)
Epsy = 0.01 * Pi cmmrad

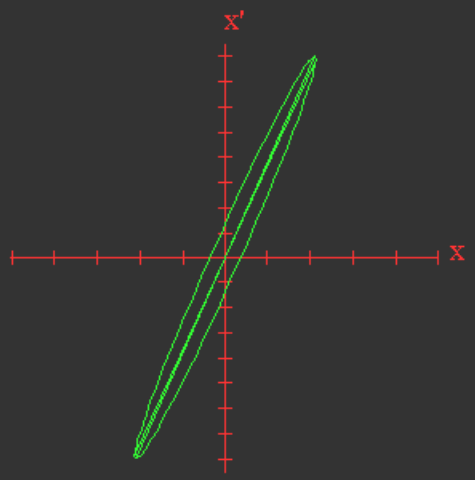


Xm = 0.2 cm, X'm = 2.7 mrad
D = 0.0 cm, D'= 0.0 mrad
QUAD z = 5.898 m QUAD

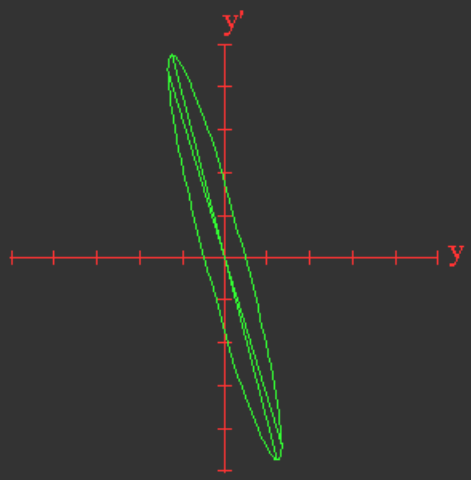
Ym = 0.1 cm, Y'm = 0.7 mrad



Lwx = -0.03 m
Chix = 80.1 deg (0.9850)
Epsx = 0.01 * Pi cmmrad

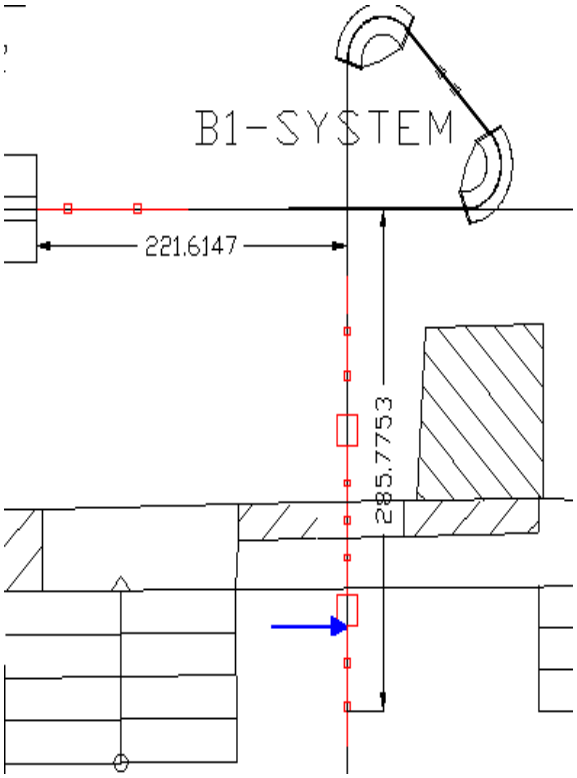


Lwy = 0.03 m
Chiy = -68.3 deg (-0.9294)
Epsy = 0.01 * Pi cmmrad

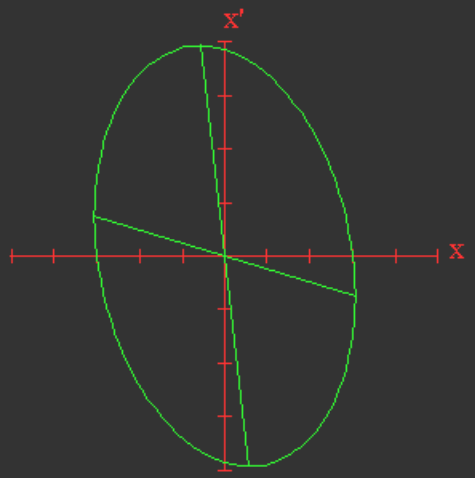


Xm = 0.1 cm, X'm = 1.7 mrad
D = 0.0 cm, D'= 0.0 mrad
QUAD z = 7.269 m QB21

Ym = 0.1 cm, Y'm = 1.0 mrad

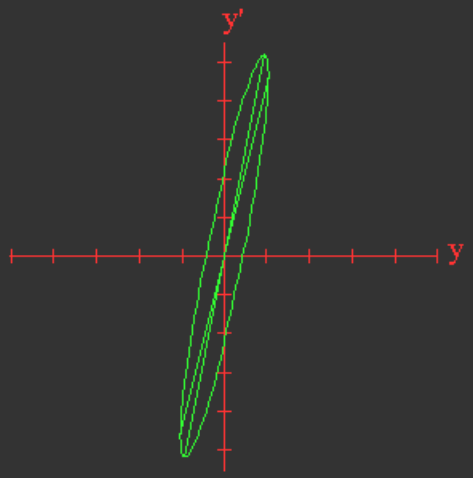


Lwx = 0.06 m
Chix = -11.0 deg (-0.1903)
Epsx = 0.01 * Pi cmmrad

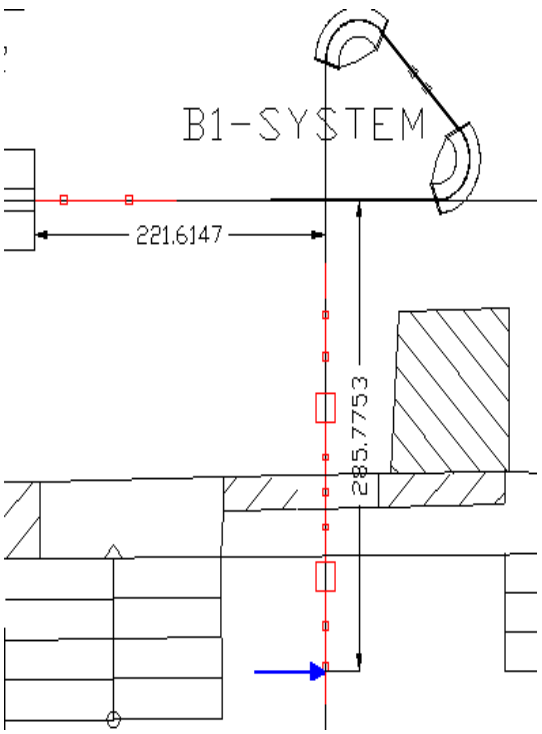


Xm = 0.1 cm, X'm = 0.2 mrad
D = 0.0 cm, D'= 0.0 mrad
Z RO z = 8.341 m

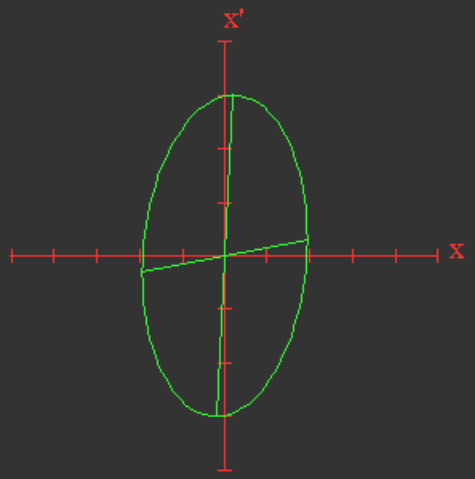
Lwy = -0.02 m
Chiy = 64.6 deg (0.9037)
Epsy = 0.01 * Pi cmmrad



