Proton Accelerator Project at the Turkish Accelerator Centre

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*On behalf of the TAC PA working group

Outline

- Turkish Accelerator Center (TAC) Project
- TAC Proton Accelerator Team
- Main Goals
- Applications of Proton Accelerators
- 3 MeV Test Stand: General Layout and Details
- Simulation Codes and Studies
- Future Prospects
- Summary

Turkish Accelerator Center (TAC) Project

- Feasibility Report of TAC (2000), General Design Report of TAC (2005)
- Web page: http://thm.ankara.edu.tr
- Supported by the Turkish State Planning Organization (SPO)
- Tecnical Design of TAC and the first facility (IRFEL and Bremsstruhlung) (2006-2013)
- **The first facility:** IR Free Electron Laser (wavelength 2-300 μm) and Bremstrahlung facility based on 15-40 MeV electron linac (It is planned that the facility will be commisionned in 2013 in Ankara)
- **The proposed main facilities at TAC:**
- Synchrotron Radiation Facility (TAC SR)
- SASE FEL Facility (TAC SASE FEL)
- Particle (Charm) Factory (TAC PF)
- Proton Accelerator Facility (TAC PA)

(The Tecnical Design Report of TAC is planned to be completed in 2013)

Recently

- Accelerator Technology Institute has been established in Ankara University (Coordinator of TAC Collaboration) http://hte.ankara.edu.tr

- Graduate programs on
  - Accelarator Physics and Technologies,
  - Accelerator Based Radiation Sources, and
  - Detectors and Data Analysis Technologies

TAC collaboration and current project team

- **TAC: An Inter-University Collaboration (10 Turkish Universities)**
- **Project Team: 52 staff with PhD + 64 graduate students**

Ankara University (Coordinator)

Gazi University

İstanbul University

Uludağ University

Dumlupınar University

Boğaziçi University

Doğuş University

Erciyes University

Süleyman Demirel University

Niğde University

International Scientific Advisory Committee of TAC (established in 2009)

- Ercan Alp (Argonne, USA) (Head)
- Behçet Alpat (INFN, Perugia, Italy)
- D. Asner (PNL, Richland, WA),
- Swapan Chattopadhyay (The Cockcroft Institute, UK)
- Ken Peach (Oxford Univ., UK)
- Luigi Palumbo (INFN, Frascati, Italy)
- R. Sauerbrey (FZD, Dresden, Germany)
- Zehra Sayers (Sabanci University, Istanbul, Turkey)
- Saleh Sultansoy (TOBB University, Ankara, Turkey)
- Gökhan Ünel (CERN, Geneva, Switzerland)
- Helmut Wiedemann (SLAC, USA)
- Frank Zimmermann (CERN, Geneva, Switzerland)
- W. Eberhard (HZB-BESSY, Berlin, Germany)
- E. Minehara (JAEA, Japan)

Proposed TAC Proton Accelerator Facility

TAC PA DESIGN GROUP
Coordinator: Dr. Baki Akkuş
Deputy Coordinator.: Dr. Latife Şahin
Deputy Coordinator: Dr. Metin Yılmaz

Accelerator and Beamline Group

COORDINATOR: Dr. Yeşim Öktem

- Dr. Ela Ganioğlu
- Dr. Lidya Susam
- Gülfem Susoy
- Abdüllatif Çalışkan
- Fatih Kışoğlu
- Ayşegül Ertoprak
- Fatma Çağla Öztürk
- Bengü Bilgier
- Hatice Canan Közer

Experimental Stations and Research Potential Group

COORDINATOR: Dr. Emel Algın

ADS Energy Production

COORDINATOR Dr. Hüseyin Yapıcı

- Dr. Metin Arık
- Dr. Gamze Genç
- Dr. Nesrin Demir
- Dr. Mustafa s. Genç
- Gülşah Özışık
- F. Aslıhan Şenzeybek
- Veli Yıldız
- Cemile Ezer

Engineering and Nuclear Applications

COORDINATOR Dr. Abdullah Kaplan

- Selin Durak
- Erdoğan Akyazı
- Hakan Pekdoğan
- Abdullah Aydın

Nuclear Physics

COORDINATOR Dr. Eyyüp Tel

- Dr. Burcu Çakırlı
- Levent Küçük

Health and Radiation Protection

COORDINATOR Dr. Bayram Demir

- Dr. Rahmi Küçer
- Sevil Gelgün
- İffet Çavdar
- Murat Okutan

Main Goals

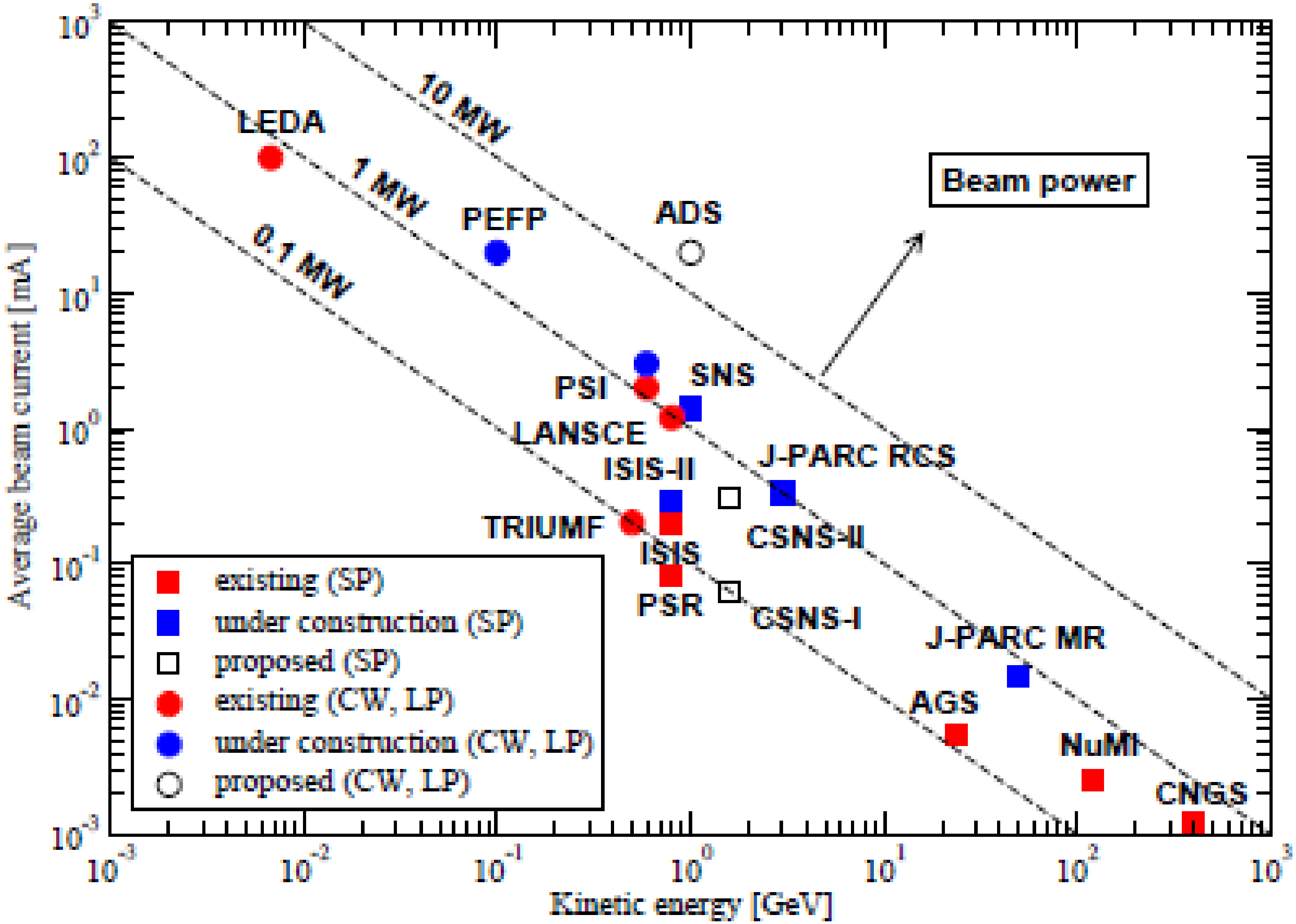
- Presently, the project is at an early technical design stage.
- Final goal: Beam power 1 MW and 1-3 GeV energy
- First: Three stages are planned:
  - 3 MeV test stand
  - 55 MeV DTL part
  - 100 MeV CCDTL part

➢ Better to start with low power and low energy beam:
  - where beam quality set for entire machine
  - where we will build experience
  - where some medical and industrial applications

3 MeV Test Stand Working Group

Ion source, LEBT	Latife ŞAHİN, Hakan PEKDOĞAN, Abdullah AYDIN, Abdullah KAPLAN
RFQ, MEBT	Metin YILMAZ, Abdullah ÇALIŞKAN, Fatih KIŞOĞLU, Veli YILDIZ
Power systems	Lidya SUSAM, Ayşegül ERTOPRAK
Cooling systems	F. Çağla ÖZTÜRK, Bengü BİLGİER, Yeşim ÖKTEM
Vacuum systems	Emel ALGIN
Cost analysis	Bayram DEMİR
Radiation protection	Bayram DEMİR, Rahmi KÜÇER
Magnets	Ela GANİOĞLU, Candan KÖZER

Proton Accelerators in the World



What we are planning to do!

