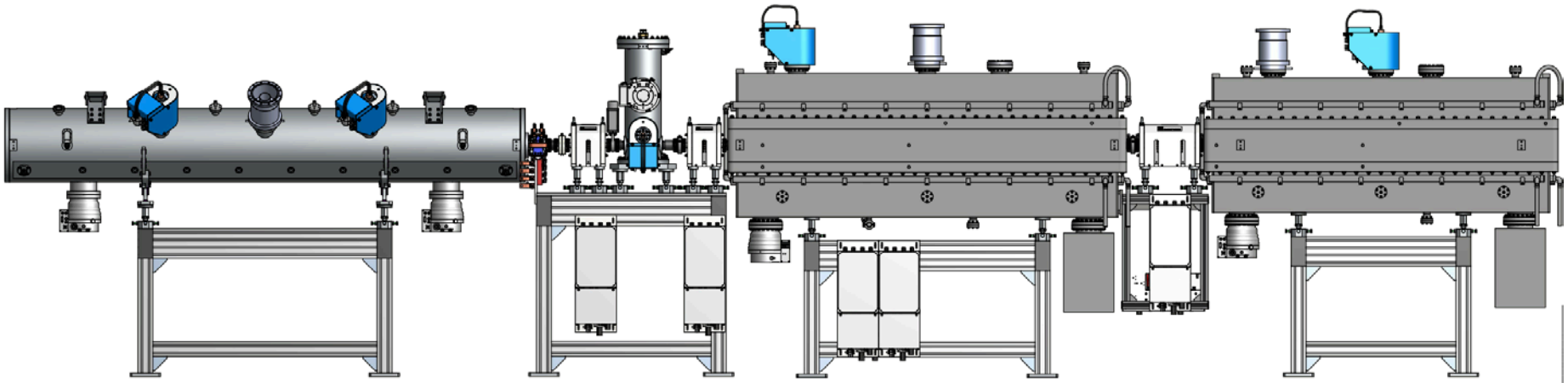
Experiences as a contractor for Linac design and production during on-site beam commissioning

Aries Workshop
‚Experiences During Hadron Linac Commissioning‘
25.01. – 29.01.2021

Uli Ratzinger
BEVATECH GmbH, Frankfurt
IAP Goethe University, Frankfurt

Table of Contents

- Collaboration between JINR and BEVATECH
- Linac diagnostics, general remarks
- Bevatech as a contractor for the JINR NICA Heavy Ion Linac Injector HILAC (2012 – 2018), including commissioning
- Conclusions



Activities at BEVATECH

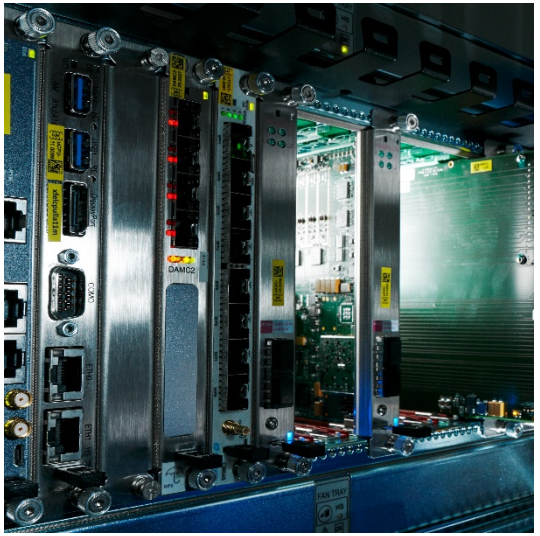
ACCELERATORS & VACUUM

- Complete LINAC Systems
- RF Cavities
- Beam Diagnostic
- Vacuum Technology
- Tumor Therapy

ENGINEERING & CONSULTING

- Beam Lines
- Vacuum
- Design Studies
- RF Research
- Outsourcing
- Project Management

ELECTRONIC & IT



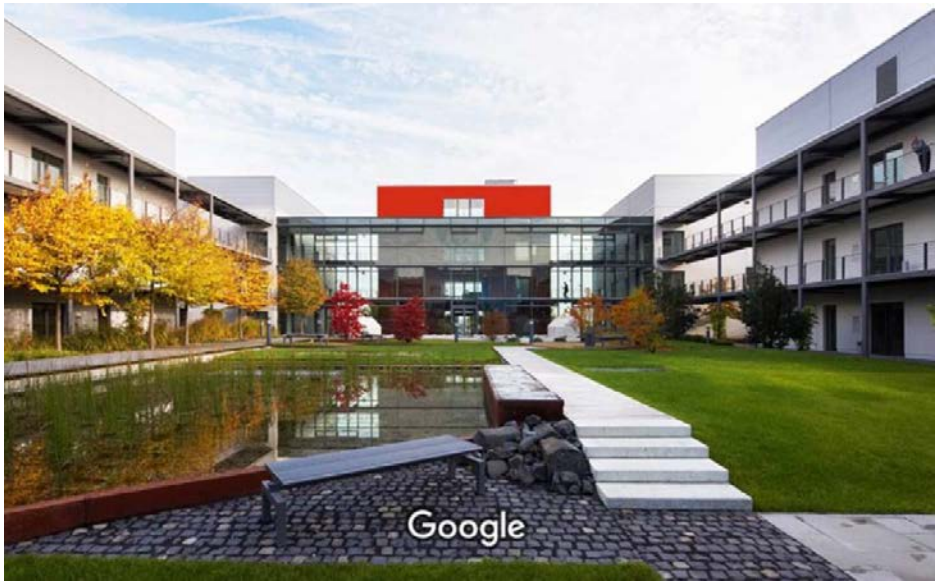
- Micro TCA
- Automation
- Instrumentation & Controls
- Project Management

BEVATECH

Locations across the street

Physics building GU Frankfurt and FIZ with Bevatech

Frankfurt Innovation Center FIZ with offices from BEVATECH GmbH



BEVATECH

How much diagnostics in Linacs?