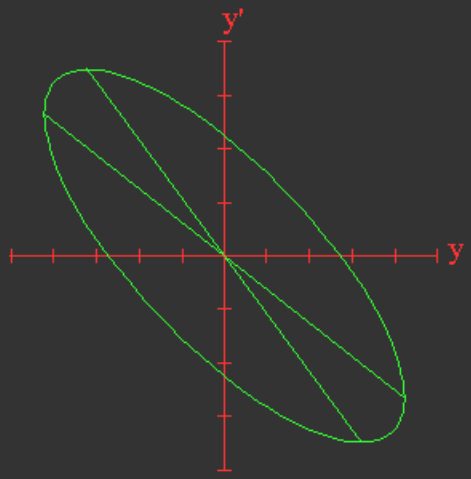
Ym = 0.1 cm, Y'm = 1.1 mrad



Lwx = -0.01 m
Chix = 6.2 deg (0.1081)
Epsx = 0.01 * Pi cmmrad



Lwy = 0.37 m
Chiy = -49.7 deg (-0.7631)
Epsy = 0.01 * Pi cmmrad

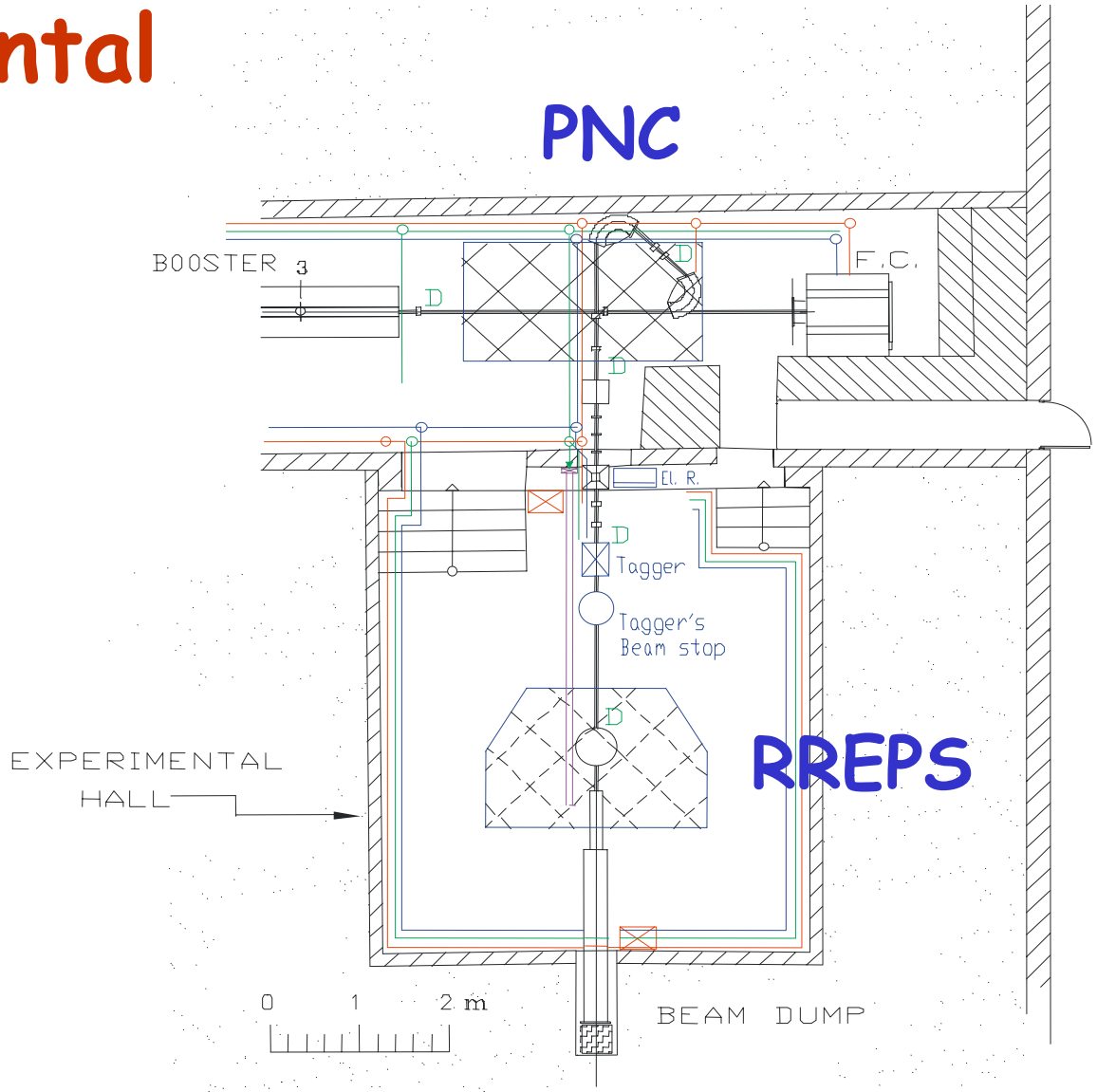


Xm = 0.1 cm, X'm = 0.4 mrad
D = 0.0 cm, D'= 0.0 mrad
QUAD z = 8.841 m Q3_3

Ym = 0.1 cm, Y'm = 0.2 mrad

Experimental Areas

: Electric Power Supply
: Air Supply
: Water System (supply/return)
: Rack
: NPC exp. site
D : Diagnostic elements
: Tagger
: Electric Rack
: RREPS exp. site
: Radiation Monitor