- A multi-purpose proton accelerator facility

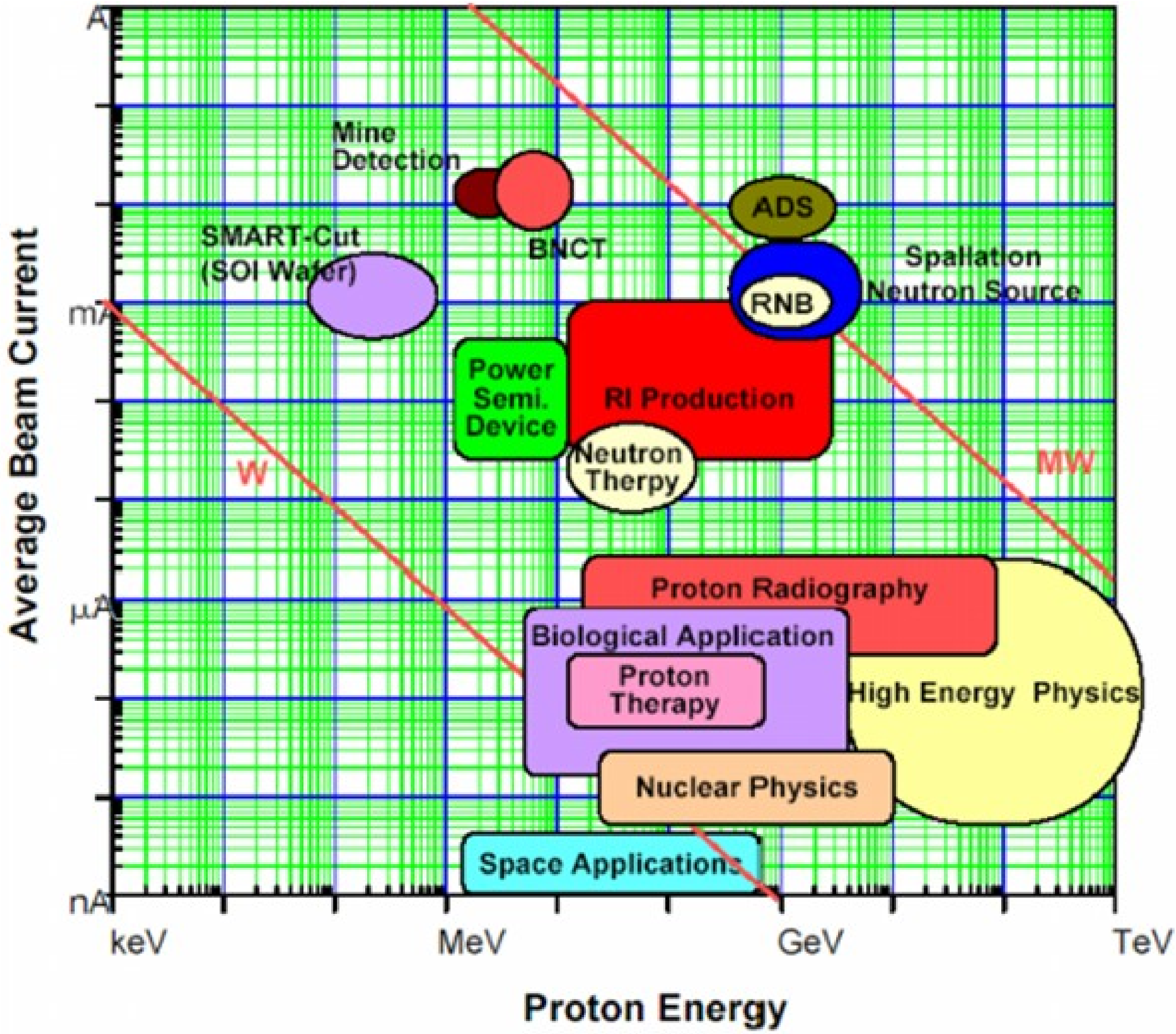
Short Term Goals:

- Medical facility for cancer therapy (BNCT, Proton)
- Irradiation and isotope production facility
- Neutron radiography
- Proton microbeam facility

Long Term Goals:

- Neutron spallation facility
- Radioactive ion beam facility
- Research on ADS

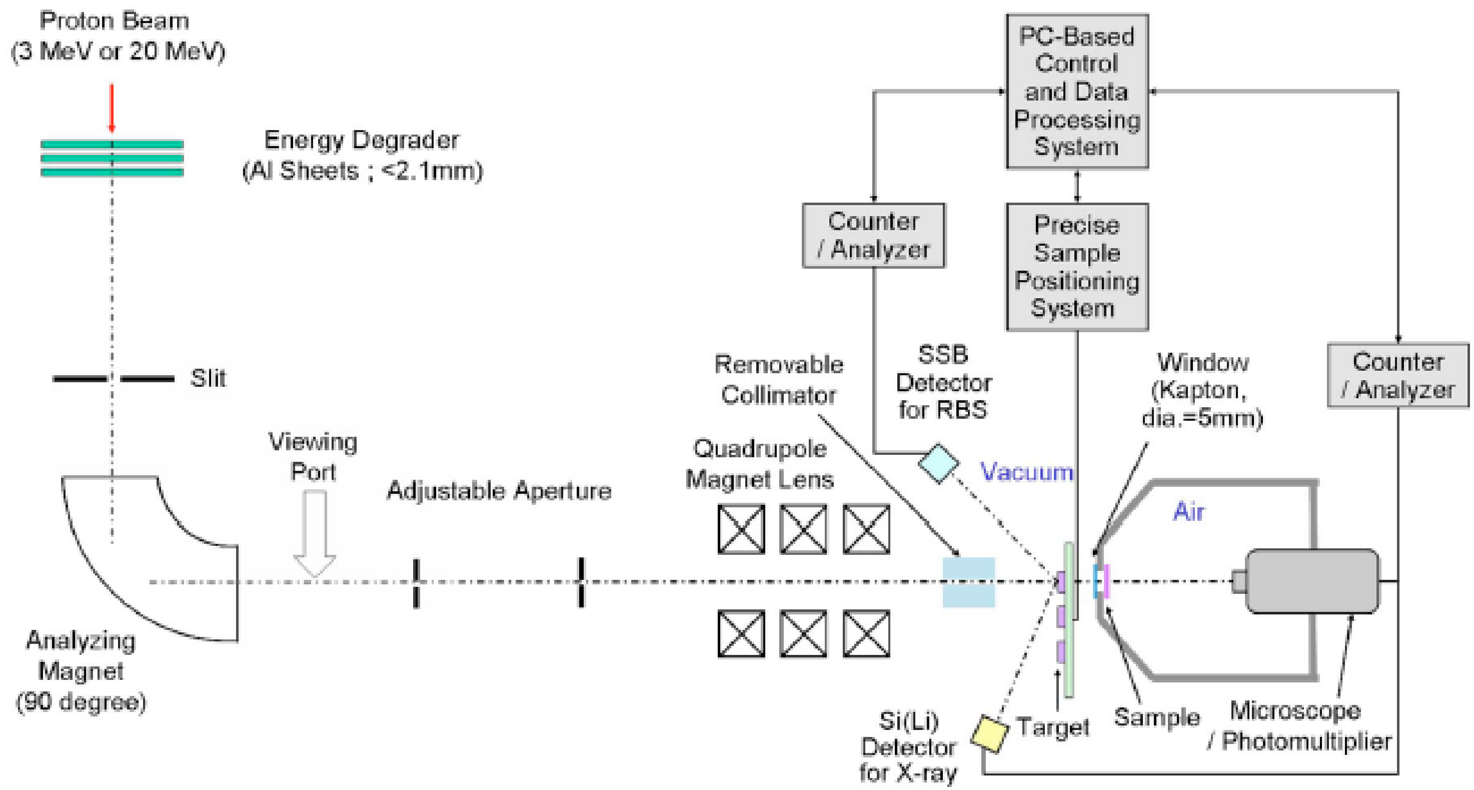
Typical Applications



Applications of Proton Accelerators

- Secondary particles, such as neutrons and radioisotopes can be produced by a high-power proton accelerator.
- High-current proton beams with low energy (< 10 MeV) are useful in industrial and defense applications.
- Low-current proton beams with moderate energy (10–250 MeV) are valuable in biological and medical applications.
- High-power proton beams with energies around 1-3 GeV are widely utilized in spallation neutron sources, radioisotope beam facilities, nuclear and high energy physics experiments, and accelerator-driven systems.