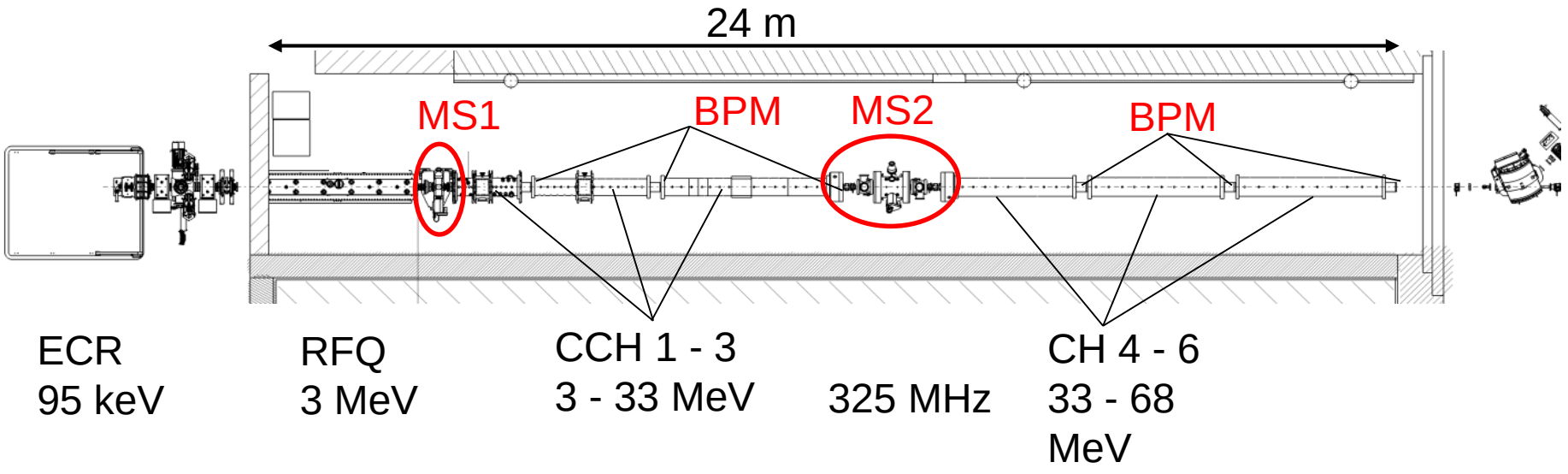
A general conflict has to be solved in every new linac layout:

How many drifts are needed for beam diagnostics installations and how long is each of them?

- The linac offers by far the fastest acceleration concept with the highest time averaged beam current
- Any drift is an interruption of the acceleration process
- Such discontinuities can lead to emiitance growth
- Drifts limit the acceleration rate to avoid instabilities
- Too less beam diagnostics hinders to find optimum parameter settings
- Missing diagnostics can cause risks in linac safety (in particular with increasing beam power)

How much disgnostics ?

Layout example: 325 MHz p – linac for FAIR
(Layout by IAP Frankfurt, construction together with GSI/FAIR)



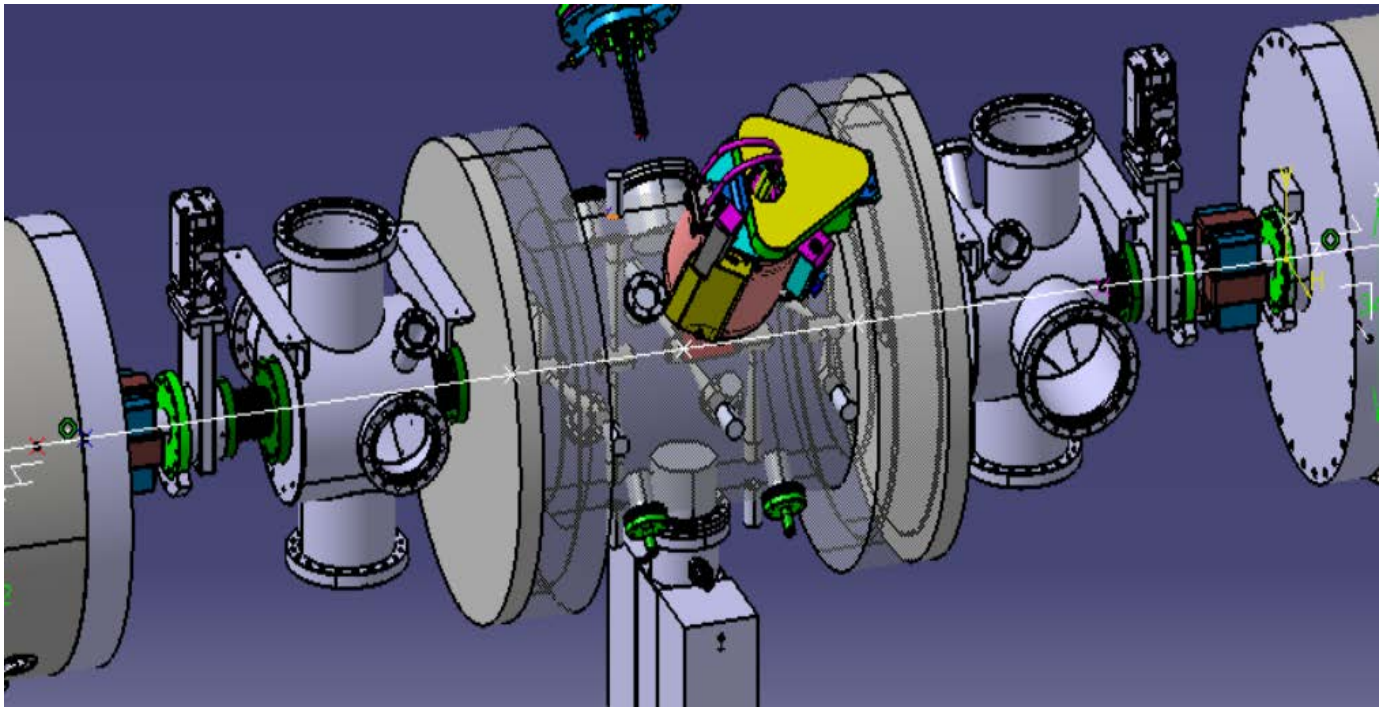
MS1: matching from RFQ to DTL: BPM & CT

MS2: Matching section (2m) within the DTL

BPM: There is a 4-knob phase probe placed after each DTL – cavity

Trend: Phase Probe → 4-Button-Probe BPM

How much diagnostics?