Possible experiments

- Parity non-conservation (PNC) – no bending of the electron beam
- Novel sources of Radiation from Relativistic Electrons in Periodic Structures (RREPS) – in the experimental area

Study of the Parity Non-Conserving Force between Nucleons through Deuteron Photodisintegration

Experimental Goal

Reduce the systematic errors to a better level than 10^{-7} for the neutron asymmetry Az in the reaction

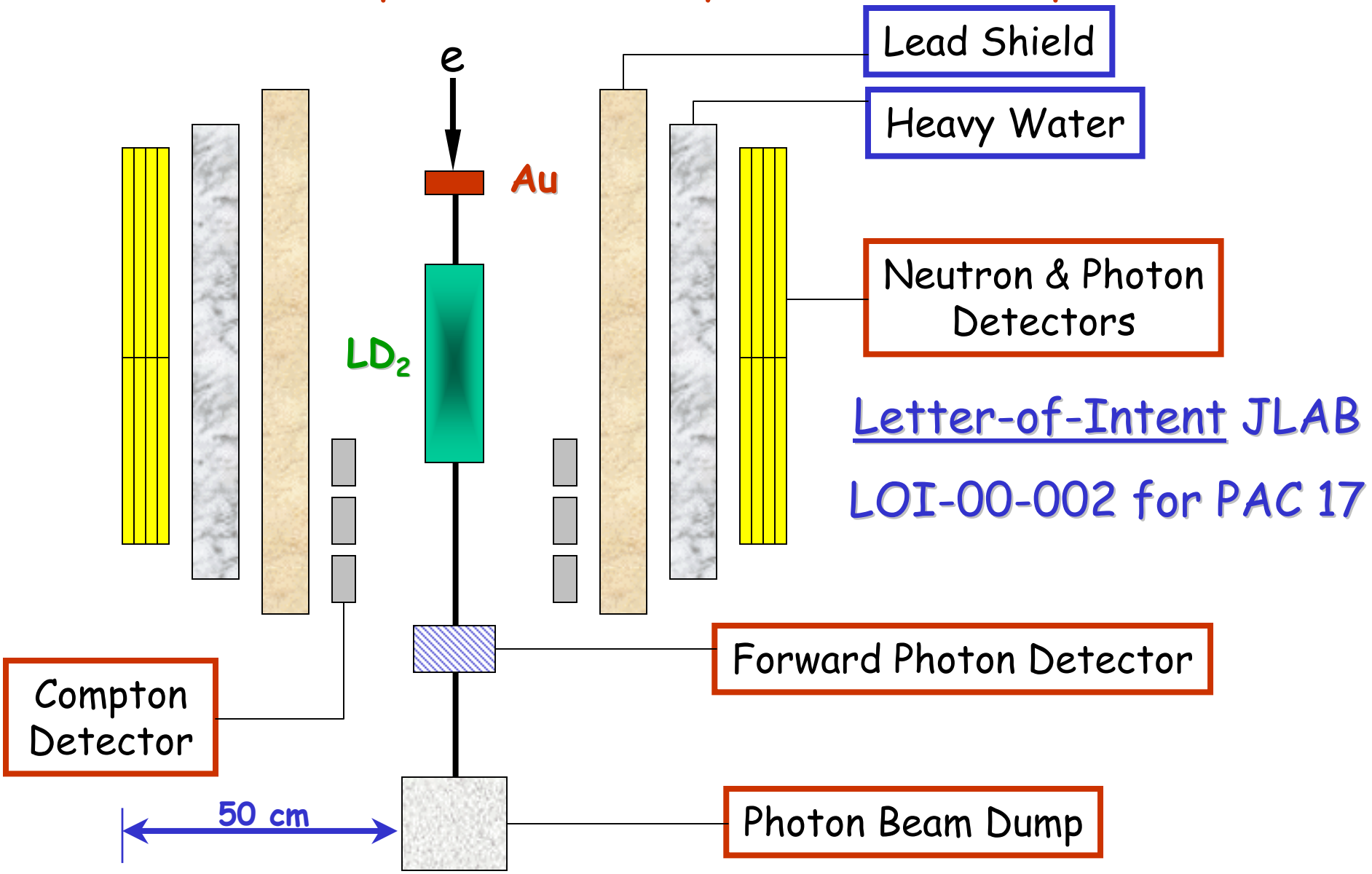
$$\vec{\gamma} + d \rightarrow p + n \quad E(\gamma) = 3 - 8 \text{ MeV}$$

What is needed ?

