# Russia – BINP for HL-LHC

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8th HL-LHC Collaboration Meeting,
CERN, 15-18 October 2018

# Outline

- BINP
- Opportunities for in-kind contribution
- 30 kA energy extraction system
- CCDTL for LINAC 4
- Hollow electron lens
- Vacuum chamber test facility
- Conclusion

# BINP

Budker Institute of Nuclear Physics established in 1958

Total staff ~2800 (~1000 scientists and engineers, ~1000 workshop personnel, …)

Main activities: accelerators and colliders, HEP, synchrotron radiation, thermonuclear research

Large, experienced and well-equipped workshop (60,000 $m^2$, 150 departments)

ISO9001:2015 Quality Management

# Opportunities for in-kind contributions

## BINP

| Item | Estimated contribution value | Required delivery | Collaborator |
|---|---|---|---|
| **D2 dipole orbit corrector magnets** | **5 MCHF** | **2023; in time for installation in LS3 (2024-2025)** | **BINP** |
| **Magnets and CC jacks and controls** | **0.3-0.5 MCHF** | **2021-2022; in time for equipping magnets, CC, pre-series** | **BINP** |
| **Superconducting link feedboxes package** | **5.6 MCHF** | | |
| **DFH 10 units** | **2.8 MCHF** | **2023; in time for installation in LS3 (2024-2025)** | **BINP** |
| **DFX 10 units** | **2.8 MCHF** | **2023; in time for installation in LS3 (2024-2025)** | **BINP** |
| TAXN (in progress, Krasnov, Zolotarev) | 2.8 MCHF | 2023; in time for installation in LS3 (2024-2025) | BINP |
| TAXS (in progress, Krasnov, Zolotarev) | 1.2 MCHF | 2023; in time for installation in LS3 (2024-2025) | BINP |
| **Current leads matching section 5 units** | **1.55 MCHF** | **2023; in time for installation in LS3** | **BINP** |
| **Current leads Inner Triplets 5 units** | **5.1 MCHF** | **2023; in time for installation in LS3** | **BINP** |
| **Collimation Package** | **20 MCHF** | | |
| **Part of secondary collimators (baseline)** | **1.5 MCHF** | **2023; in time for installation in LS3** | **BINP** |
| **TCLX Collimators (next to TAXN)** | **2 MCHF** | **2023; in time for installation in LS3** | |
| Hollow electron lens for beam halo removal (A. Levichev) | 7-20 MCHF | 2023; in time for installation in LS3 (2024-2025) | BINP |
| **Second half of Crab Cavities** | **24 MCHF** | **2029; in time for installation in LS4** | **BINP?** |

B. Di Girolamo

Red – work is close to the contract signing
Blue – BINP potentially is ready to take

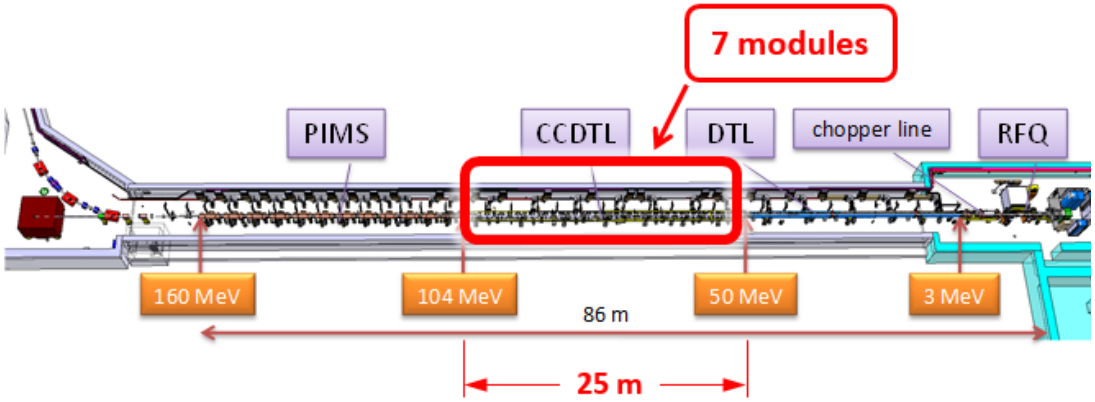
Main problem is who pays? Russia through in-kind or CERN directly?