MS2 contains two diagnostic boxes - before and after the 2 MV Rebuncher and two xy – steerers.

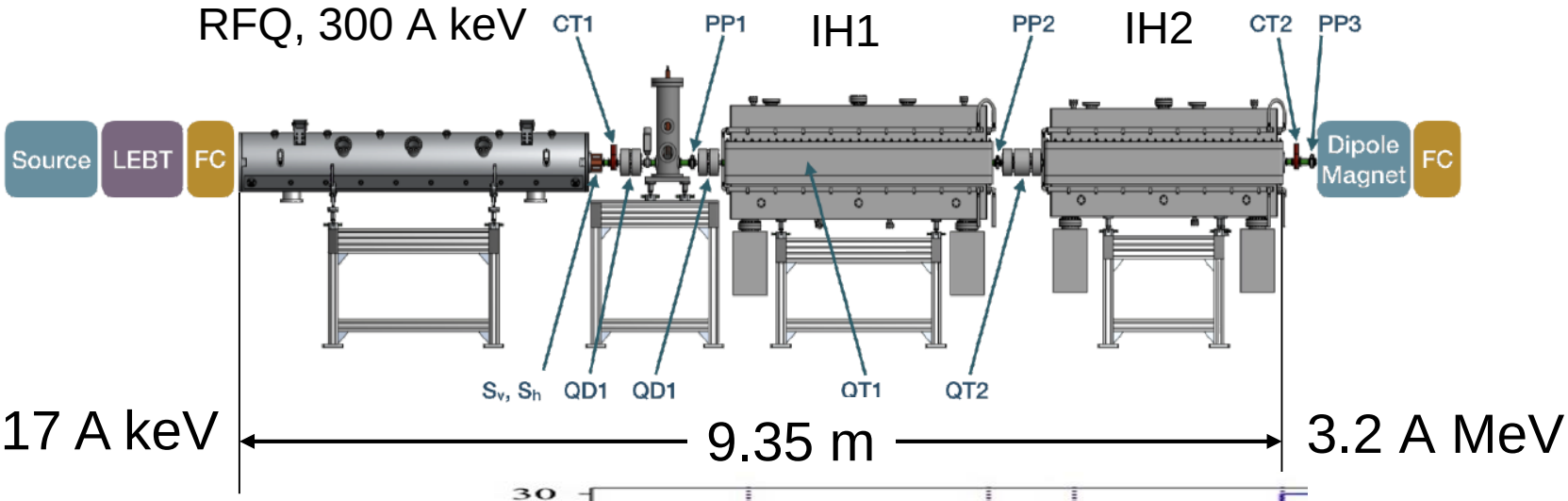
But: Rebuncher needed for this long drift, 150 kW,

and an extra Quadrupole triplet!

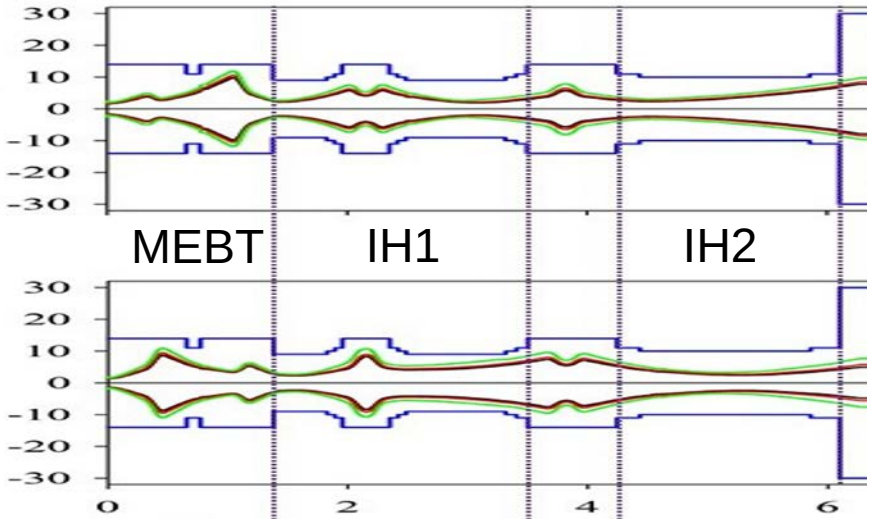
JINR Heavy Ion Linac - HILAC

JINR HILAC, Dubna, 101 MHz, 3.2 AMeV, A/q < 6.3

Bevatech contracted for design, construction and participation in commissioning for cavities, lenses amplifiers



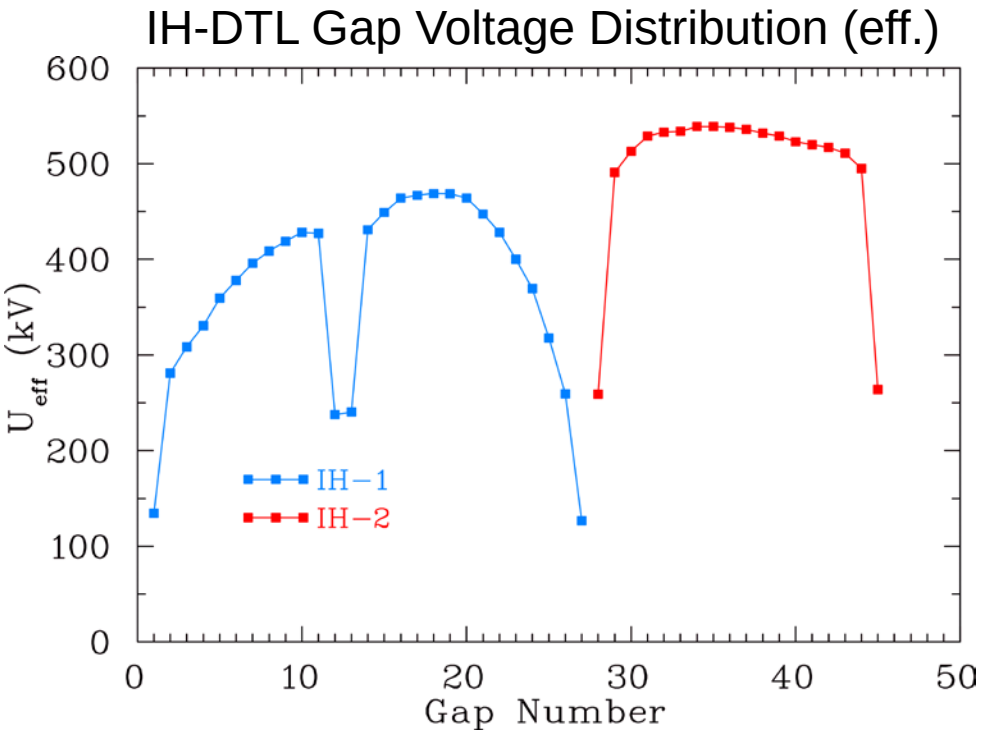
- Current transformers CT1, CT2
- Phase probes PP1, PP2, PP3
- Analyzing magnet
- Faraday cup FC