An example:
Proton accelerator as a proton microbeam facility, Kore



Example: Schematics of the conceptual design of PEFP's microbeam (Korea)
Kye Ryung Kim *et al.*, Review of Scientific Instruments **79,** 02C720 (2008).

3 MeV Test Stand (R&D of Linear Accelerator)

- As the first step of the R&D work, prototype IS and RFQ can be fabricated in order to demonstrate the RF cavity and IS performance.
- As the second step of the R&D, 3 MeV test stand can be fabricated and tested.
  - To understand high intensity proton accelerator linacs
  - To check the basic RFQ technologies such as tuning, beam matching
  - Beam dynamics at low energy
  - Required time structure of proton beams
  - To develop and test the components of low energy part of linac

Principal front-end beamline components

- H- ion source (IS)
- Low energy beam transport system (LEBT)
- Radio-frequency quadrupole linac (RFQ)
- Medium energy beam transport line (MEBT)

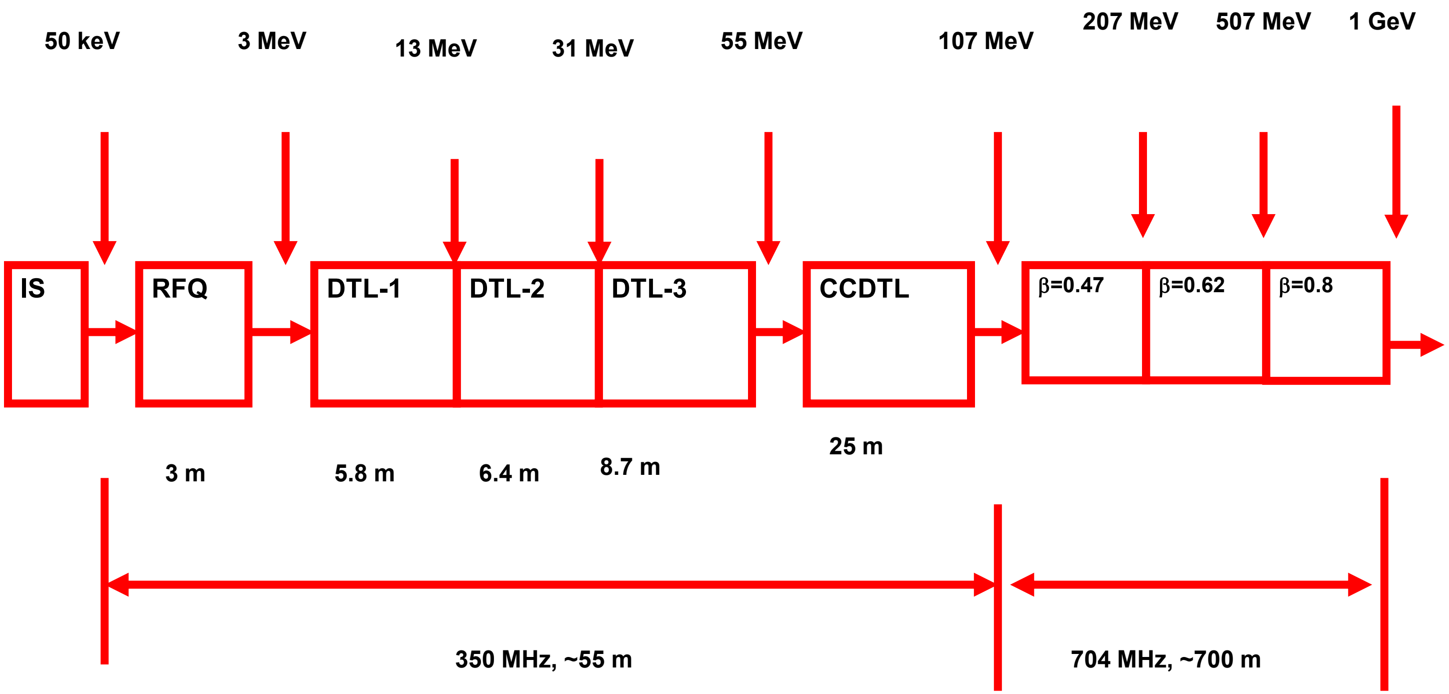
To produce an appropriate beam of H- ions and inject it at 3 MeV into a following linear accelerator chain for further acceleration.

Supporting technical components for 3 MeV test stand

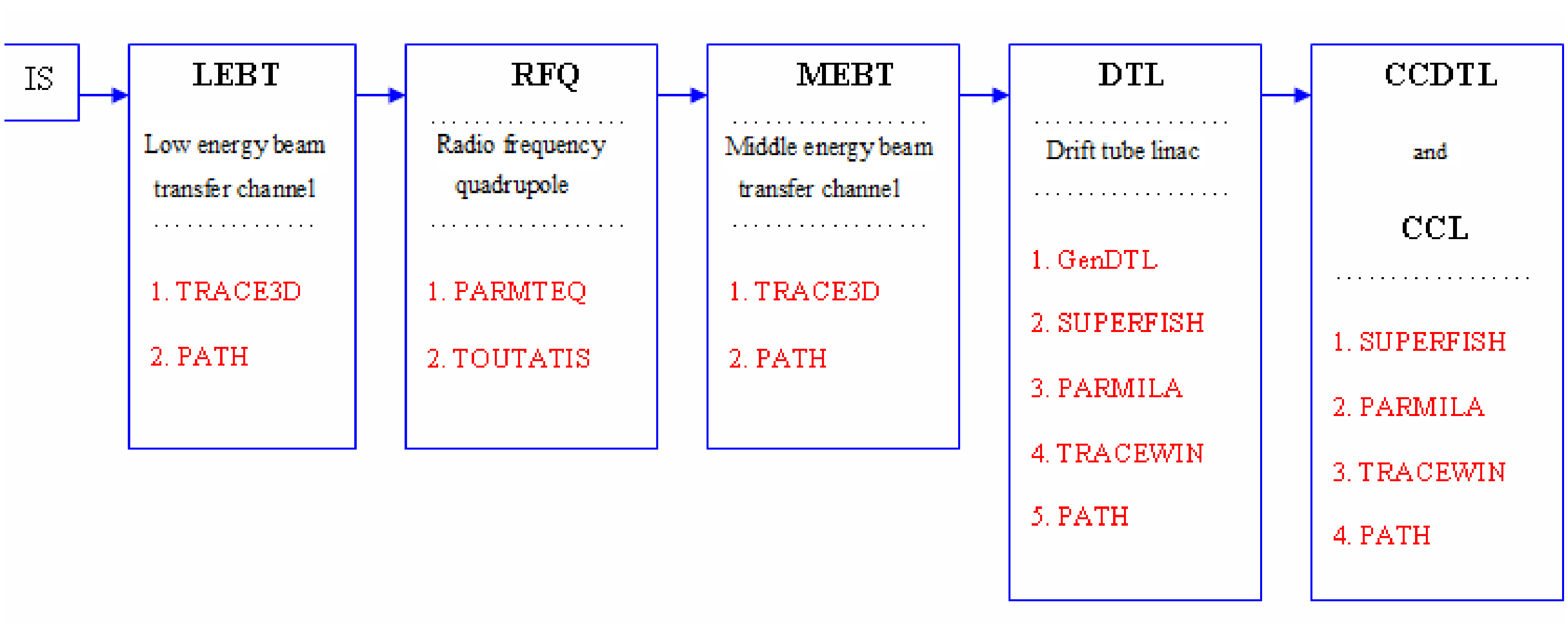
- Mechanical systems
  - Ion source
  - RFQ structures
  - Transport structures (LEBT, MEBT)
  - Local water systems (for cooling and temperature stabilization)
  - Front end buildings
  - Mechanical subsystems
    - Front End Diagnostics and Instrumentation
    - Water Subsystems
    - Support and Alignment
    - Vacuum Subsystems
    - Electrical Power
    - Reliability, Availability and Maintainability