# 30 kA energy extraction

30 кA energy extraction semiconductor switch designed and produced for cluster SM-18 (pre-series sample manufactured and successfully tested). Modular structure from 7.5 kA to 30 kA. We hope for the series production.

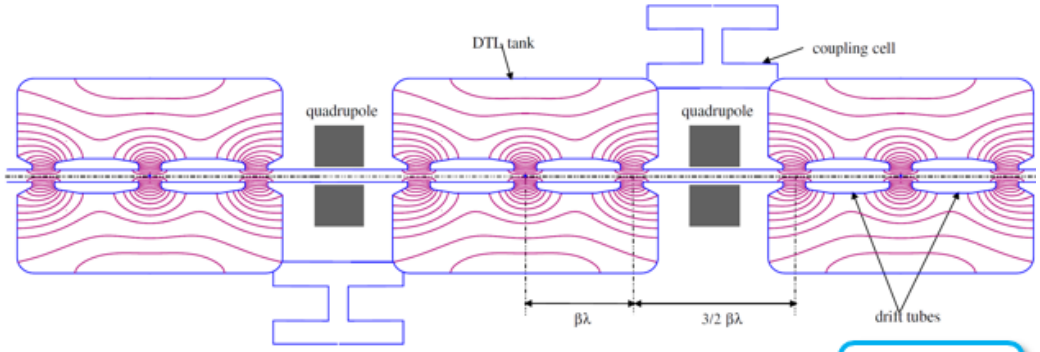
# CCDTL for LINAC 4

Linac4, a new 160 MeV H- accelerator will replace the 50 MeV proton Linac2 as an injector to the PS Booster.



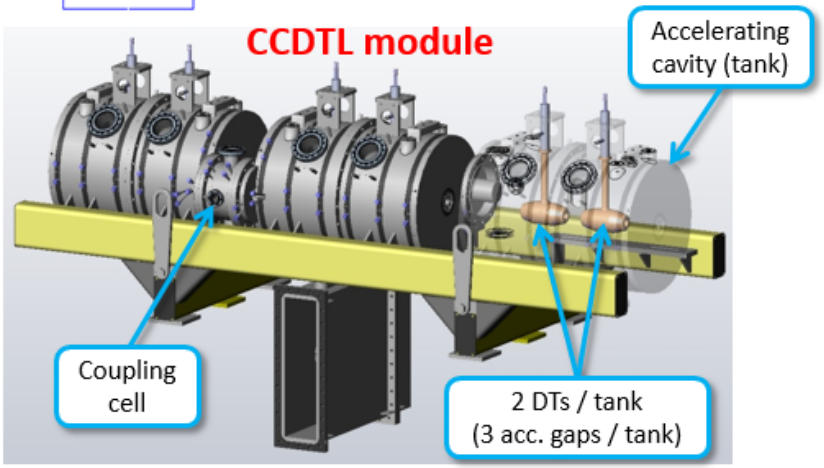

**CCDTL features:**

1. Separate accelerating cavities (tanks) with 2 drift tubes / tank,
2. single cell off-axis coupling cavities (cells),
3. operates in the stable π/2 mode,
4. Quads placed between the tanks.




**CCDTL advantages:**

1. Small drift tube diameter ⇒ high RF efficiency.
2. EMQs between the modules ⇒ flexibility for transverse beam dynamics.
3. Quads can be aligned on the supports independently from the cavities ⇒ relaxed tolerances of the drift tube positioning.



# CCDTL for LINAC 4

During 2004-2014 BINP (Budker Institute of Nuclear Physics of Siberian Branch of Russian Academy of Sciences, Novosibirsk) and VNIITF (Russian Federal Nuclear Center – Russian Scientific Research Institute of Technical Physics, Snezhinsk) built 7 CCDTL modules for Linac4.

All modules were tested above the Linac4 specifications: ≥ 700 kW (which corresponds to 3.6 MV gap voltage per tank and peak surface field $E_{Spk}$ = 34 MV/m that is 1.85 Kilpatrick) at 0.16% duty cycle (0.8 ms pulse length, 2 Hz repetition rate) and installed in the tunnel in 2016.

On 25 October 2016, Linac 4 reached its design beam energy of 160 MeV.