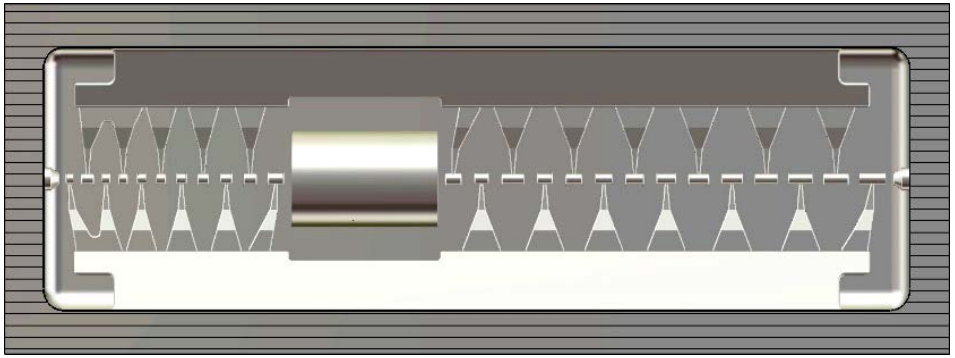


BEVATECH

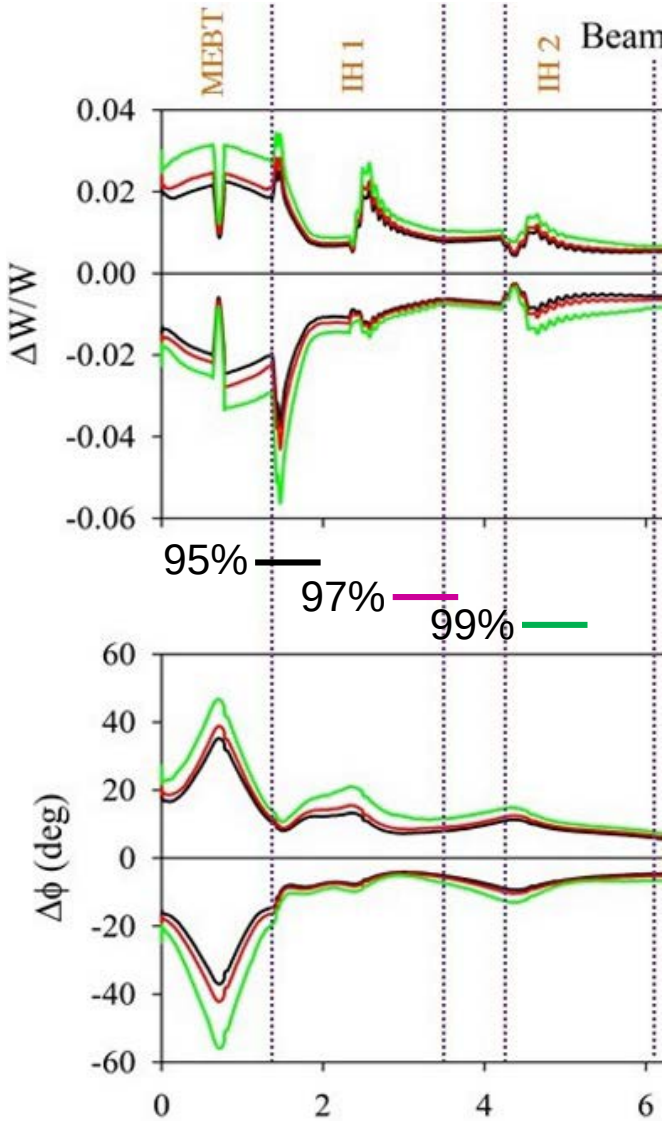
HILAC Commissioning at JINR

Commissioning Example - HILAC





IH1-cavity



KONUS Beam Dynamics

BEVATECH

Commissioning Example - HILAC

Design, construction & installation: 2012 – 2016

First joint beam commissioning phase : Second half of 2016

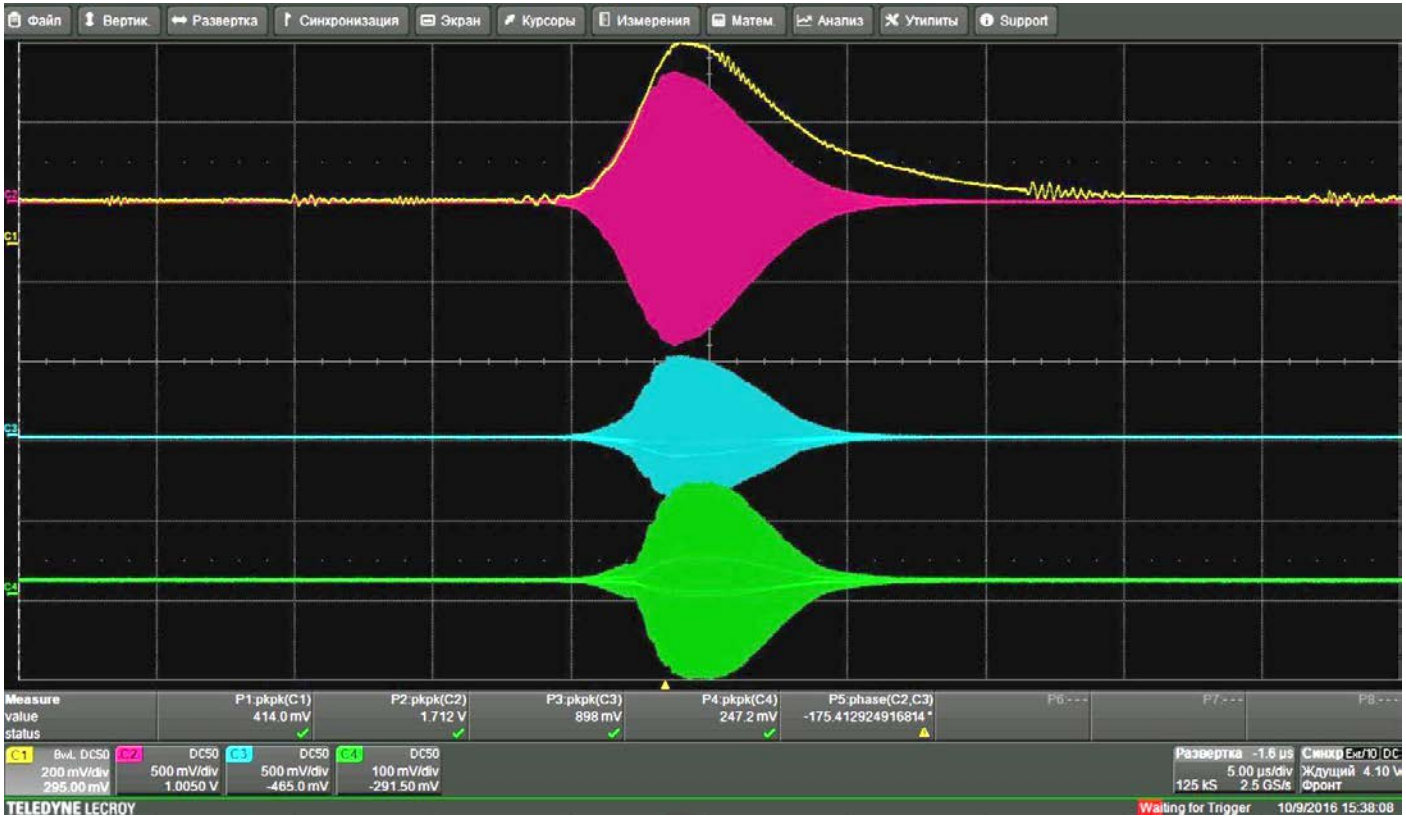
Second joint beam commissioning: 10 days in Oct 2018

First multiturn injection into Booster Ring: Dec 2020