- Electrical systems
  - Power supplies
  - Beam diagnostics
  - RF systems
  - Front end control systems
  - Electrical site services
  - Mechanical /Piping utility systems
  - Front end communications

Block diagram of the accelerator



Computer codes to be used for design



Simulation Studies and Codes

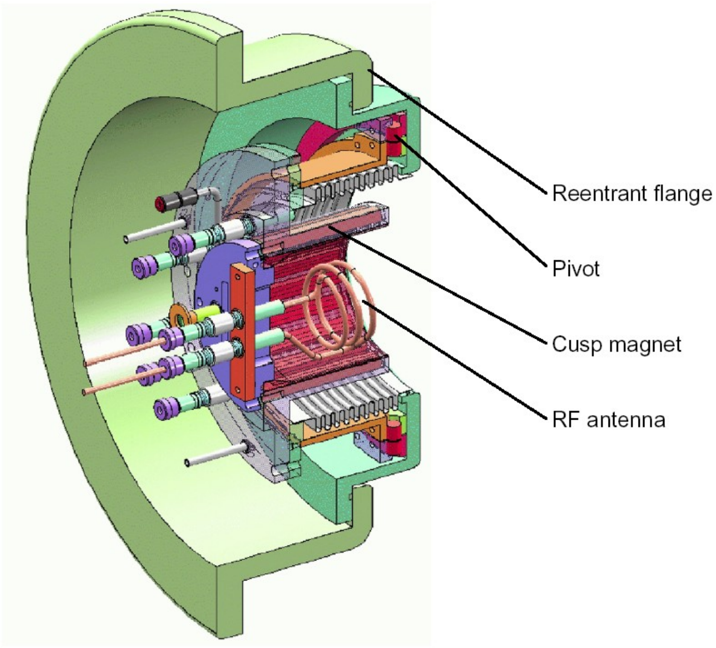
- **TOUTATIS** : We used TOUTATIS code for pre-simulation of RFQ accelerator. To design RFQ structure exactly we need to use PARMTEQ code.

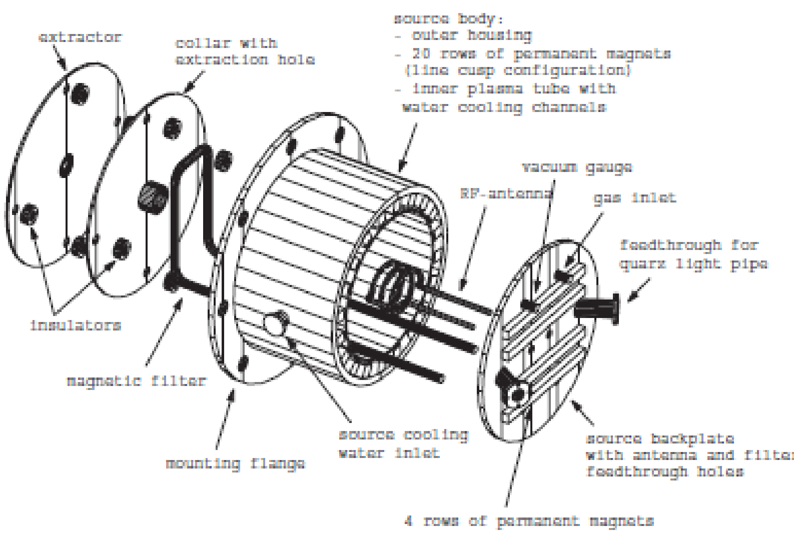
- **SUPERFISH** : This code is a cavity design program. It consists of RFQfish, DTLfish, CDTfish, CCLfish corresponding the RFQ, DTL, CCDTL and CCL accelerators respectively.

- **PARMILA** : Parmila is an ion-linac particle-dynamics code. The name comes from the phrase, "Phase and Radial Motion in Ion Linear Accelerators." Parmila uses data generated by the Poisson Superfish.

Toward Selecting an H^- Source

- The ion source is a multicusp, rf-driven, cesium-enhanced source of H^-.
- Design concept - for example SNS, Linac4.
- Design issues – in general these sources are well understood.





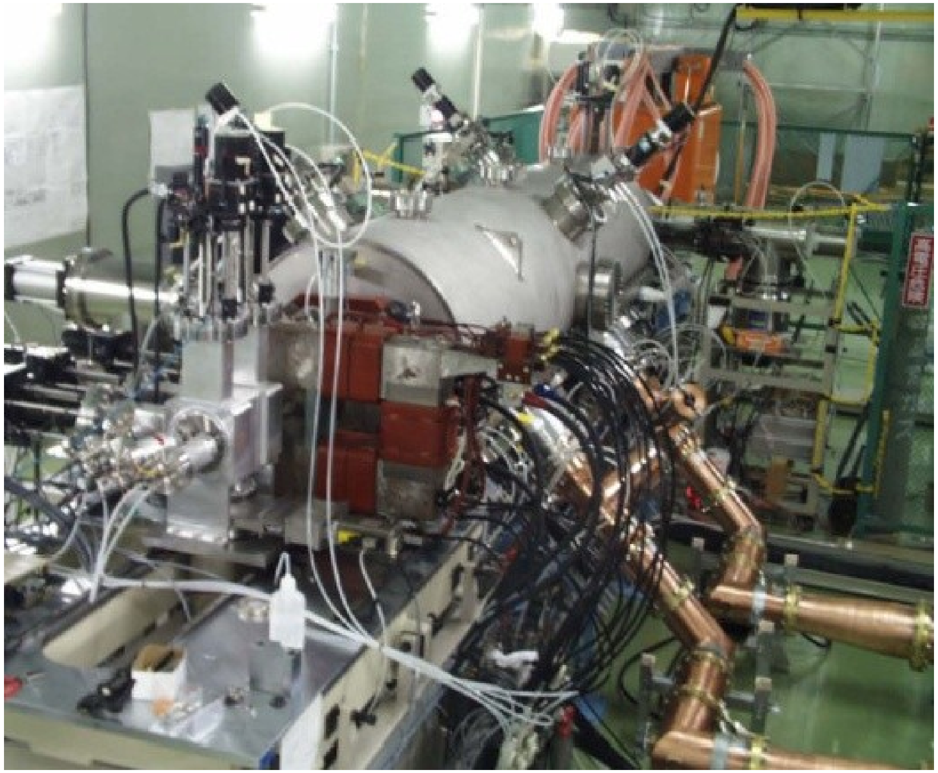
R. Keller *et al.*, Proceedings of EPAC, Vienna, Austria (2000).