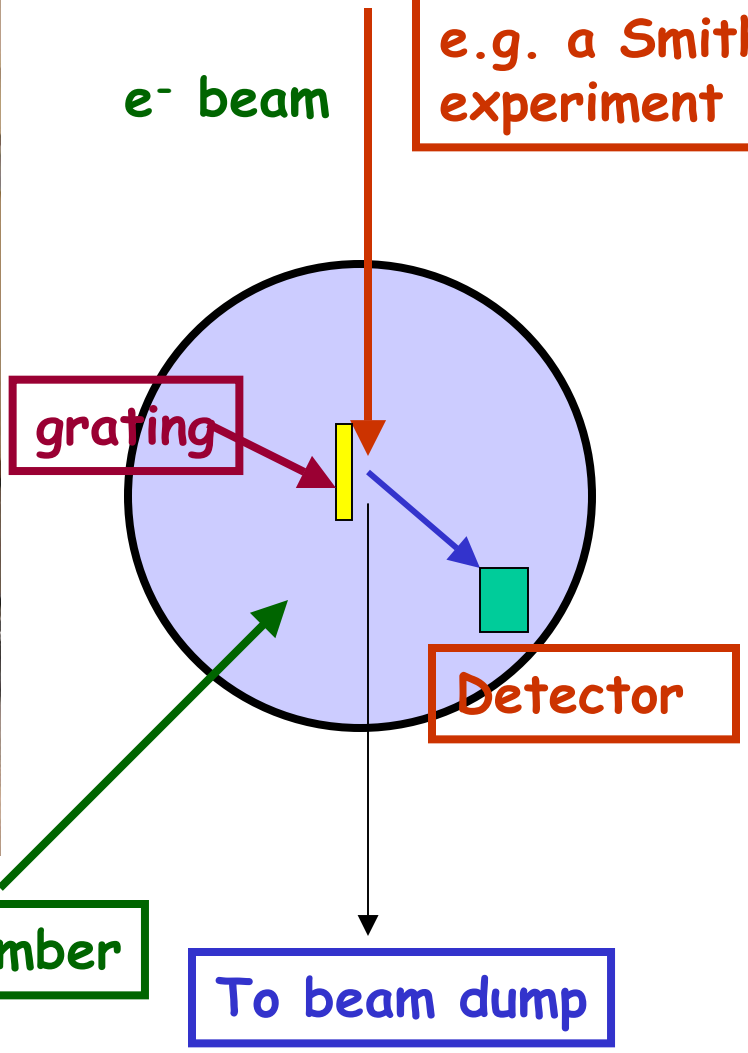
- A polarized photon beam
- An improved n-detection system
- Beam quality and stability with quick feed back system