The HILAC will deliver highly charged heavy ions (e.g. Au $^{32+}$) from an EBIS source

The beam commissioning was accomplished with carbon ion beams from an intense Laser Ion Source LIS: C^{2+}, C^{3+}, C^{4+}. A few mA for each charge state are possible. Ring commissioning was performed with 7 – 10 mA from the Helium source.

Commissioning Results - HILAC



CT1

PP1

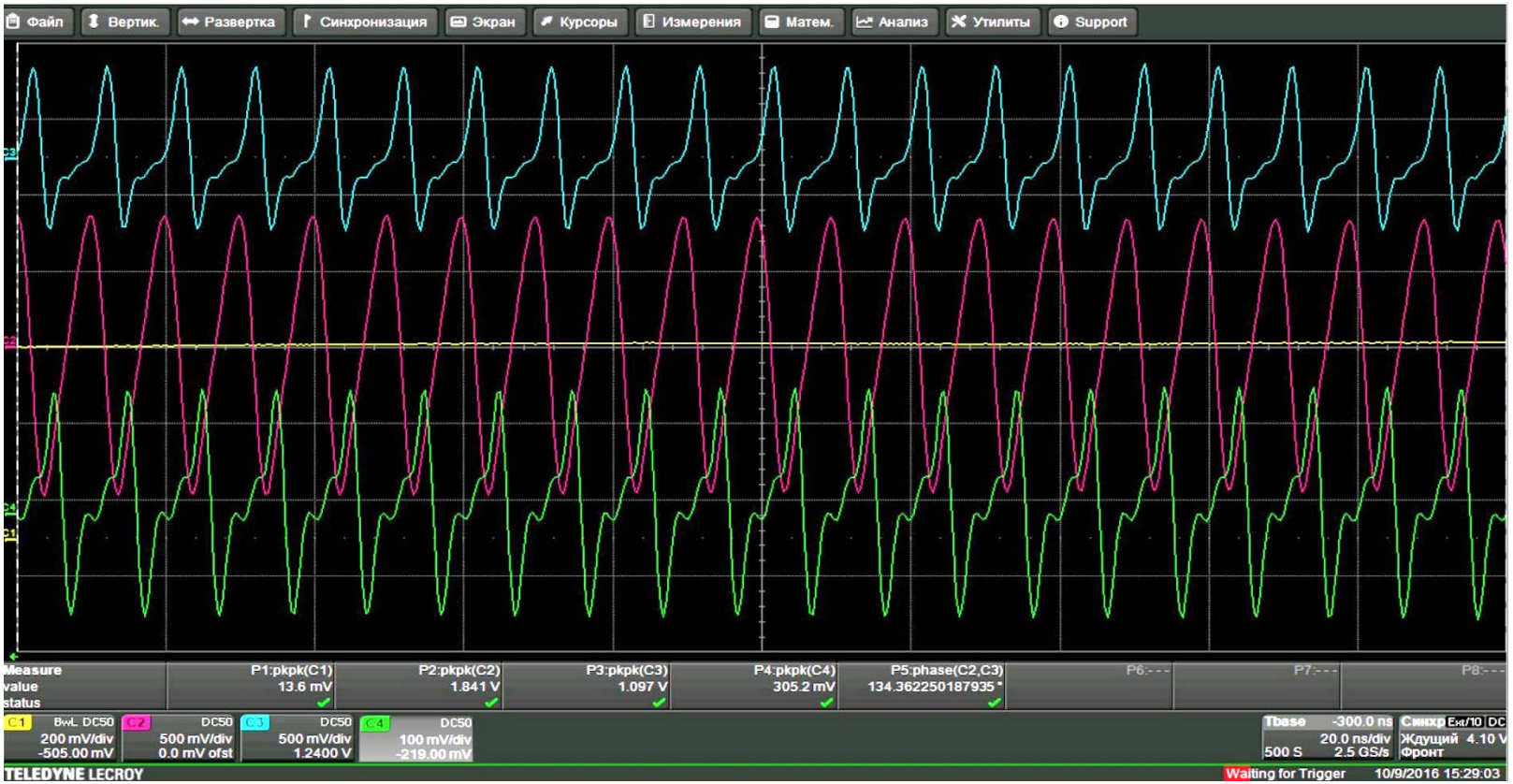
PP2

PP3

First beam tests in 2016: Up to 60% of C^{3+}were accelerated to the final beam energy of 3.2 A MeV.

