# Status and prospects of VEPP-5 Injection Complex

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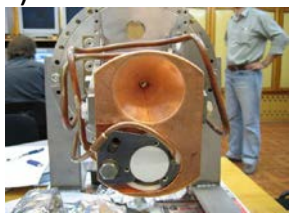
on behalf of Injection Complex team,
BINP

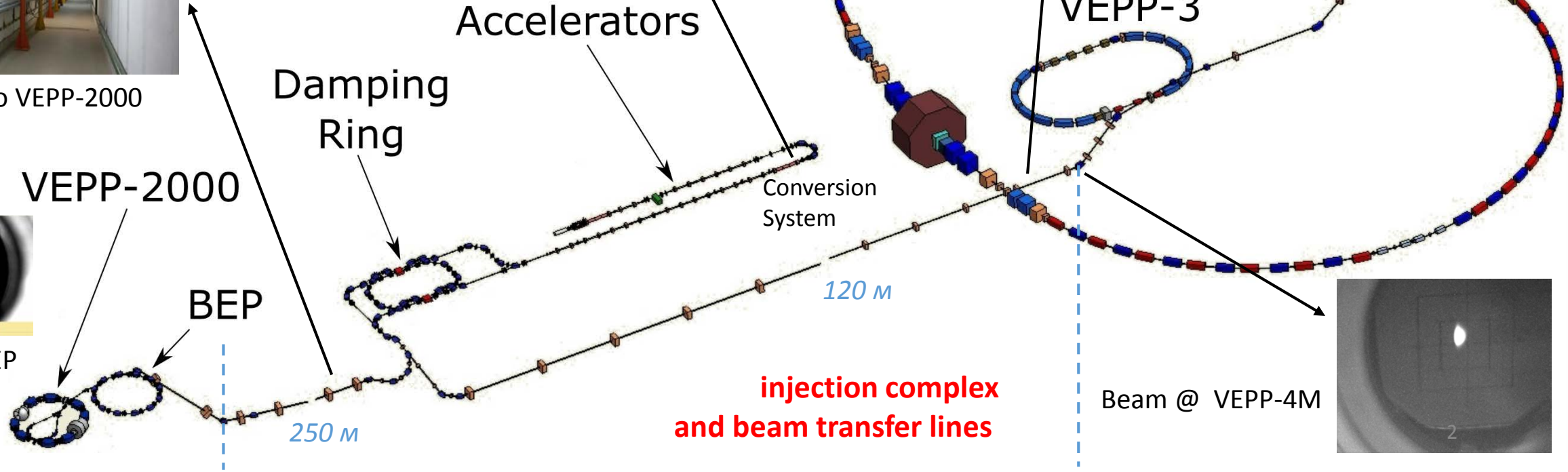
# Injection complex routinely supply with electrons and positrons both BINP colliders - VEPP-2000 and VEPP-4 in order to carry out HEP experiments at maximum colliders luminosity

Parameters (records): Energy: **395 МэВ**
$e^-$ storage rate at 12.5 Hz repetition rate: **$2.0 \cdot 10^{10}$/s** (35 mA/s)
$e^+$ storage rate at 12.5 Hz repetition rate: **$2.0 \cdot 10^{9}$/s** (3.5 mA/s)
Maximum beam current $e^-$ : **200 mA, $4.2 \cdot 10^{10}$ particles**
Maximum beam current $e^+$ : **200 mA, $4.2 \cdot 10^{10}$ particles**