Starting ion source parameters

Ion Source	RF Multicusp H^-
Average current (mA)	30-50
Output energy (keV)	45-65
Repetation rate (Hz)	25-50
Beam pulse length (ms)	1-2

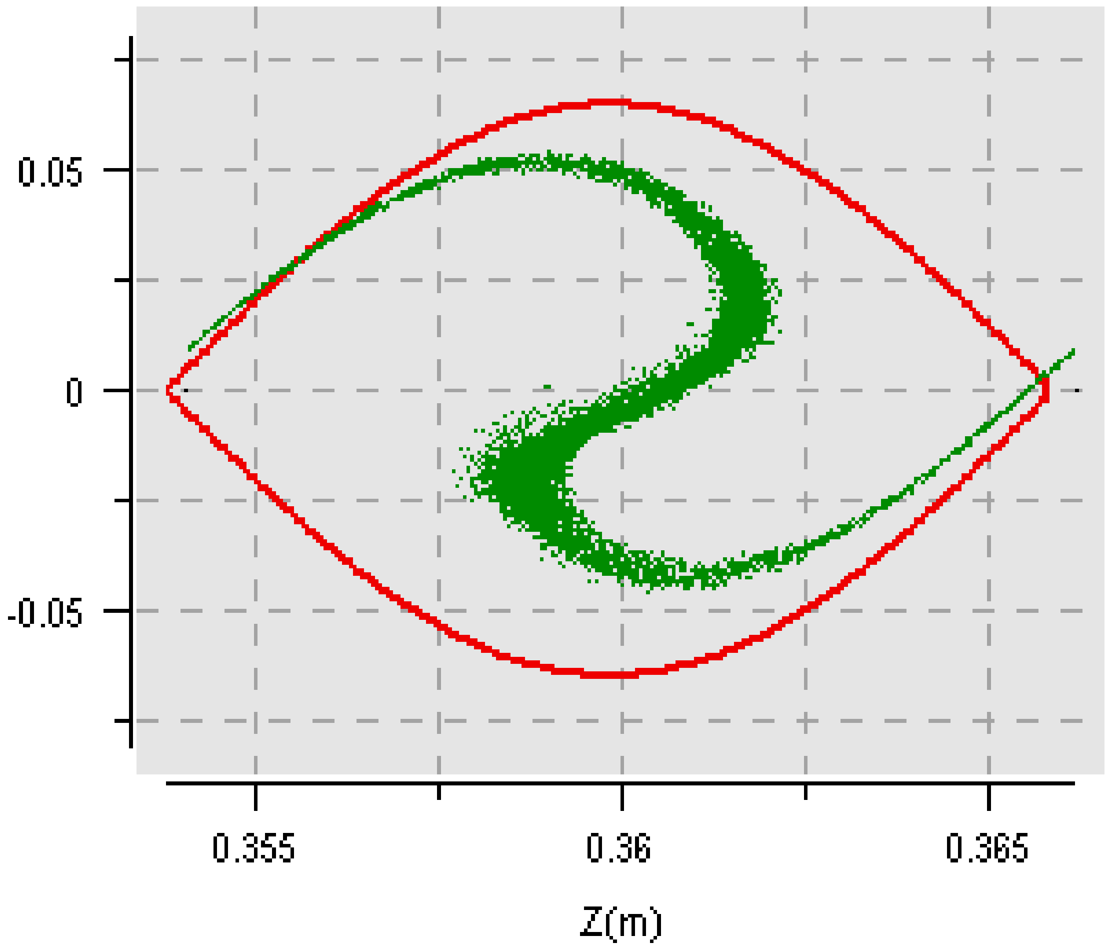
RFQ

- RFQ (Radio Frequency Quadrupole) is a resonant structure used to focus, bunch and accelerate a continuous stream of ions simultaneously
- Now RFQs are standard devices for proton machines. There are good designs (SPL, J-PARC, SNS) and we can copy appropriate technical solutions

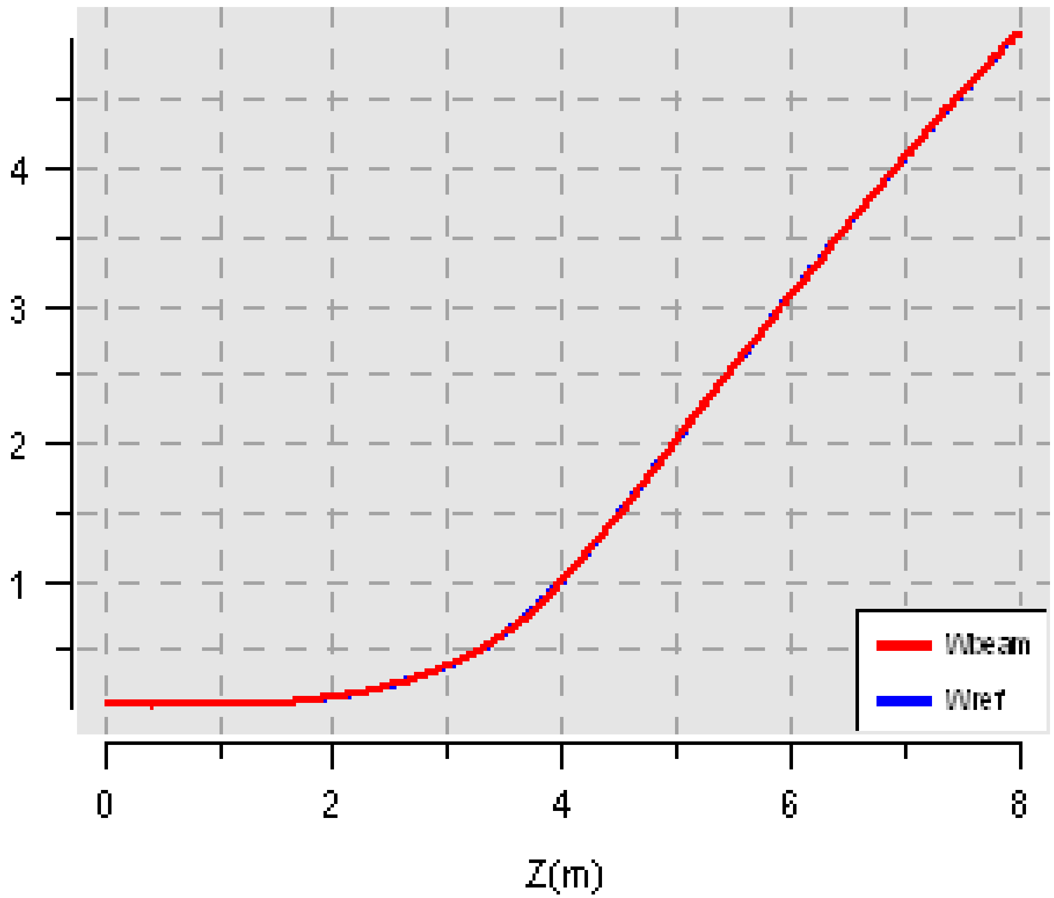


J-PARC 30 mA RFQ

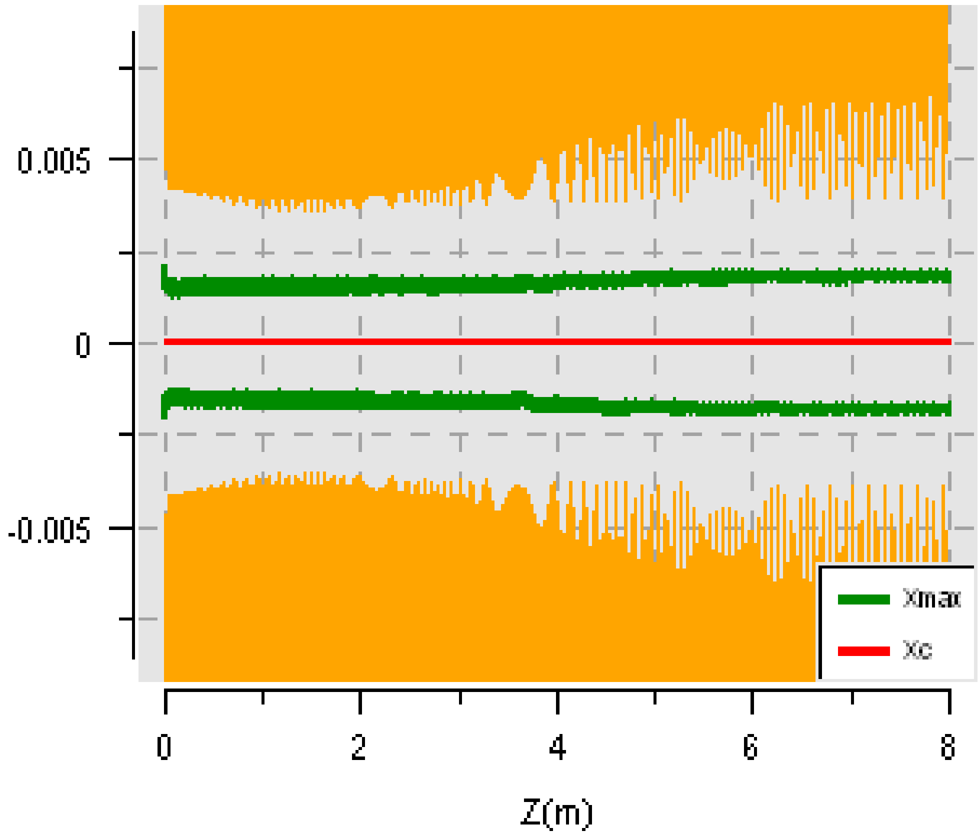
RFQ simulation results: Beam bunch in the direction of