Commissioning Results - HILAC

First commissioning autumn 2016, C^{3+} – beam.



IH2
3.2 A MeV

RFQ
300 A keV

IH1
1.87 A MeV

Phase probe signals give information on the longitudinal bunch structure with increasing energy.

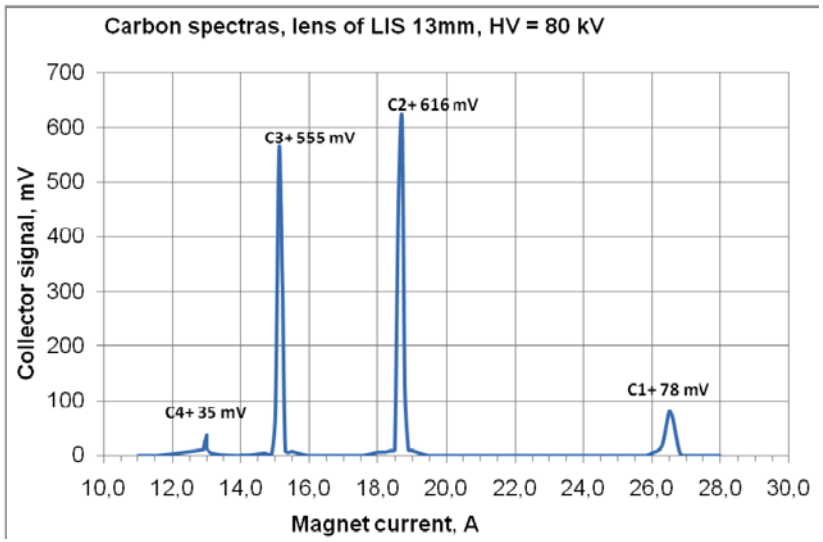
Much better if available: INR – type bunch shape detector (A.V. Feschenko et al.)

BEVATECH

Commissioning Results - HILAC

Commissioning week in Oct. 2018, C^{2+} – beam.

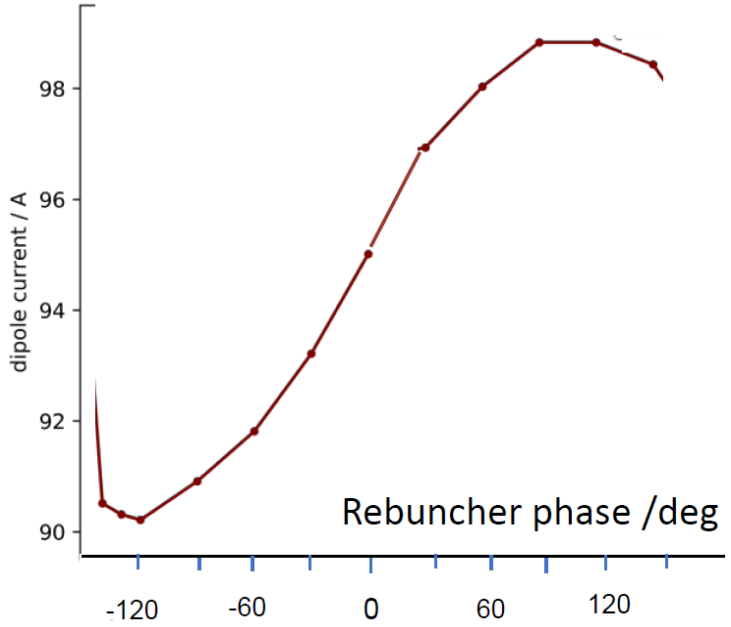
- Transport mode of the DTL: Good transmission of the 300 A keV C^{2+}- beam from RFQ down to the analyzing magnet.
  Finding: Beam contains C^{3+} at the 1% level only, ratio stable.



Typical LIS ion source charge state spectrum

Commissioning Results - HILAC

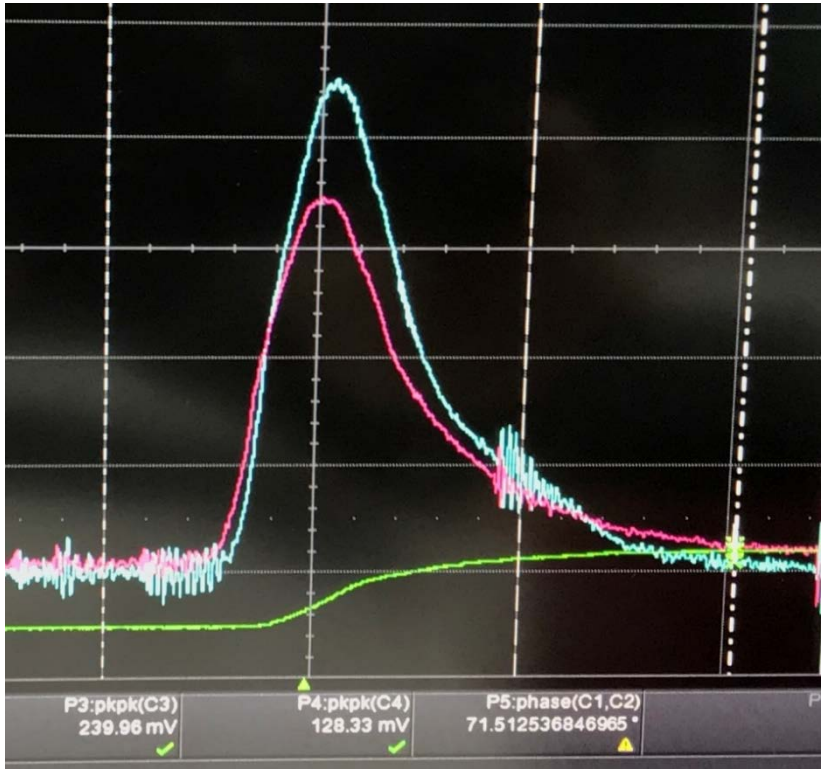
- Energy against Rebuncher RF phase, measured by the dipole magnet behind IH2