Beamline to VEPP-2000



Beamline to VEPP-4M

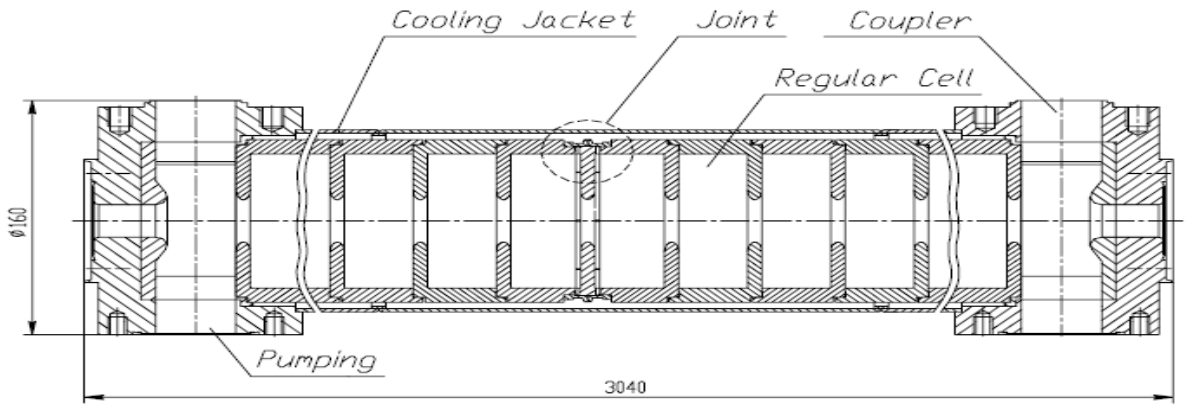


Beam @ BEP

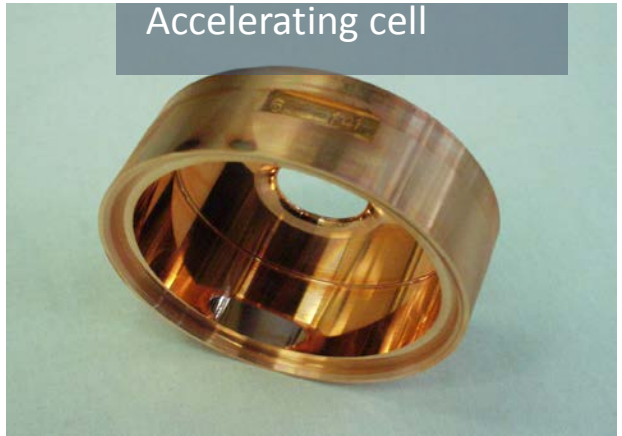


Beam @ VEPP-4M

# Injection Complex, Accelerating structures (round disk-loaded waveguide)

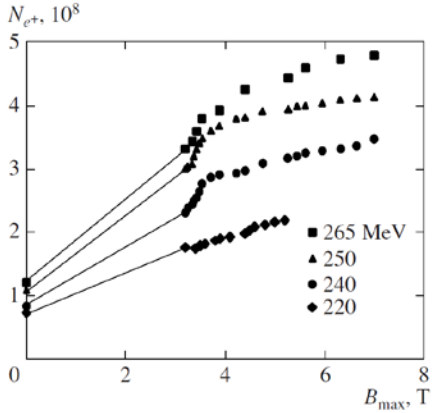


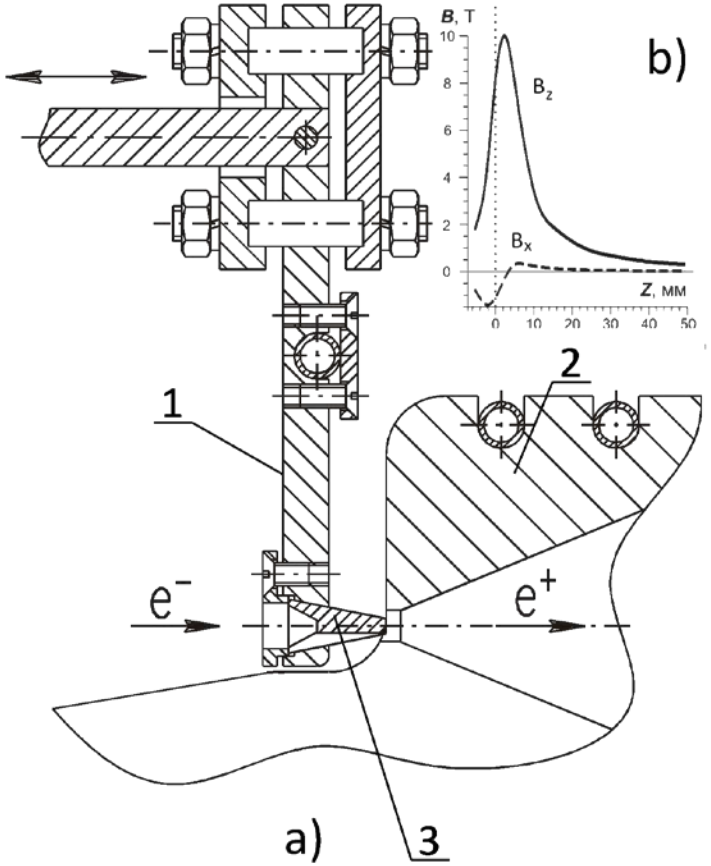

| | |
|---|---|
| Operational frequency | 2855.5 MHz |
| Internal cell diameter $2b$ | 83.75 mm |
| Iris diameter $2a$ | 25.9 mm |
| Iris thickness $t$ | 6 mm |
| Period $D$ | 34.99 mm |
| Operational mode of oscillation $\theta$ | $2\pi/3$ |
| Relative phase velocity $\beta_p$ | 1 |
| Relative group velocity $\beta_g$ | 0.021 |
| Section length $L$ | 2.93 m |
| Total number of cells (incl. 2 WTT) | 85 |
| Unloaded quality factor $Q_0$ | 13200 |
| Shunt impedance $R_{sh}$ | 51 MOhm/m |
| Time constant $\tau_{0a}=2Q_0/\omega_0$ | 1.471 μs |
| Attenuation (by field) $\alpha=1/(\tau_{0a}v_{gr})$ | 0.108 $m^{-1}$ |
| Filling time $T_f=L/v_{gr}$ | 0.465 μs |

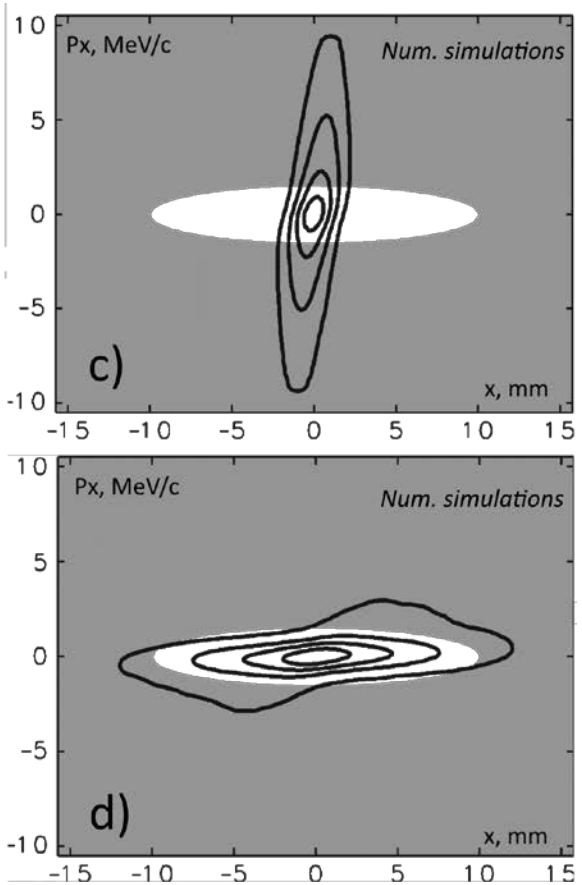


# Injection Complex, conversion system

Pictures are:
a) 1 - movable target holder
2 - magnet flux concentrator
3 – target
b) magnetic measurements
c) e+ beam phase portrait after the target
d) e+ beam phase portrait after the flux concentrator.