*09/05/2017 Linac4 inauguration ceremony.*

# TAXN & TAXS: scope

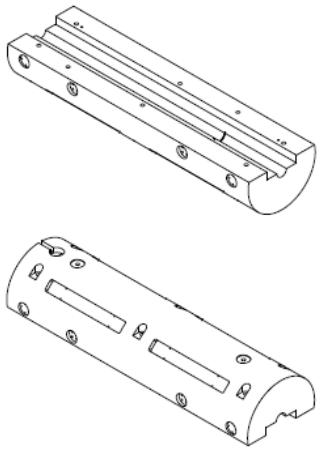
| Item | Mass x No | Slabs dims | Work (wh) |
|---|---|---|---|
| TAXS lower part | 1720 x 4 | 1800 x 500 ∅ | 180 |
| TAXS upper part | 1276 x 4 | 1800 x 500 ∅ | 180 |
| TAXN (absorber block) bot | 1600 x 4 | 3819 x 400 x 170 | 180 |
| TAXN (absorber block) top | 1600 x 4 | 3819 x 400 x 170 | 180 |
| TAXS vacuum chamber | … x 4 | | 200 |
| Y chamber | … x 4 | | 800 |

1 working hour (wh) ≈ 15 €

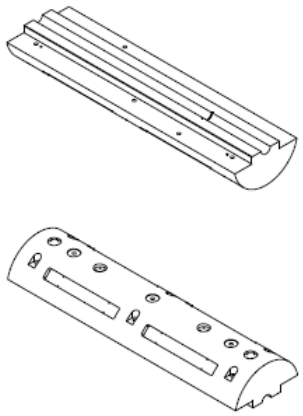
Total weight of row cupper slabs about 45 tons

Row cupper price about 10 €/kg

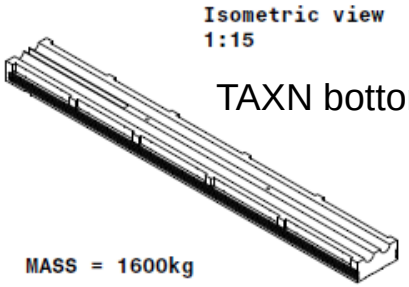
For vacuum chambers (and Y chambers) CERN provides cupper tubes



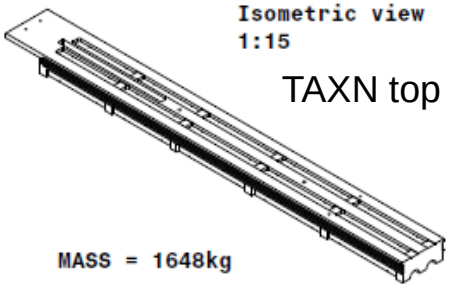
TAXS lower part



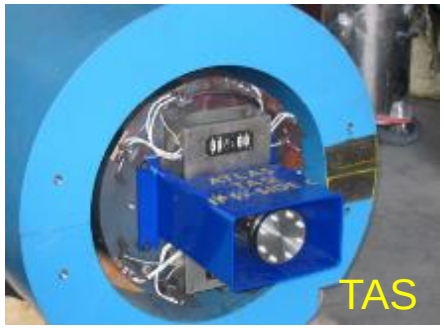
TAXS upper part




TAXN bottom




TAXN top

# TAXN & TAXS: questions/problems

Qs:

- Mechanical tolerance 100 μm seem excessive, is it possible to change it to 300-500 μm?
- Surface roughness 3 μm seems excessive.

No decision:

- TAXN grooves for cooling tubes. Who install the tubes, BINP?
- Who install the baking heaters, BINP?
- Who responsible for adjustment mechanics?
- Who responsible for assembling?

Ps:

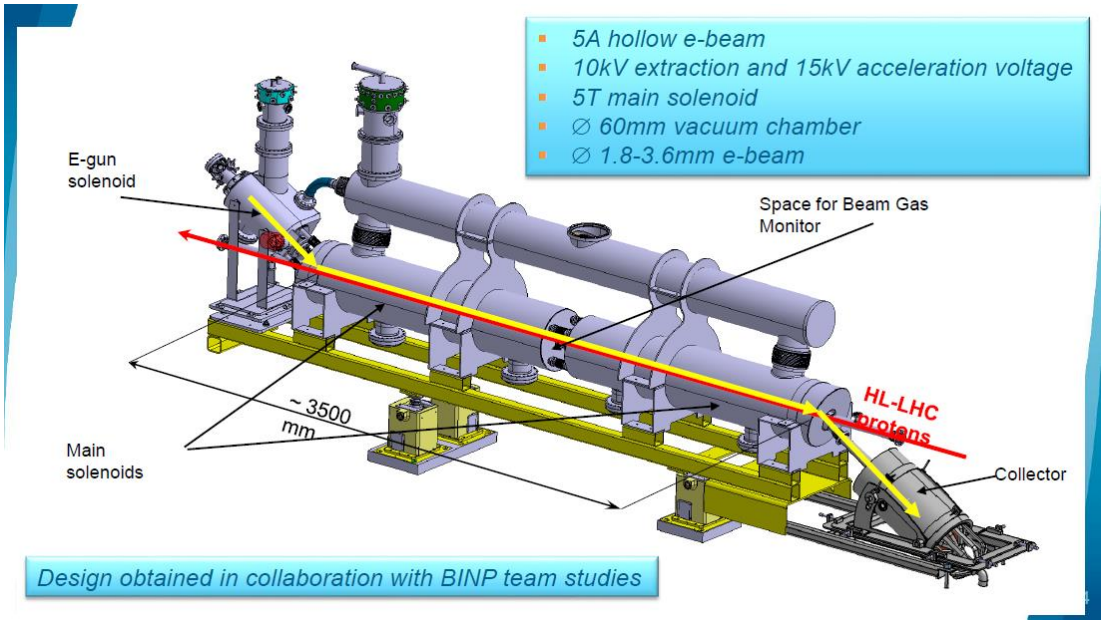
- The production of every half of every absorber take about one working moth on the BINP milling machine, it can create problem for other BINP contracts.
- The procedure for purchasing of the long cupper slabs is not clear now.
- The technology for TAXS production isn't clear now.

For transportation 4 trucks are necessary.
Total transportation cost is about 28 000 €.

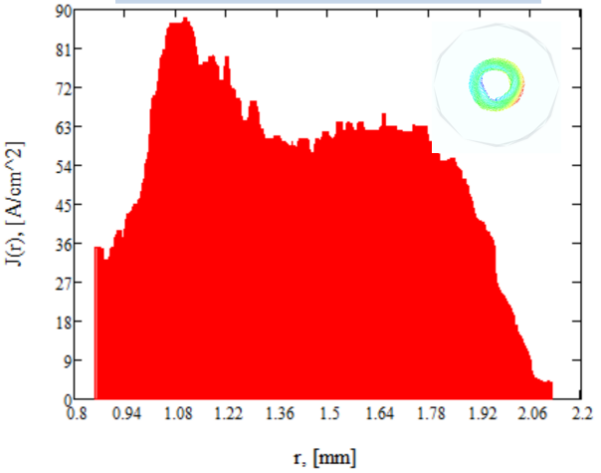
The total cost of the contract about 1 350 000 CHF.

# Hollow electron lens

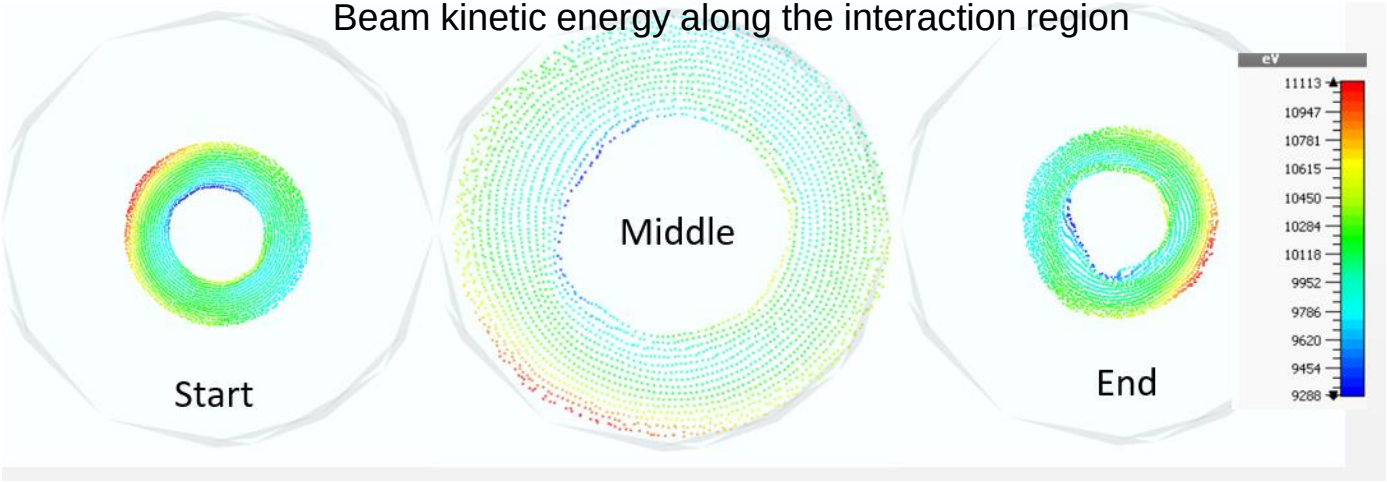
Study and simulation of the HEL e-beam dynamics.