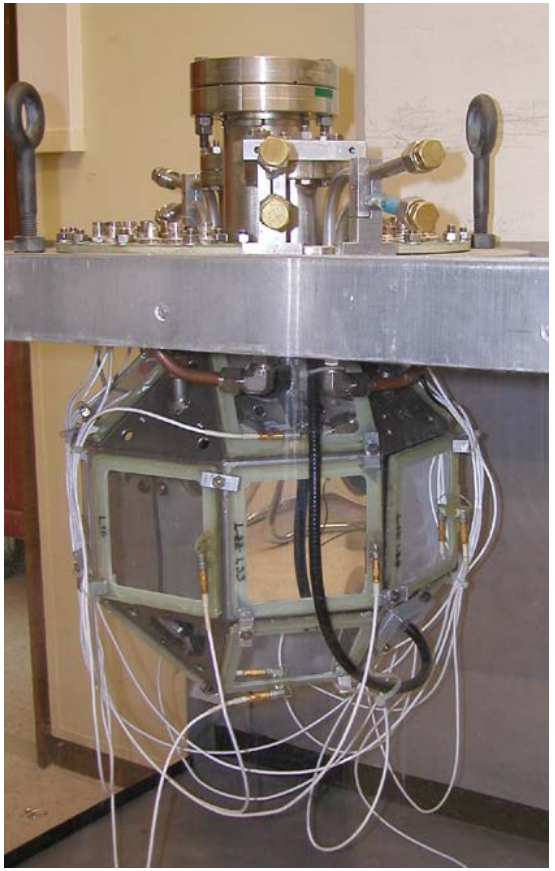
The Proposed Experiment

Detector Set Up (schematically) for the d(γ,n)p reaction

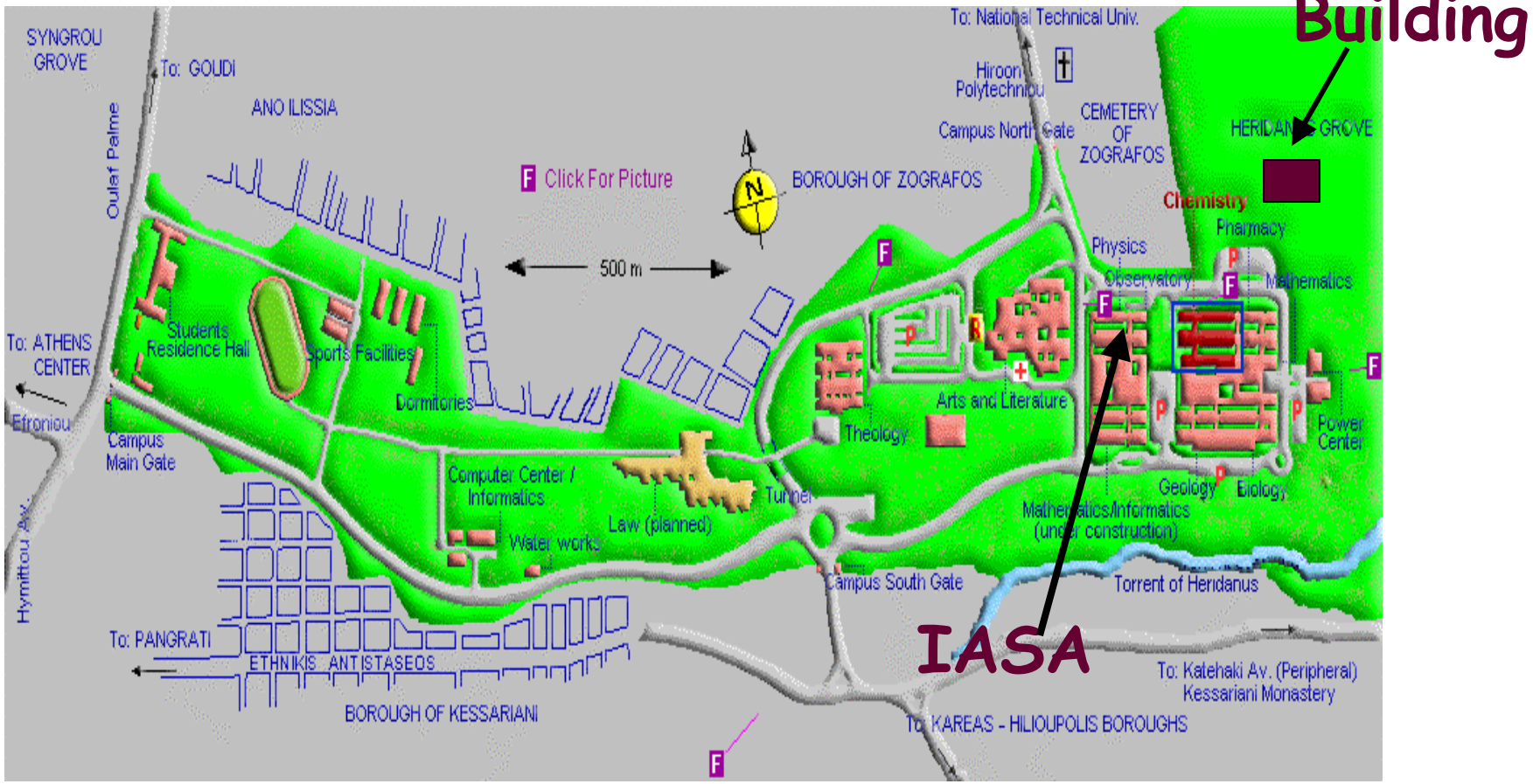


Radiation from Relativistic Electrons from Periodic Structures (RREPS)