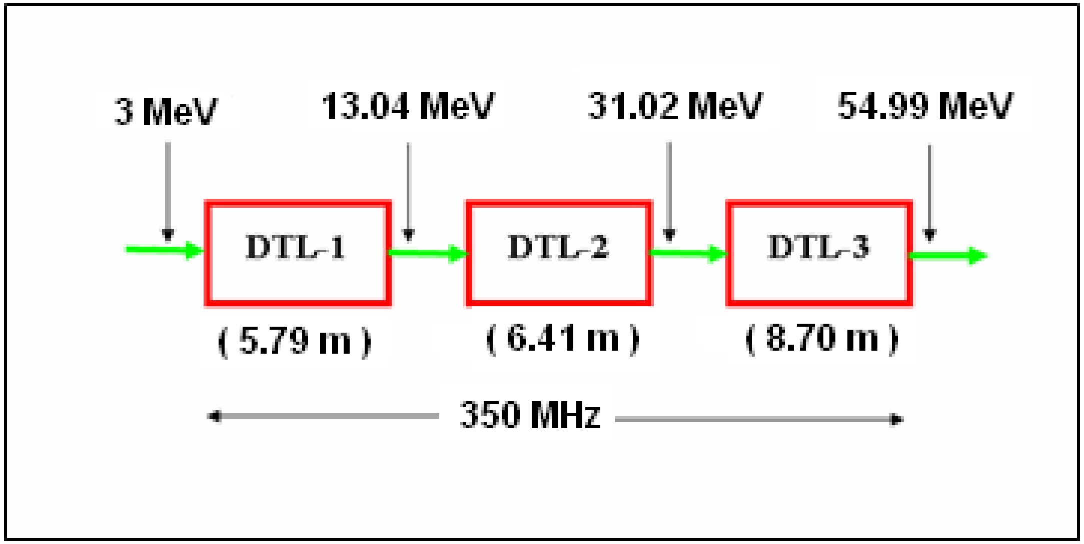
RFQ simulation results: Energy plot in MeV in the direction of x



RFQ simulation results: Beam envelop in the direction of x

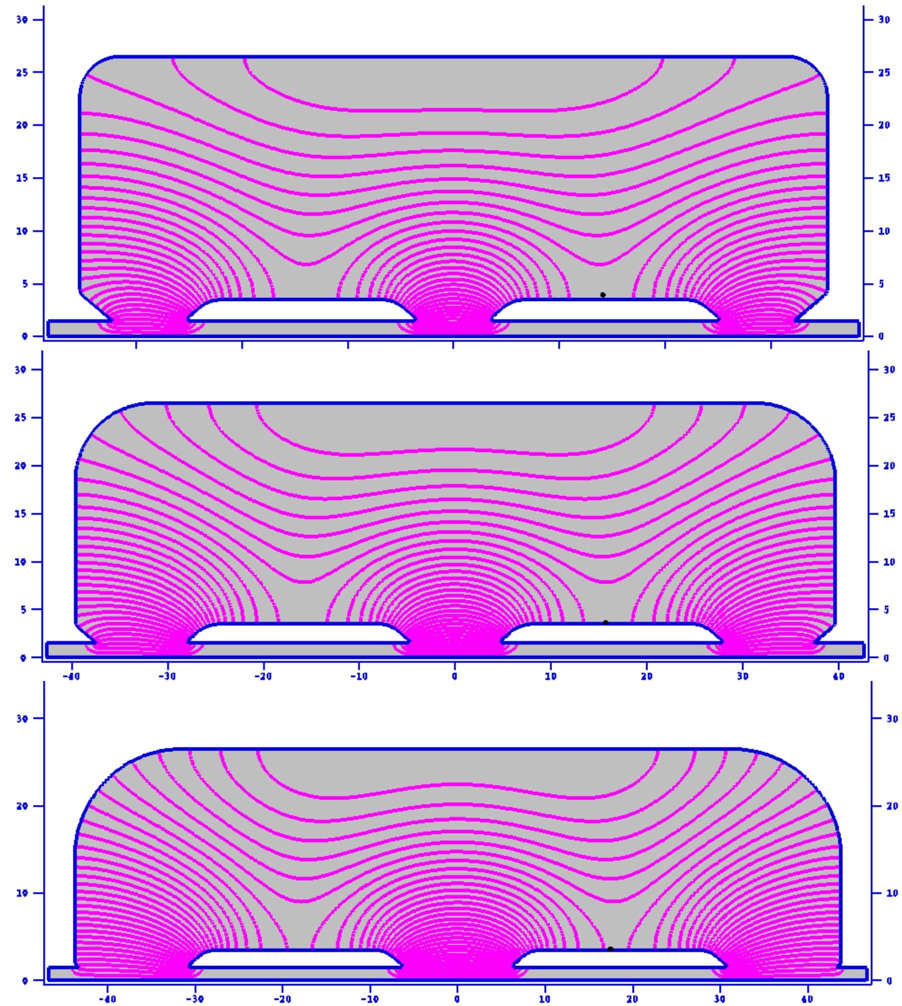


DTL Design



The design of the DTL was started with a 3 MeV input energy and by using three tanks, 55 MeV output energy was achieved.

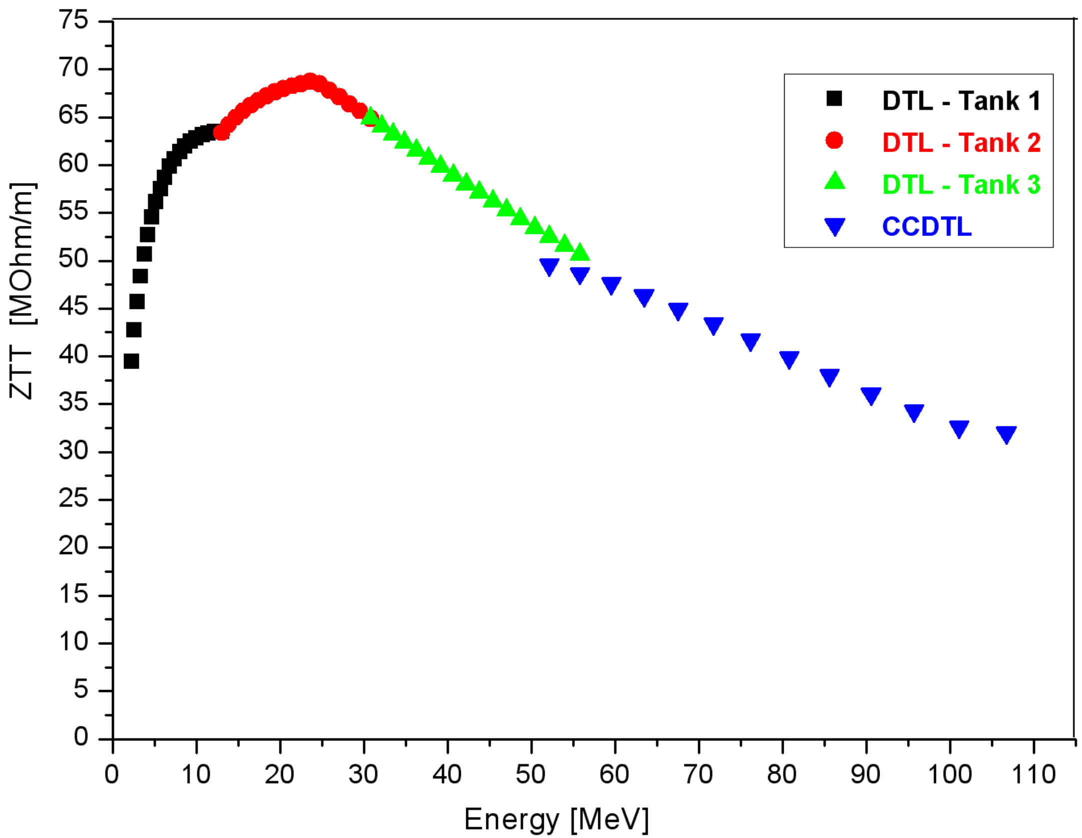
Electric field distributions of CCDTL half cavity for 55.' MeV, 71.75 MeV, and 90.03 MeV energies, respectively



Optimized parameters for CCDTL cavities

PARAMETER	VALUE	UNIT
Energy region	55~90.5	MeV
Beta factor	0.33~0.41	-
RF frequency	350	MHz
Tanks per module	3	-
Gaps per tank	3	-
Tank diameter	53	cm
Equator Flat	63	cm
Inner corner radius	0.8	cm
Inner and outer nose radius	0.05	cm
Cone angle	40	degrees
Drift-tube diameter	8	cm
Stem diameter	2	cm
Drift tube Inner and outer face angles	50	degrees
Aperture radius	1.5	cm

Efficient shunt impedance for the DTL and CCDTL cavities of the TAC proton accelerator



Steps in near future (by considering ISAC recommendations)

- Budget to design and construct three stages (3 MeV test stand + 55 MeV DTL + 100 MeV CCDTL)

  - A project proposal for construction of 3 MeV part of facility will be submitted to Turkish State Planning Agency in 2012.