**Current density at the end of the interaction space, total current is 5 A**




Beam kinetic energy along the interaction region



# Hollow electron lens

1. HEL parameters were studied for a stable electron beam.
2. The aperture of vacuum tube of 60 mm and magnetic field of the main solenoid of 5 T are OK.
3. 5 A beam current with 15 kV with voltage are OK. The virtual cathode is not a problem.
4. The beam shape slightly changes in time but the field variation inside the beam is less than 5%.

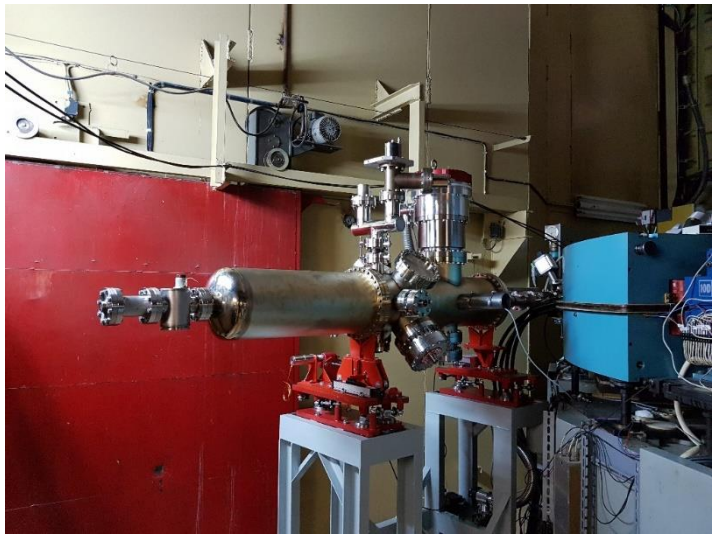
All critical HEL parameters seem fixed.

# Vacuum surface coating

Addendum P110/A2

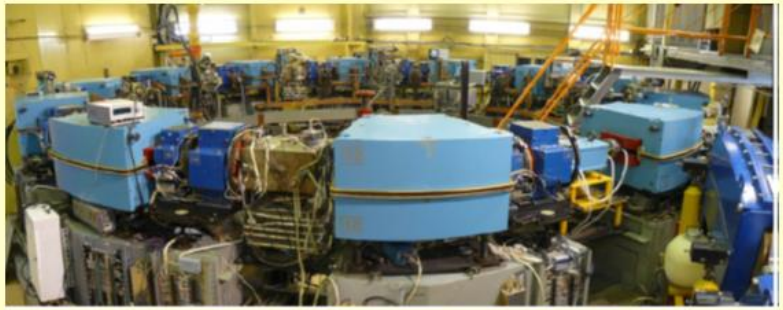
Study of photo-stimulated desorption and photoelectron emission of HL-LHC inner vacuum chamber surface under SR flux at room/cryo temperatures. A test beamline was developed at BEP storage ring (~10-1300 eV of critical energy, ~$5 \cdot 10^{16}$ ph/m/s). In the first experimental set Cu and a-C (anti-multipactor) coating were compared.