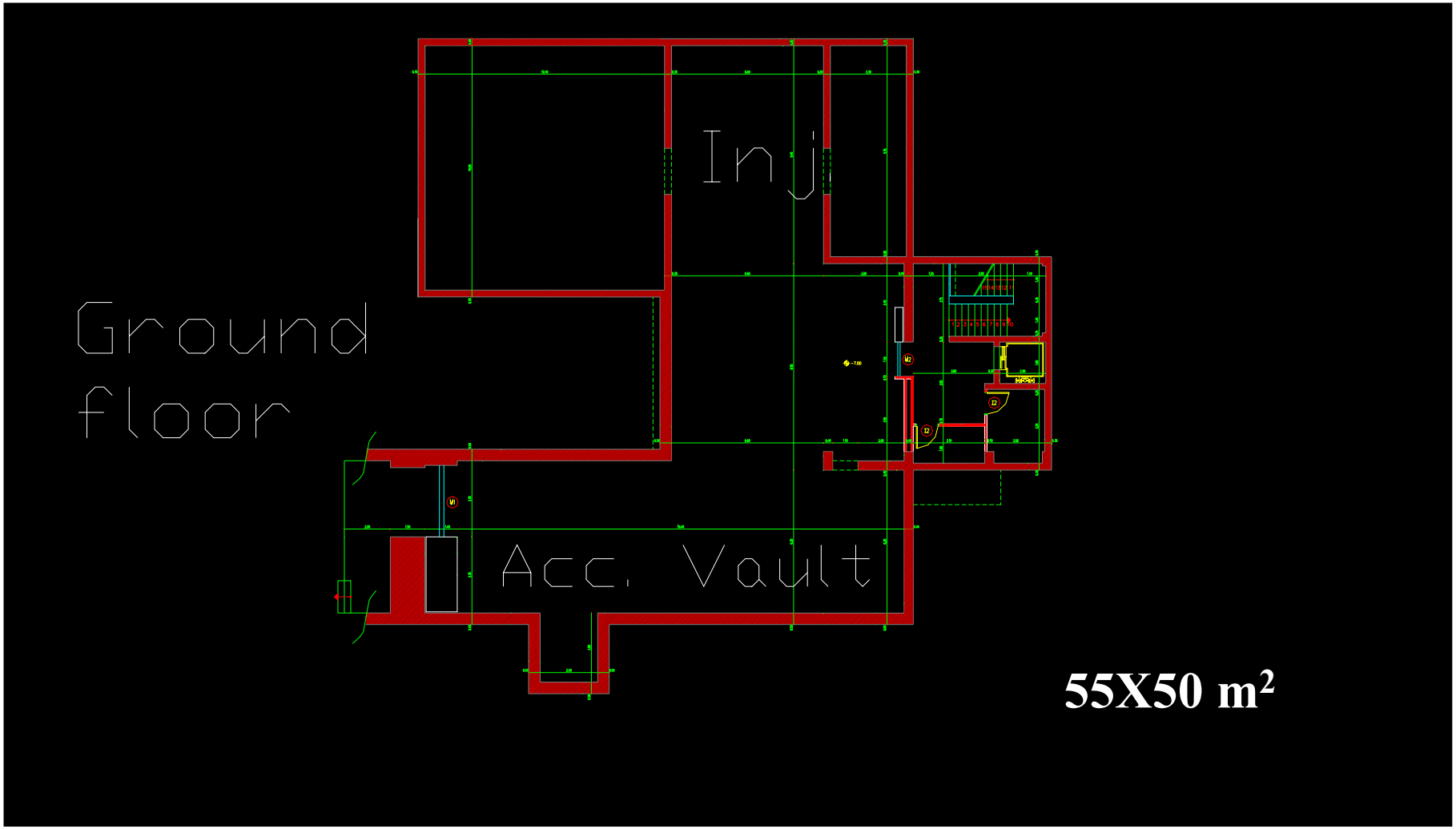


The new building…

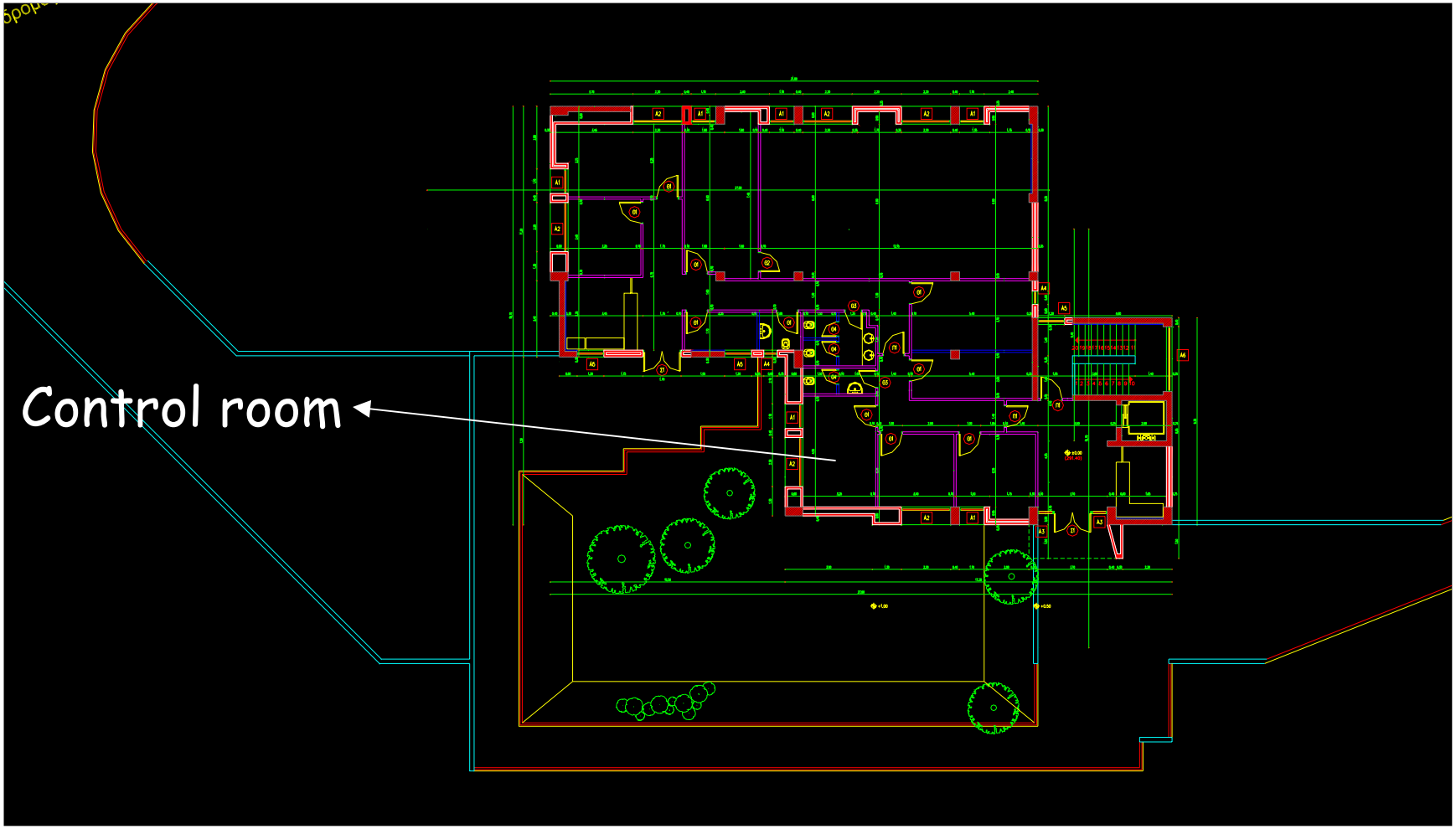


The site of the New building (excavation already started)

IASA Main building : Ground floor



1st floor: control and data taking area



Future plans

- Commissioning of the 10 MeV machine – beam tests
- Full occupation of the experimental areas