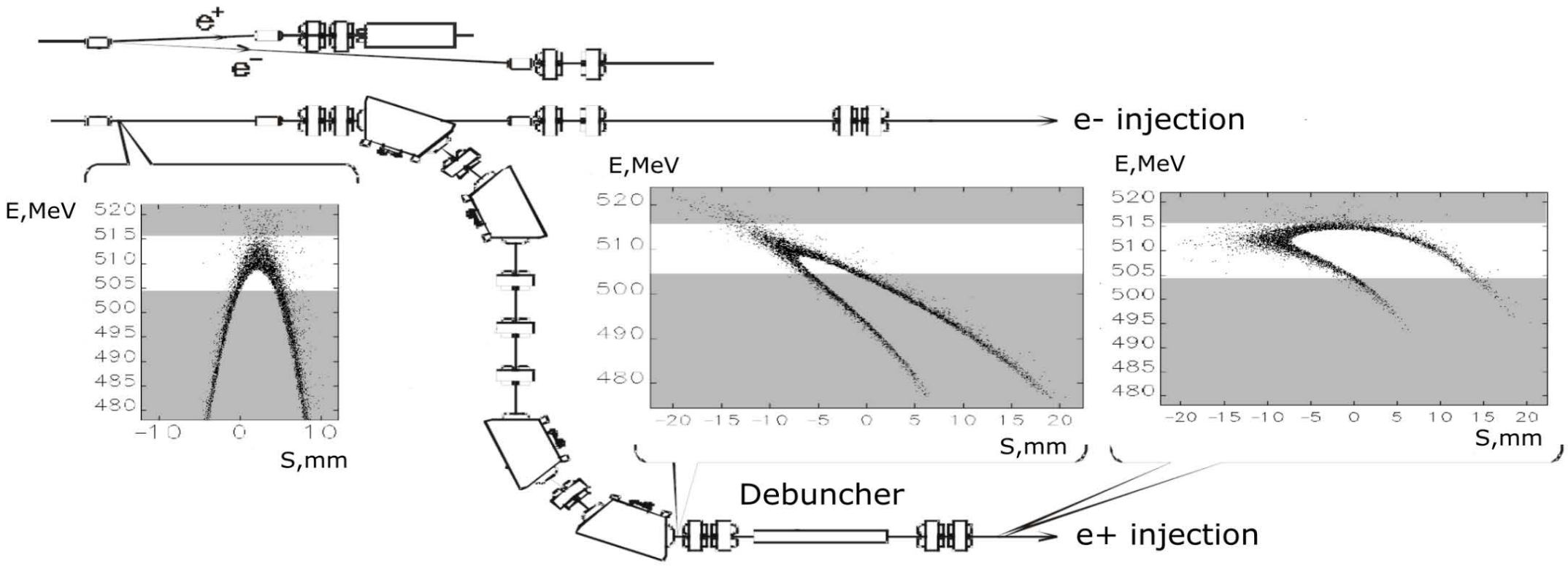



| | | | |
|---|---|---|---|
| Max. magnetic field | 10 T | Repetition rate | 50 Hz |
| Full current on the cone surface | 120 kA | Max. Average power | 4 kW |
| Pulse energy | 90 J | Operating max. magnetic field | 7 T |
| Pulse duration | 26 us | | |