Finding the correct phase setting for the 300 A keV rebuncher

Commissioning Results - HILAC

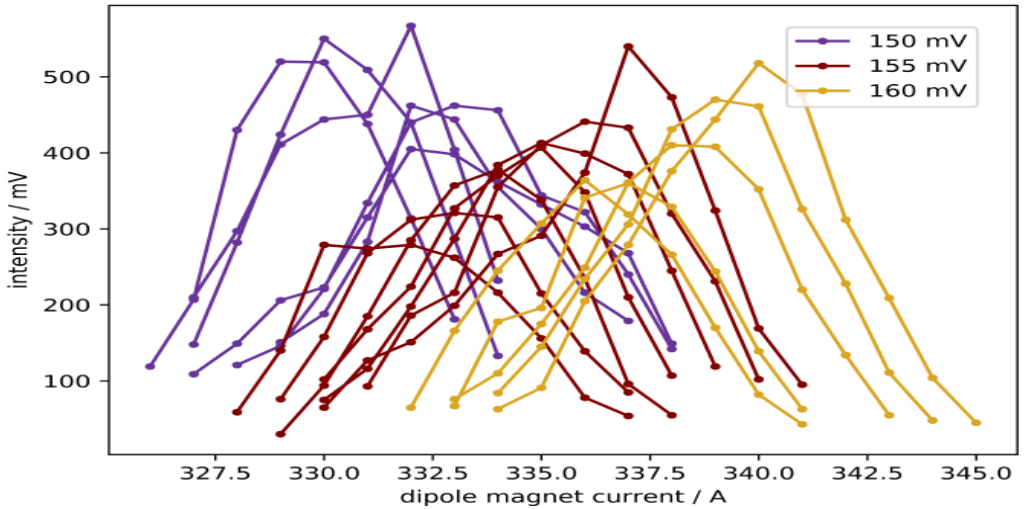
- Optimization of all linac parameter settings
- Result: Up to 75% transmission from RFQ exit to IH2 exit
- RF controls not yet satisfying – new digital system in progress

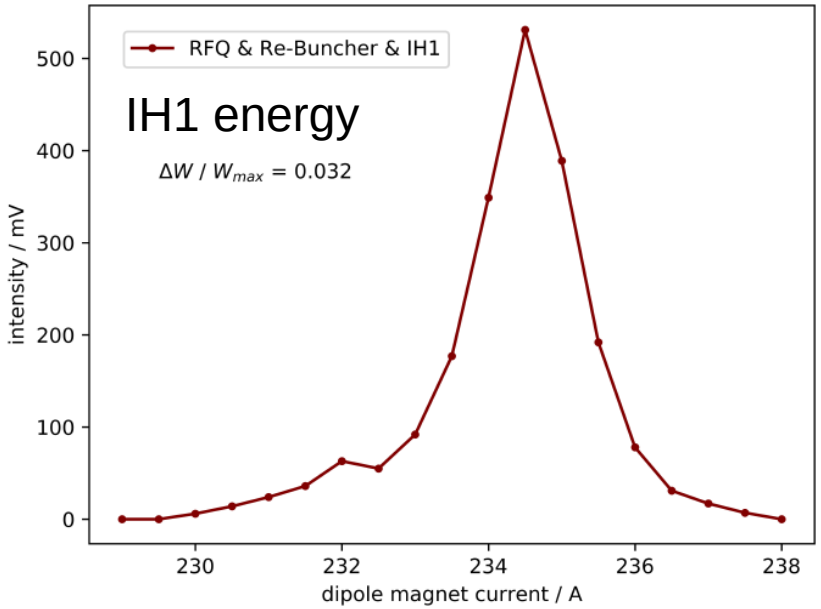


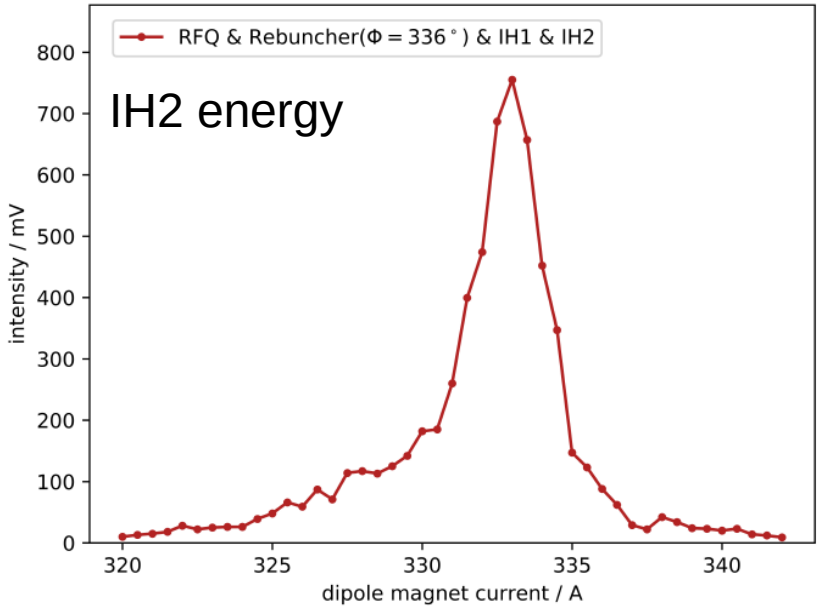
Comparison of Current transformer signals CT1 and CT2