  - Another proposal is planned to IAEA. The budget of this proposal is planned for training and gaining experience on designing and building a proton facility. Team members will take part in visiting similar laboratories such as the SNS, ESS, CERN SPL, J-PARC, ISIS, CSNS, CPHS of China, PEFP of Korea.

Steps in near future, cont.

- Extensive list of applications achievable with three stages will be prepared
  - Potential local and international users will be informed/consulted
- Clinical case for BNCT will be developed
- “3 MeV + DTL” part will be renamed.

Steps in near future, cont.

- A detailed layout of accelerator tunnel and associated halls will be carried out.
- Location of the project will be selected.
- Careful evaluation of running costs at maximum duty cycle will be done.
- The project plan
  - Cost
  - Schedule
  - Manpower
  - Financial resources

Steps in near future, cont.

- Qualified person needs: physicists, engineers, technicians
  - To face three stage project requirements and long-term solutions
- Consultancy of experts for technical aspects
  - Time-based contracts to one or two experts

Steps in near future, cont.

- There is an ongoing activity to build a 30 MeV cyclotron facility at TAEK
  - Synergies with Sarayköy Nuclear Research and Education Center (SANAEM) of Turkish Atomic Energy Agency (TAEK) on proton beam project in general
    - Focusing on RFQ and ion source
    - On specific radionuclide production

Steps in near future, cont.

- A preferred proton-accelerator option for higher energy region should be selected, based on a comparative analysis of performance
  - Based on the trainings at abovementioned laboratories,
    - a comprehensive civil engineering studies,
    - cost estimation,
    - comparative performance analyses

    will be performed by taking into account additional limits on the geometry and size of the TAC facility.

Steps in near future, cont.

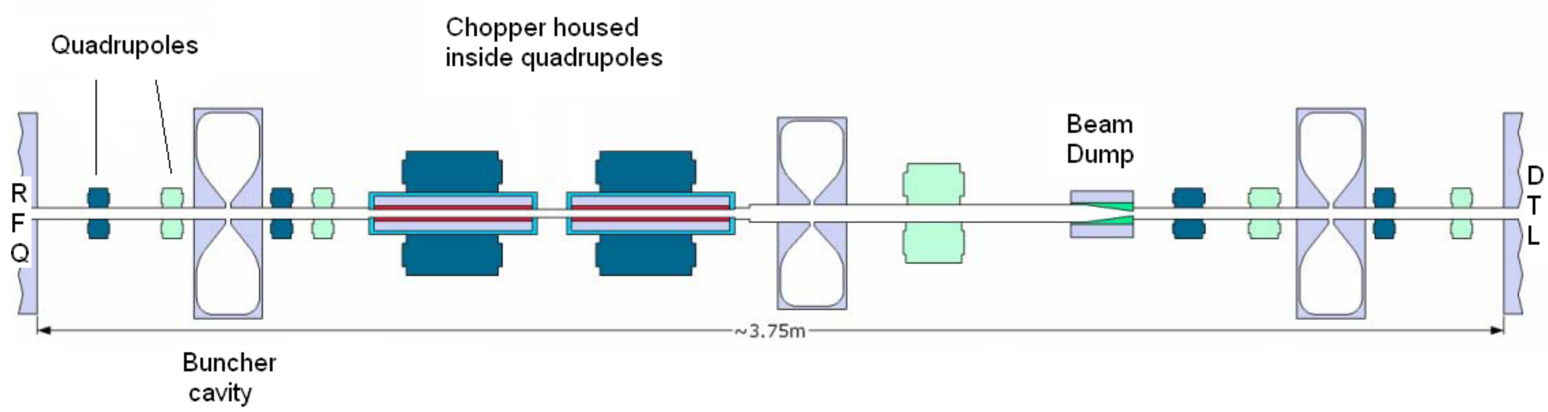
- TAC should try to closely collaborate with similar machines and projects around the world
  - TAC has an initiative to collaborate with similar machines and projects around the world, such as the the Spallation Neutron Source, European Spallation Source (ESS), CERN SPL, JPARC, ISIS, CSNS.

Two of our PhD students had been at CERN this year

- Abdüllatif Çalışkan worked with Accelerator and Beam Physics Group.

- Veli Yıldız worked with Radio Frequency Group.

Benchmarking of the results of PATH and PARMILA cod by A. Çalışkan



LINAC4 MEBT-Chopper line include 11 quadrupole magnets, 3 buncher cavities, 2 chopper plates and a beam dump.

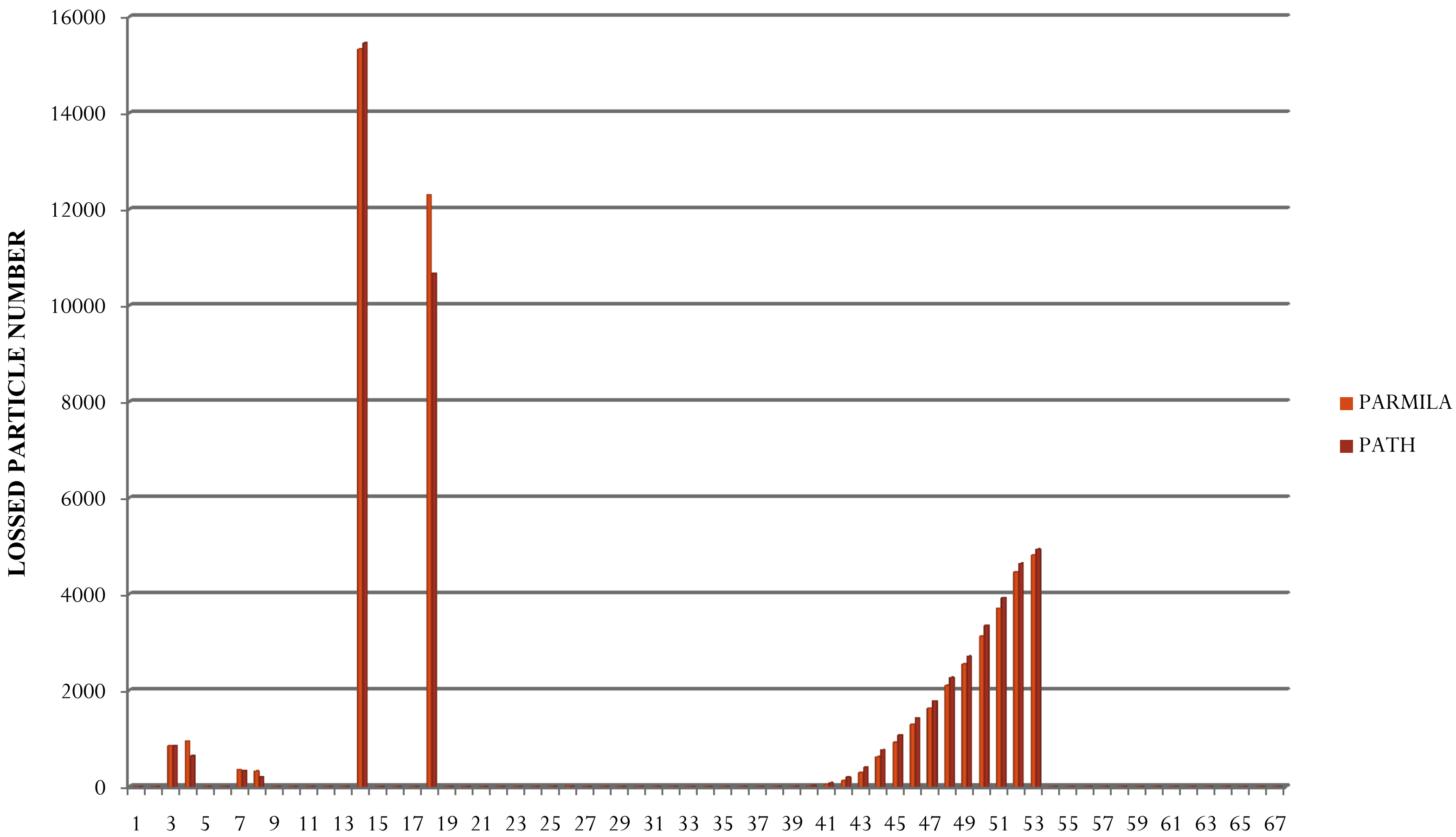
He used certain parameters for chopper line to compare PATH and PARMILA