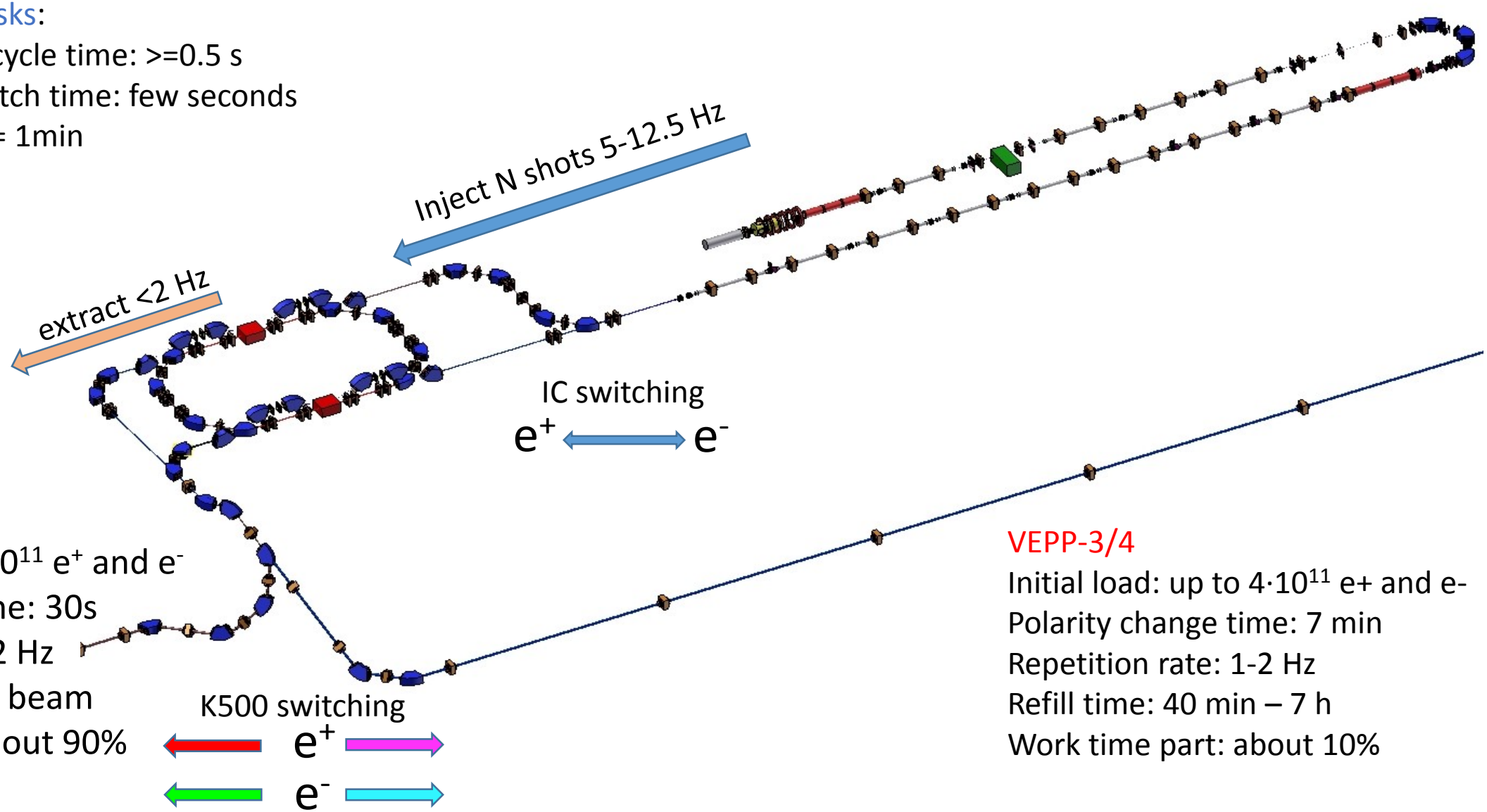
# Positron injection to Damping Ring




| Injection way | Design efficiency | Achieved efficiency |
|---|---|---|
| Straight (e+ over e- channel) | 16.4 % | |
| Normal without debuncher | 16.8 % | 10% |
| Normal with debuncher | 23.6 % | |

# Injection complex preliminary operation plans

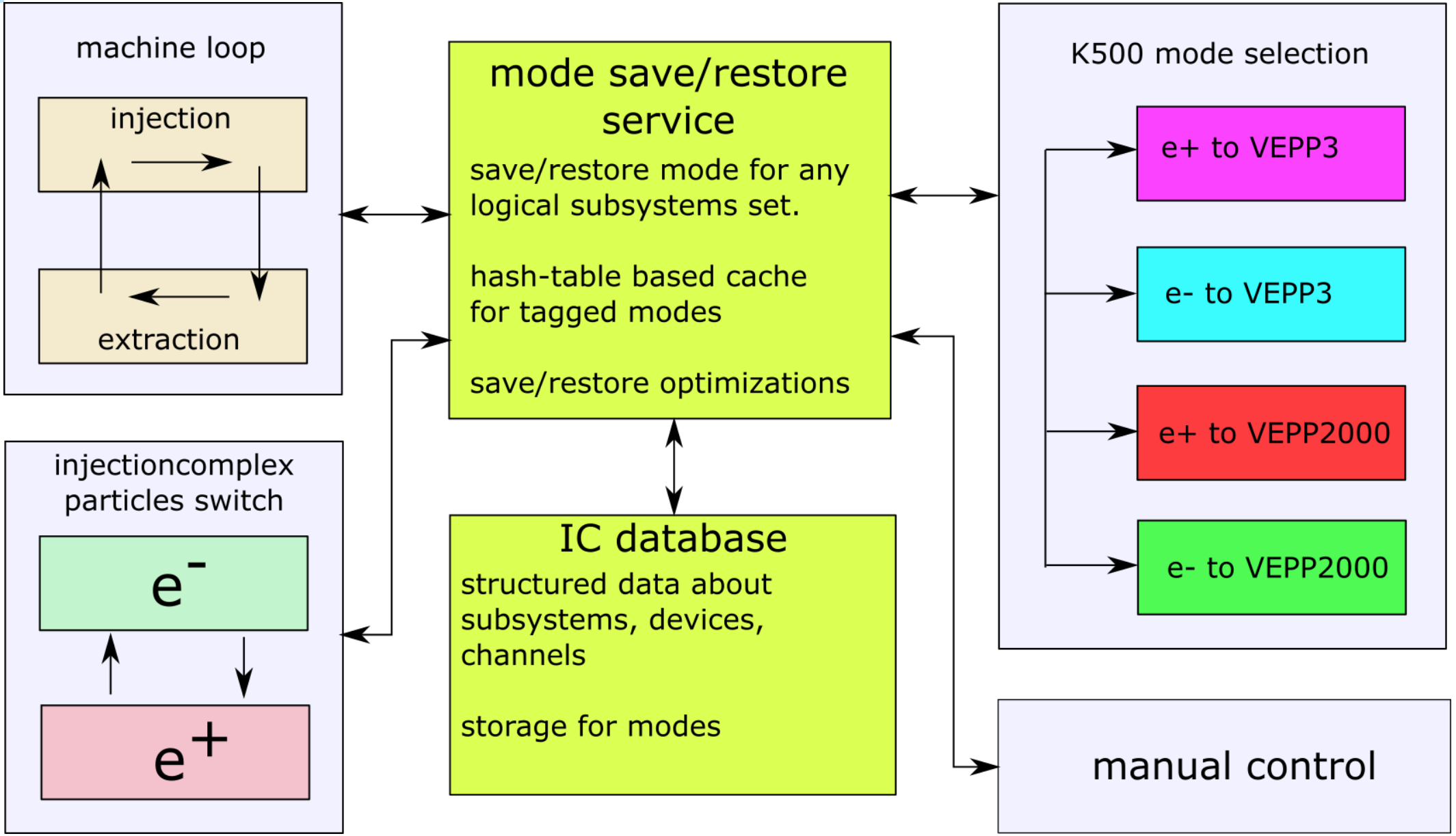
Injection Complex tasks:
Injection-extraction cycle time: >=0.5 s
Complex polarity switch time: few seconds
K500 switch time: <= 1min