Then

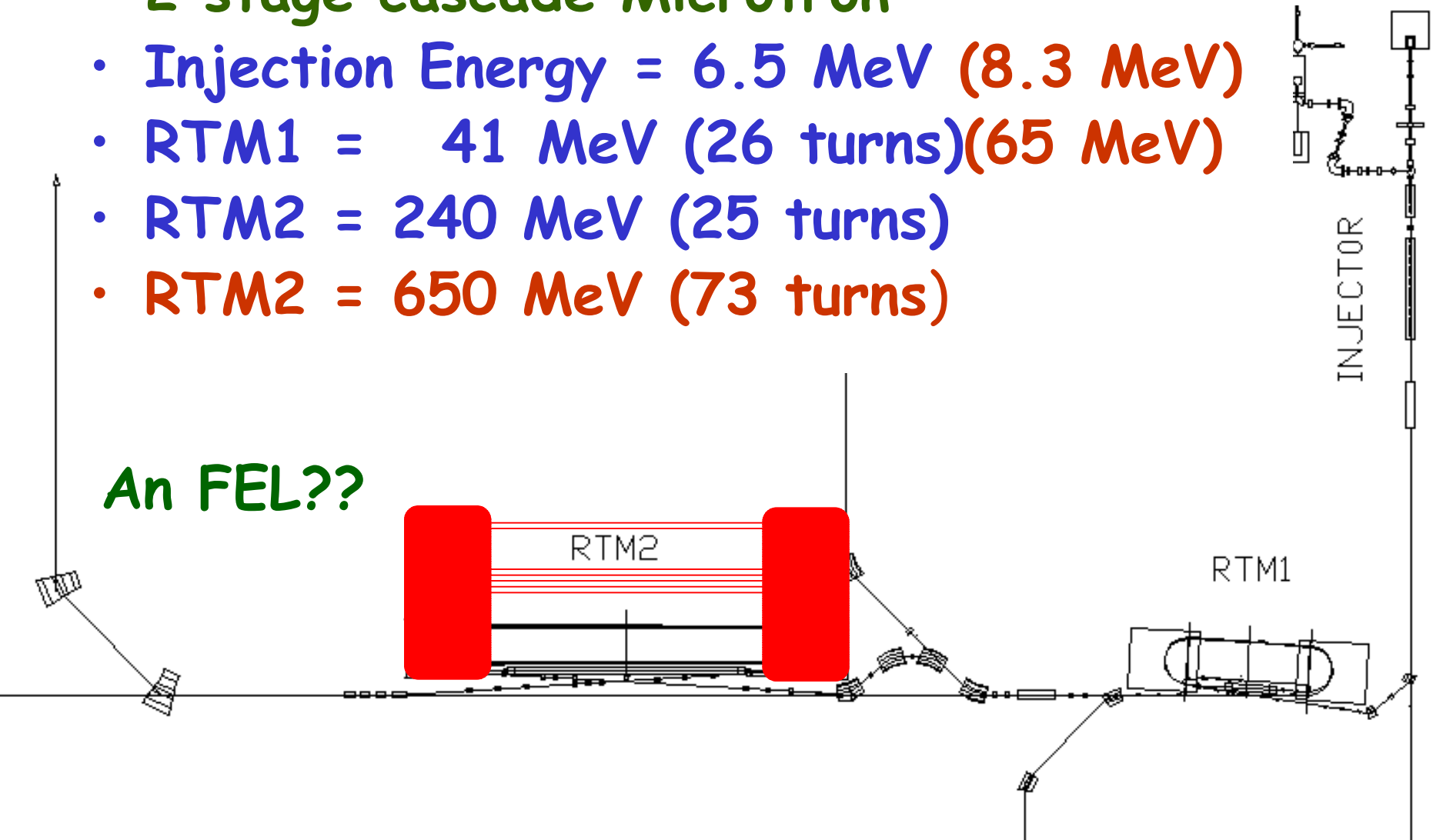
- Beginning of experiments

Oct-97	Beneficial occupancy of "Maquette" Building
Oct-97	2nd International Technical review
Oct-98	100 keV Injector Maquette Completed
Nov-98	Plans for a 10 MeV linac
Sep-99	Beneficial Occupancy of an Exp. Hall
Oct-99	3rd International Technical review
Feb-01	Upgrade to 10 MeV Maquette Initiated
Oct-03	4th International Technical review Committee

One major task is building a cw RT Microtron machine

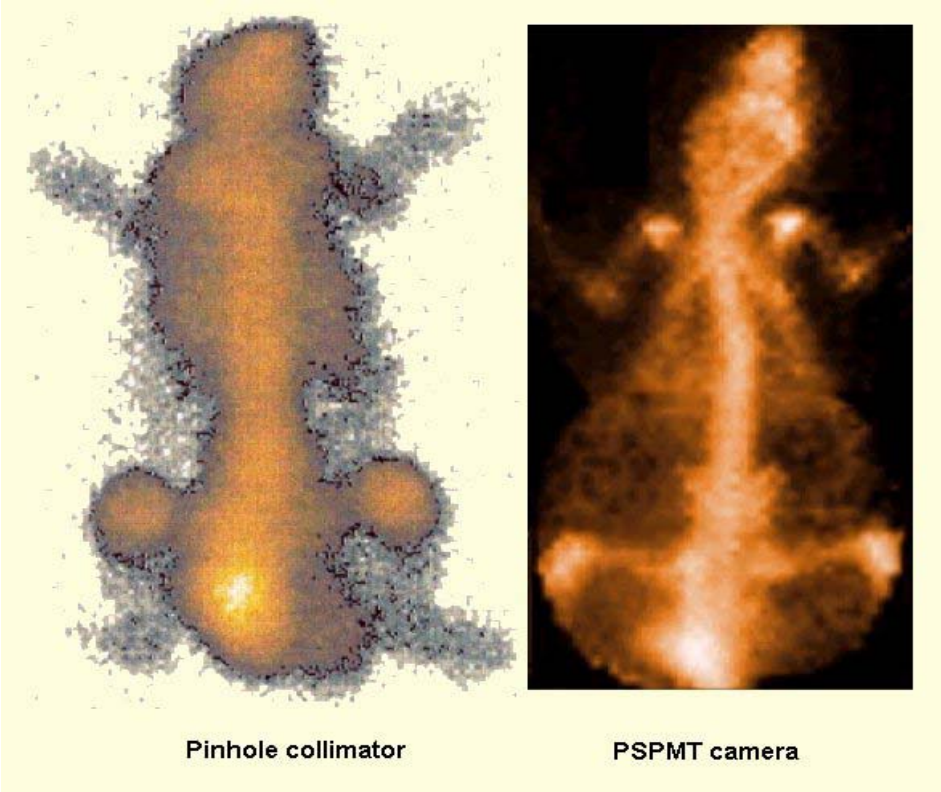
- 2 stage cascade Microtron
- Injection Energy = 6.5 MeV (8.3 MeV)
- RTM1 = 41 MeV (26 turns)(65 MeV)
- RTM2 = 240 MeV (25 turns)
- RTM2 = 650 MeV (73 turns)

An FEL??