Commissioning Results - HILAC

- Investigation of IH2
  Phase and amplitude settings

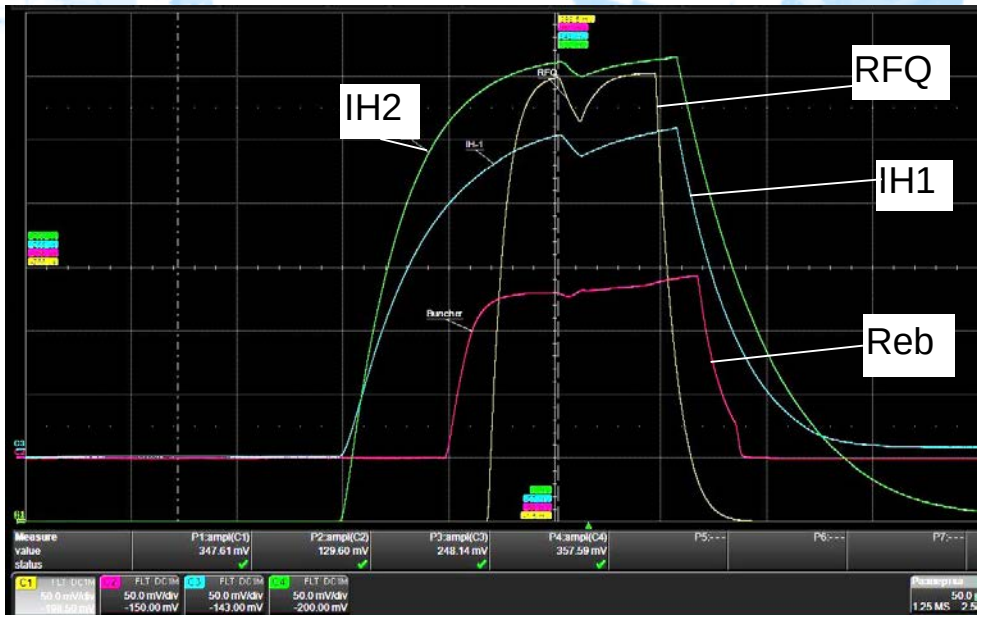




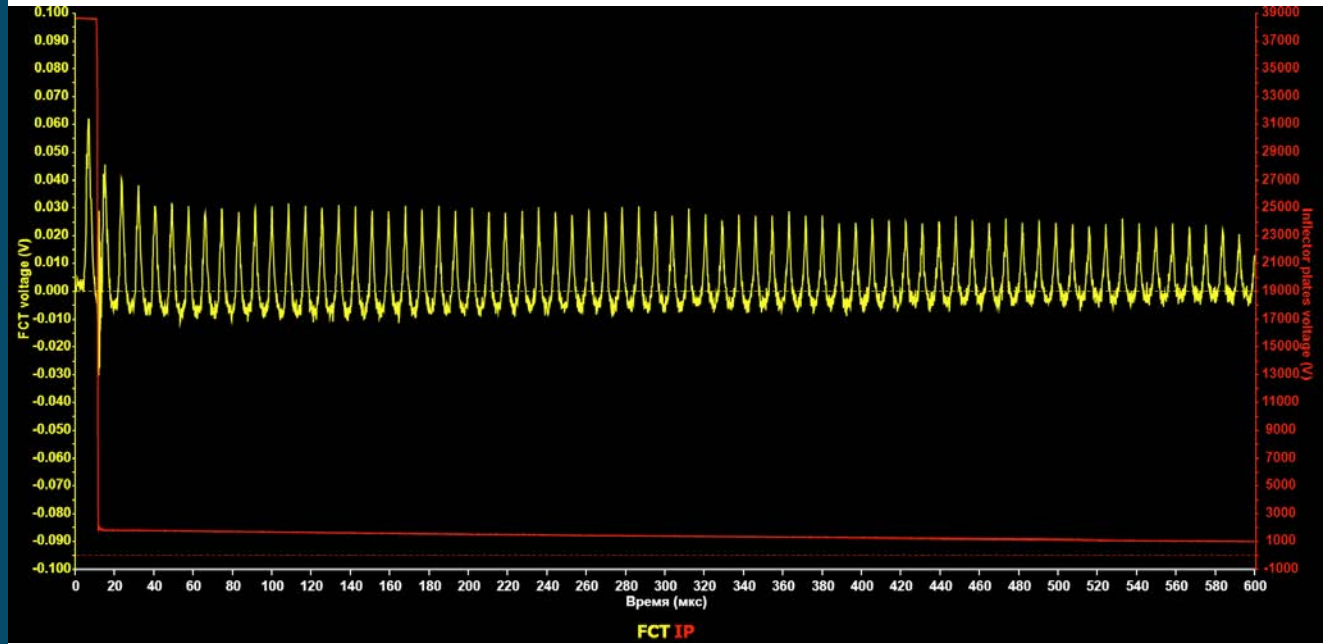


BEVATECH

Commissioning Results - HILAC



RF Pick Up Signals During Booster Ring Commissioning with He^+ -Beam. Beam Load seen without amplitude control: several mA



Booster Run:

First Multiturn Injection

Dec 2020

We congratulate our JINR - Dubna Colleagues!!!

BEVATECH

Conclusions

- Need for diagnostics equipment very much dependent on:
  - beam current and duty factor
  - end energy and ion type (activation level)

- Industry can be involved deeper into the linac development by demand

- Laboratories and industry can profit from each other

Acknowledgement

The Team behind HILac:

JINR Team, Dubna, Russia:
A.M. Bazanov, A.V. Butenko, B.V. Golovenskiy, D.E. Donets, V.V. Kobets, A.D. Kovalenko, K.A. Levterov, D.A. Lyuosev, A.A. Martynov, V.A. Monchinskiy, D.O. Ponkin, K.V. Shevchenko, A.O. Sidorin, I.V. Shirikov, A.V. Smirnov, G.V. Trubnikov and **many other colleagues from JINR institute**

ITEP, Moscow, Russia:
D.A. Liakin

BEVATECH Team, Frankfurt, Germany:
U.Ratzinger, A.Schempp, H.Podlech, H. Höltermann, D. Mäder, W. Schweizer, I. Müller, F. Dziuba, M. Busch, J. Schmidt, B. Koubek, A. Almoumani

Спасибо! Thank You! Vielen Dank!