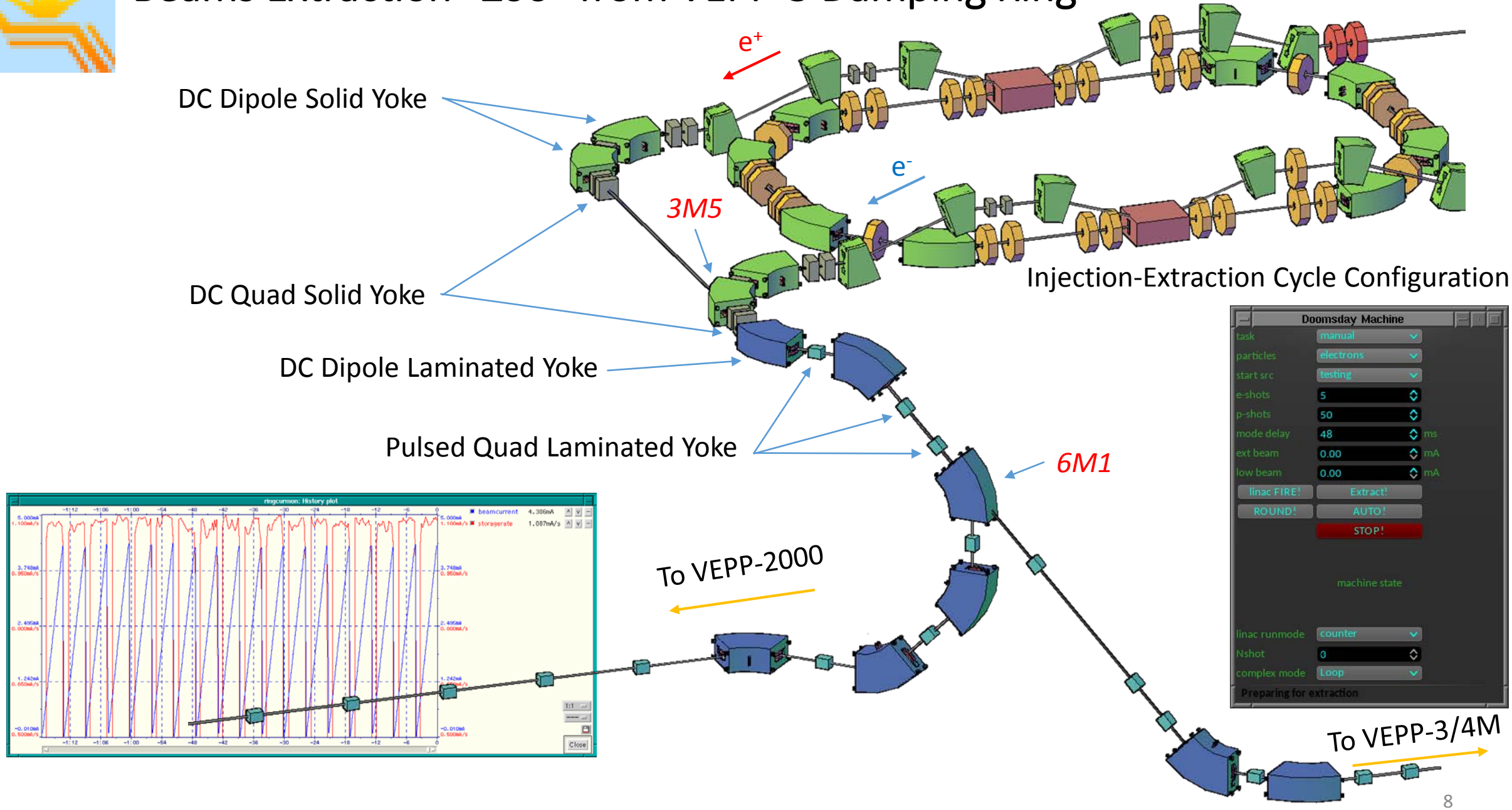

VEPP-2000:
Initial load: up to $10^{11}$ $e^+$ and $e^-$
Polarity change time: 30s
Repetition rate: 0.2 Hz
Refill time: 30s per beam
Work time part: about 90%

VEPP-3/4
Initial load: up to $4 \cdot 10^{11}$ e+ and e-
Polarity change time: 7 min
Repetition rate: 1-2 Hz
Refill time: 40 min – 7 h
Work time part: about 10%