Experimental set up at BEP



Details in A.Krasnov's talk (Thursday)

BEP storage ring



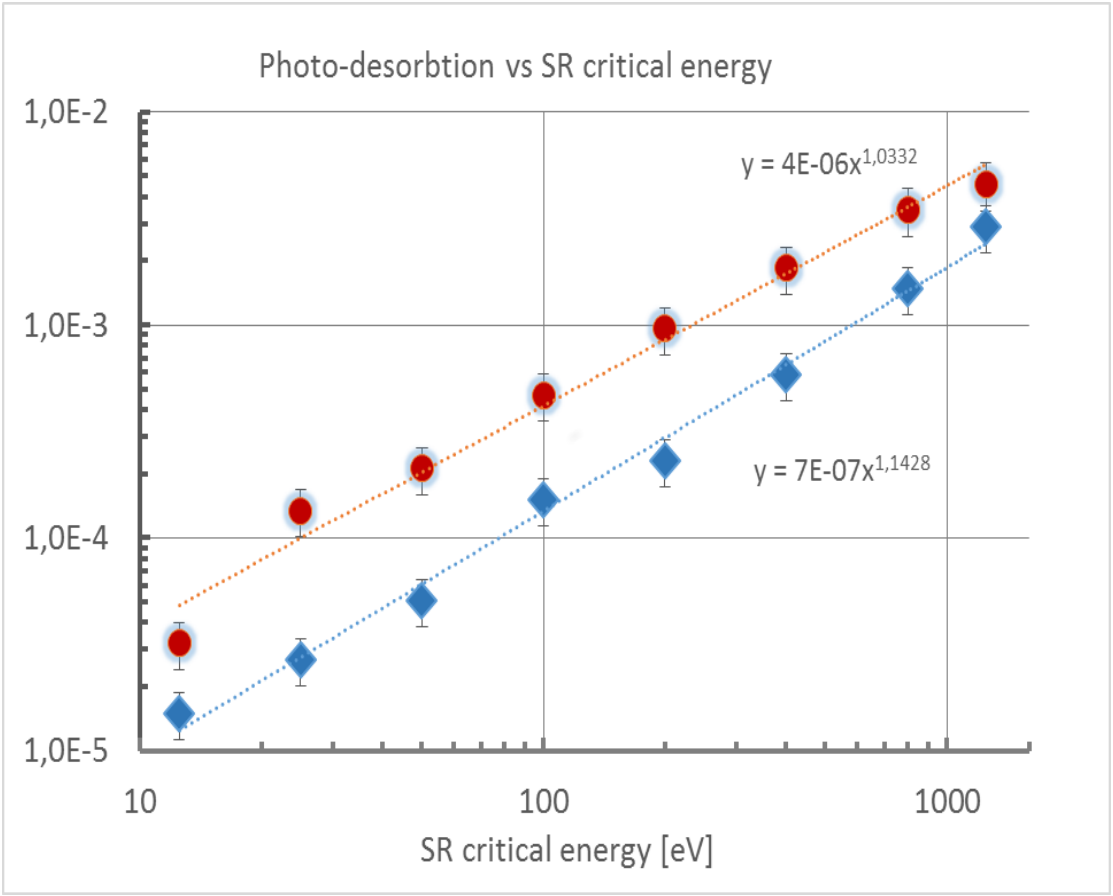
BEP after reconstruction. Maximum energy increased up to 1 GeV at circumference 22m. Max dipole field 2.6 T.

| Parameter | min | nominal | max |
|---|---|---|---|
| E [MeV] | 200 | 300 | 900 |
| Beam current [A] | 0.5 | 0.5 | 0.5 |
| Banding magnet radii [mm] | | 1280 | |
| SR critical energy [eV] | 14 | 47 | 1260 |
| SR flux [ph/mrad/s] | 1.1E15 | 1.8E16 | 5.6E16 |
| SR power [W/mrad] | 0.009 | 0.045 | 3.6 |
| SR vertical divergence [mrad] at Ec | 2.5 | 1.7 | 0.56 |

# Results (example)

Photo-desorption: amorphous carbon vs copper

| Ec eV | α-C η [mol/ph] | Cu η [mol/ph] | η(Cu1)/ η(α-C) |
|---|---|---|---|
| 12,5 | < 1,5E-5 | 3,2E-5 | - |
| 25 | 2,7E-5 | 1,3E-4 | 5,0 |
| 50 | 5,1E-5 | 2,1E-4 | 4,2 |
| 100 | 1,5E-4 | 4,7E-4 | 3,1 |
| 200 | 2,3E-4 | 9,6E-4 | 4,1 |
| 400 | 5,8E-4 | 1,9E-3 | 3,2 |
| 800 | 1,5E-3 | 3,5E-3 | 2,3 |
| 1250 | 2,9E-3 | 4,6E-3 | 1,6 |



# Conclusion

- BINP actively participates in the HL-LHC program
- BINP has potential to increase efforts
- The main question is…