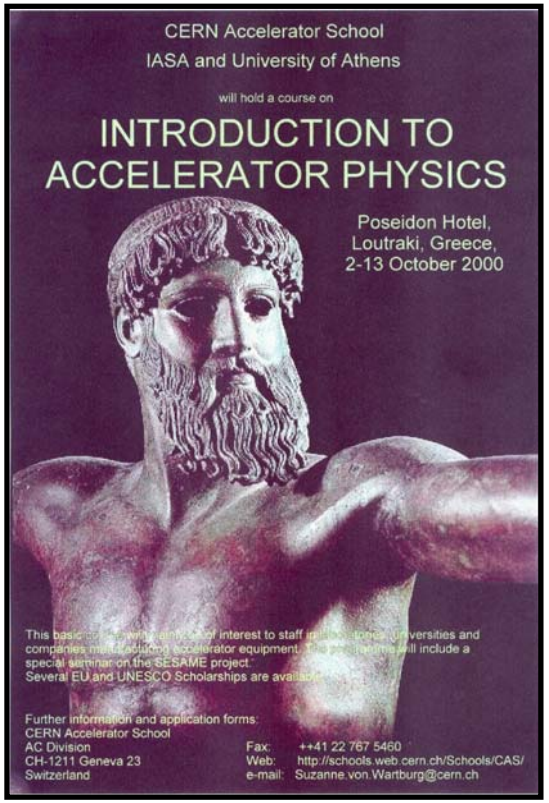
Other activities

- Medical Imaging
- RF development
- Conferences



IASA Conferences

Santorini :
4th one this year



European Research Conferences

Co-sponsored by the European Science Foundation and the Euroconferences Activity of the European Union

ELECTROMAGNETIC INTERACTIONS WITH NUCLEONS AND NUCLEI

PROBING HADRONS AND NUCLEI AT HIGHER ENERGIES

5-10 October 1999, Nomikos Center, Santorini, Greece

ITBS :
3rd one this year

IASA Publications

- EPAC-2000 : The IASA 10 MeV CW-LINAC
- EPAC-2000 : The Personnel Safety System at IASA
- EPAC-2000 : Estimation of Transversal Emittance Using an Artificial Neural Network
- PANIC-99 : The IASA RaceTrack Microtron Facility
- PAC-99 : The S-Band Transmitter Design for the IASA Microtron
- EPAC-98 : The IASA RaceTrack Microtron Facility: A Progress Report
- PAC-97 : The IASA RaceTrack Microtron Facility, A Progress Report
- SPIN-96 : The IASA RaceTrack Microtron Facility
- Gordon-96 Conference : Institute of Accelerating Systems and Applications (IASA) - Progress
- EPAC-96 : The IASA RaceTrack Mictrotron Facility
- EPAC-96 : Optics for the IASA CW RTM
- EPAC-96 : Control System Implementation for the IASA Microtron
- IASA's CDR & internal and technical reports

IASA Team

- Dimitris Baltadoros
- Samuel Cohen
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- Tasos Filippas
- Tassos Garetsos
- Evangelos Gazis
- Athanasios Geranios
- Nikos Giokaris
- Giannis Grammenos
- Andreas Karabarbounis
- Christos Ktorides
- Frantzeskos Maravelias
- Kaliopi Marini
- Nikos Papadakis
- Costas N Papanicolas
- Vicky Phinou
- Paris Sphicas
- Stathis Stiliaris
- Nikos Uzunoglou

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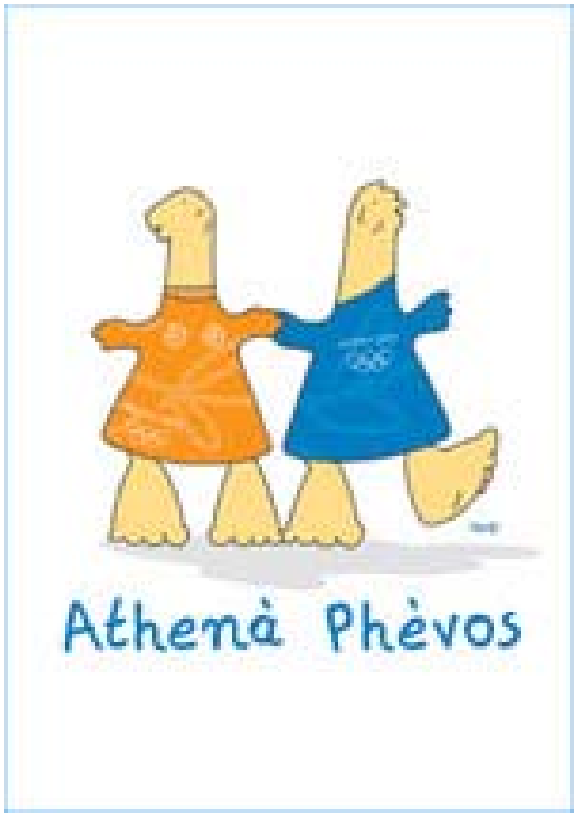
Looking forward to seeing you in Athens….



Athens 2004, the XXVIII Olympic Games