# Injection complex operation techniques

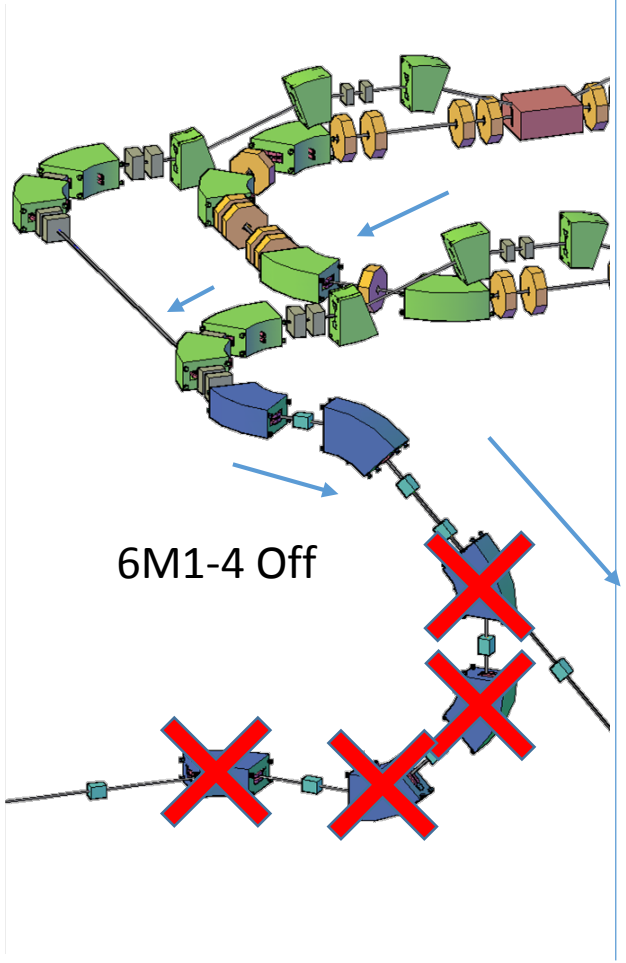


# Beams Extraction “Zoo” from VEPP-5 Damping Ring

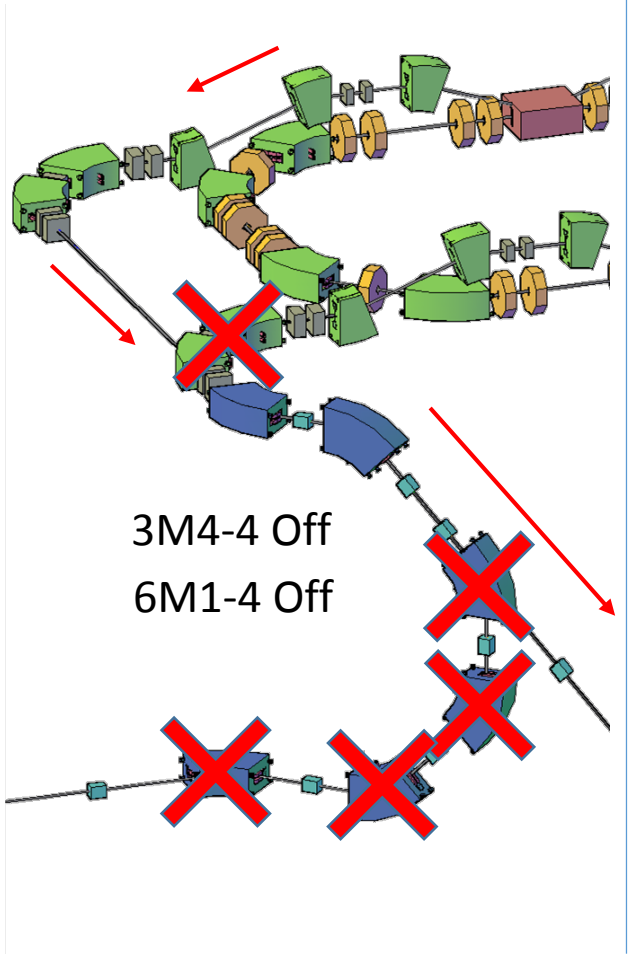


# Extraction Modes

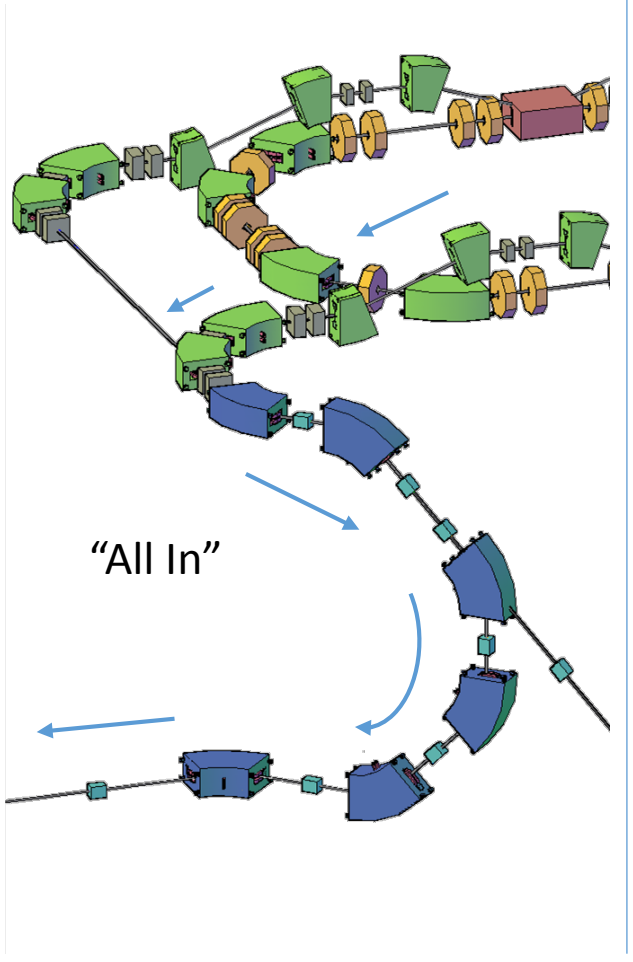
e- to VEPP-3



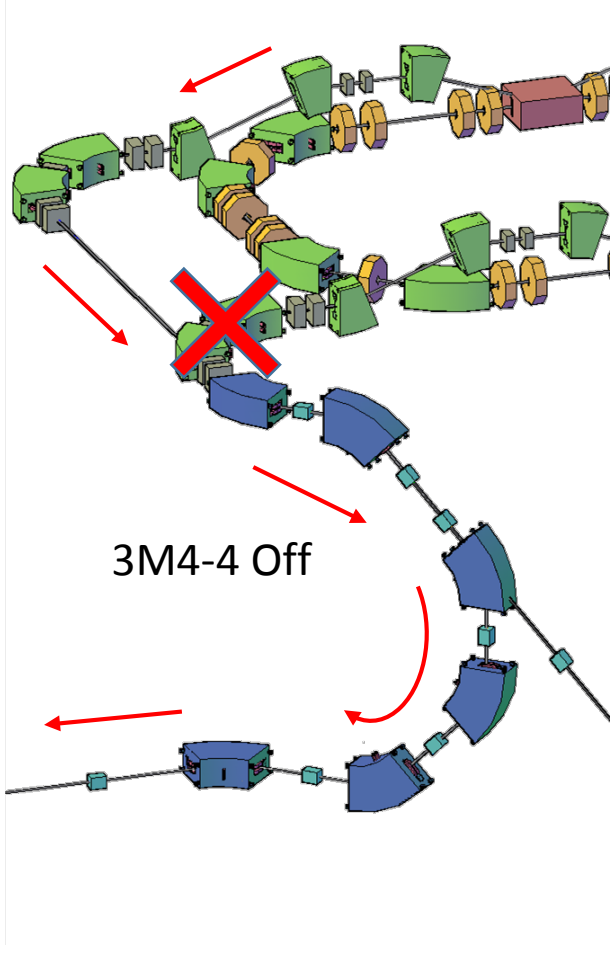