PATH and PARMILA codes were run with space charge chopper line. Particle losses are given:

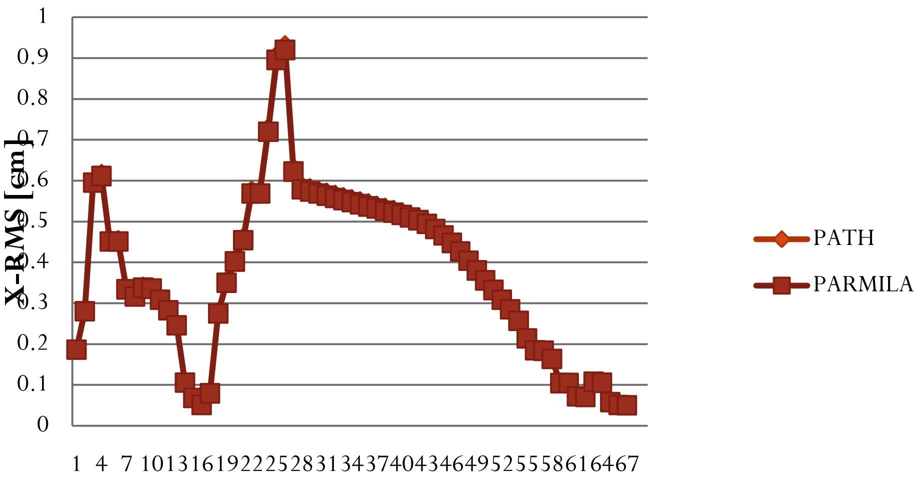
	Input Particle Number	Output Particle Number	Losses
PATH	92 841	37 158	55 683
PARMILA	92 841	37 129	55 712

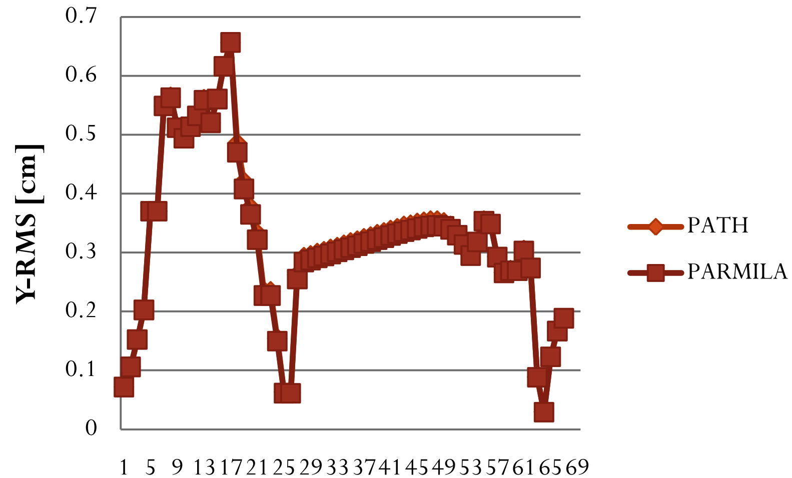
In both codes, average current in the particle distribution file was used. It's value is 0.0052 mA.

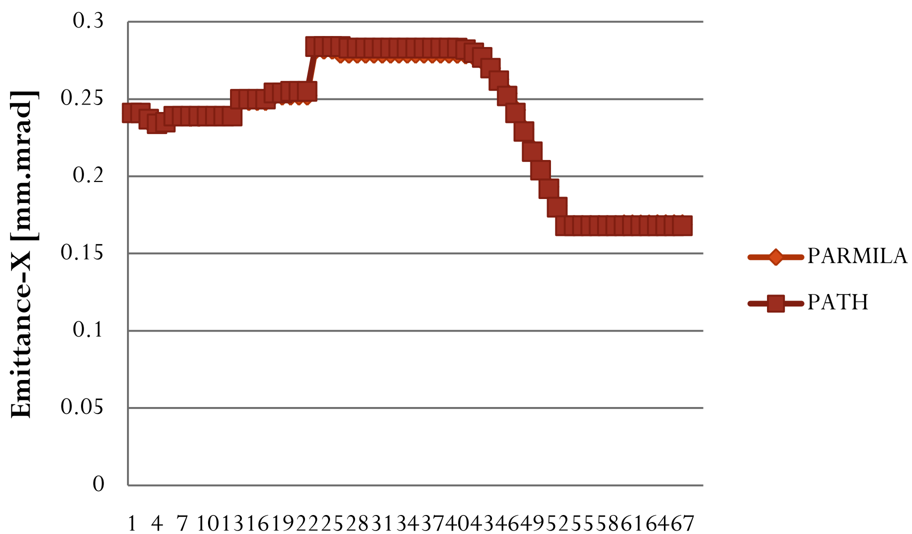
Particle losses in both codes



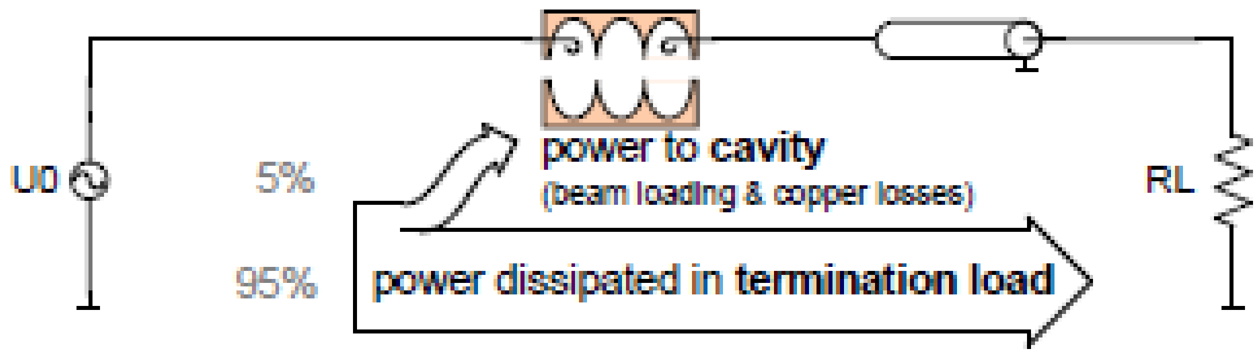
Comparison of PATH and PARMİLA







V.Yıldız helped the LİNAC4 group on the feasibility study of a hig
power rf - rectifier for an energy recovery application



In many particle accelerators considerable amounts of RF power reaching the megawatt level are converted into heat in dummy loads. For the energy recovery, they built two working laboratory prototypes.

What we need

- Simulations and R&D Studies
- Technical Design
- Human Resources
- Financial Resources
- To **make this facility complementary** to other facilities existing or under construction
  - Welcome your suggestions
- Close **international collaborations and international support**

Summary

- TAC Proton Accelerator facility will provide a multidisciplinary platform for scientific research and applications by national institutions, universities, and industries (that will be the first in its kind in Turkey.).
- The design of 3 MeV test stand and 100 MeV facility will be initial phase of TAC PA project (construction phase: 2013-2017).
- The final goal is to design and build 1-3 GeV PA facility.
- We are open for international collaboration and discussions to improve the very preliminary conceptual schematic diagram.
- We believe that, our collaboration with SPL team in frame of TAC PA facility will strengthen Turkey-CERN relationships in the period of full membership of Turkey to CERN.

THANK YOU!