e+ to VEPP-3




e- to VEPP-2000




e+ to VEPP-2000

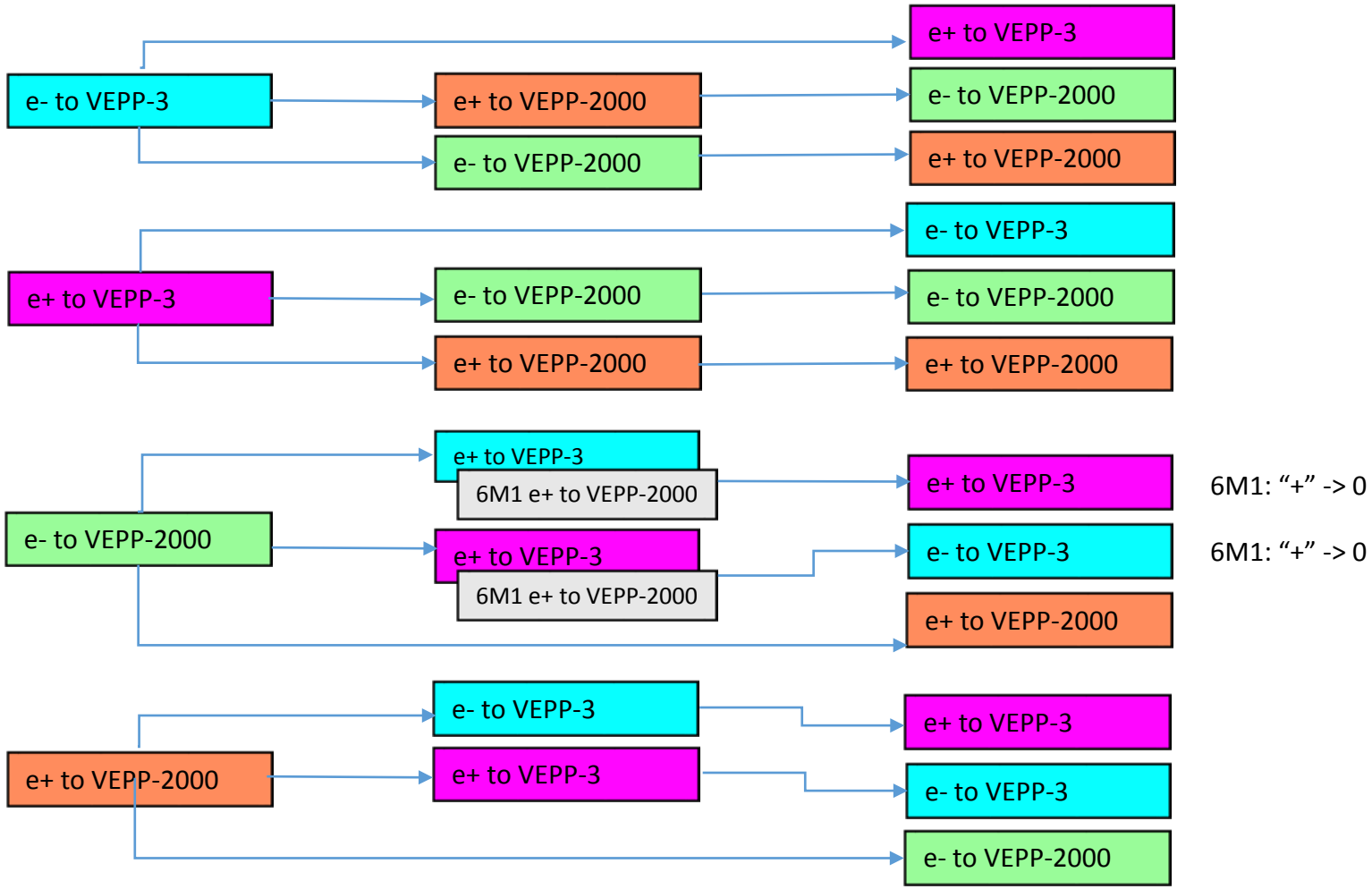


# Matrix or…

12 Variants (+1)

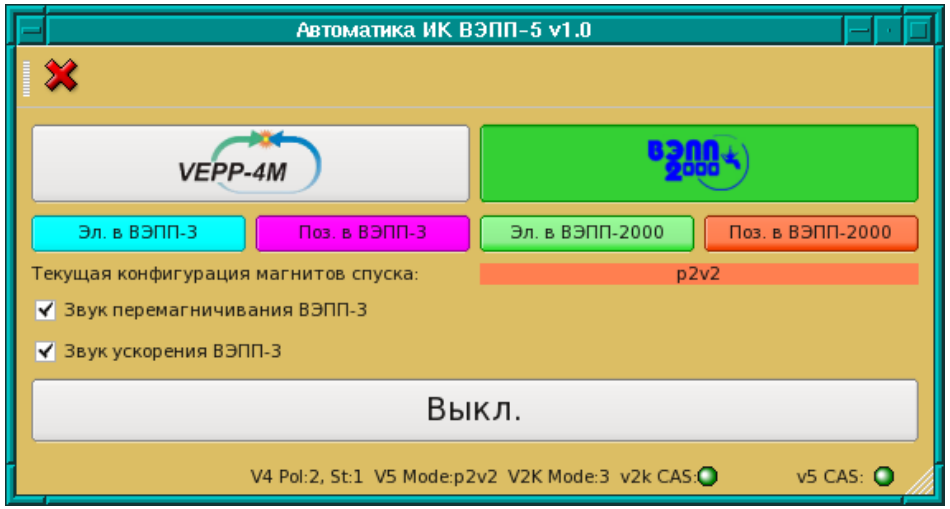
LIANC & Damping Ring goes directly to the Destination

K-500 – 30 seconds per “arrow”



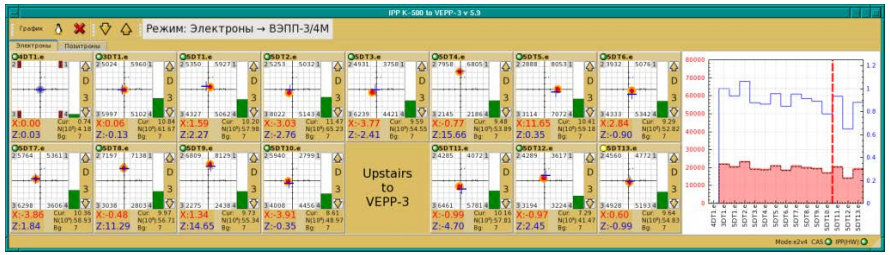

6M1: “+” -> 0

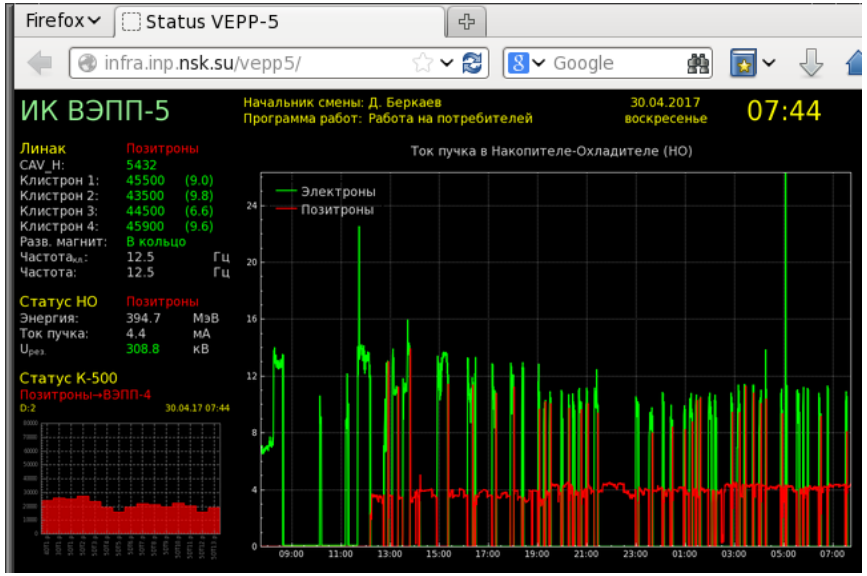
6M1: “+” -> 0

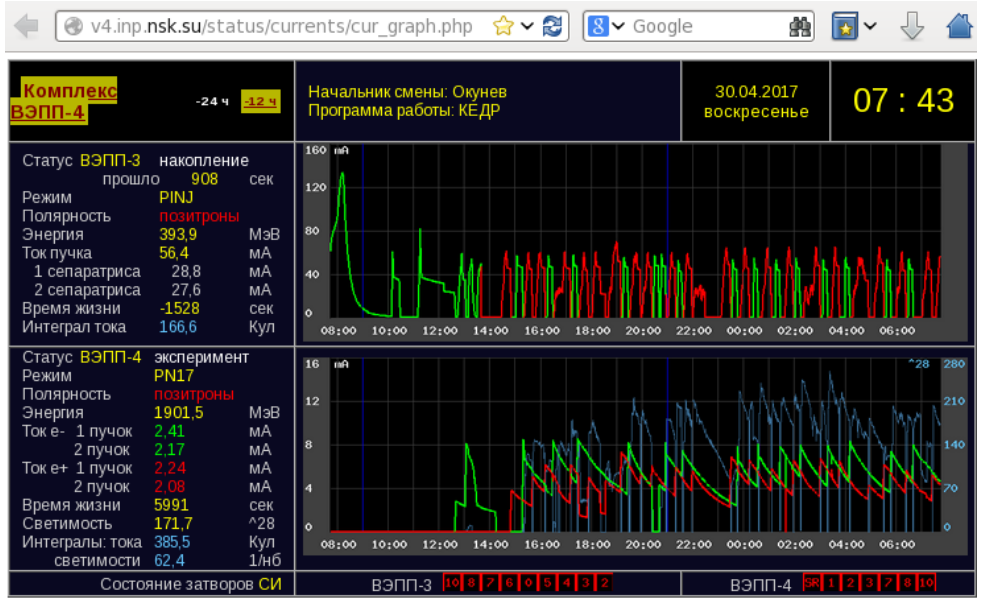


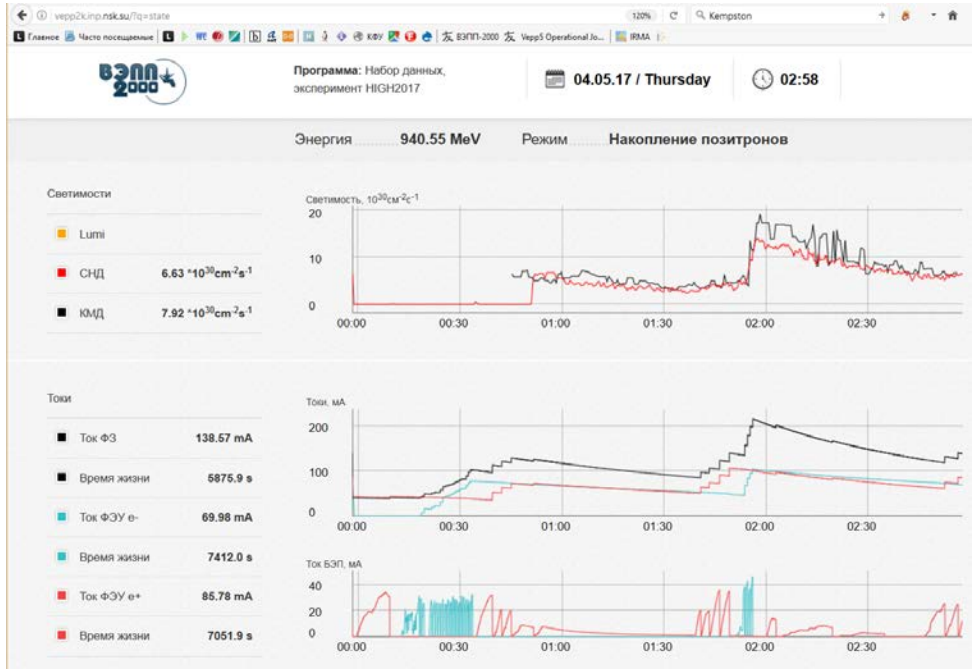

(+1) -> Current to Current – just realize current mode again

# Operation with Two Colliders

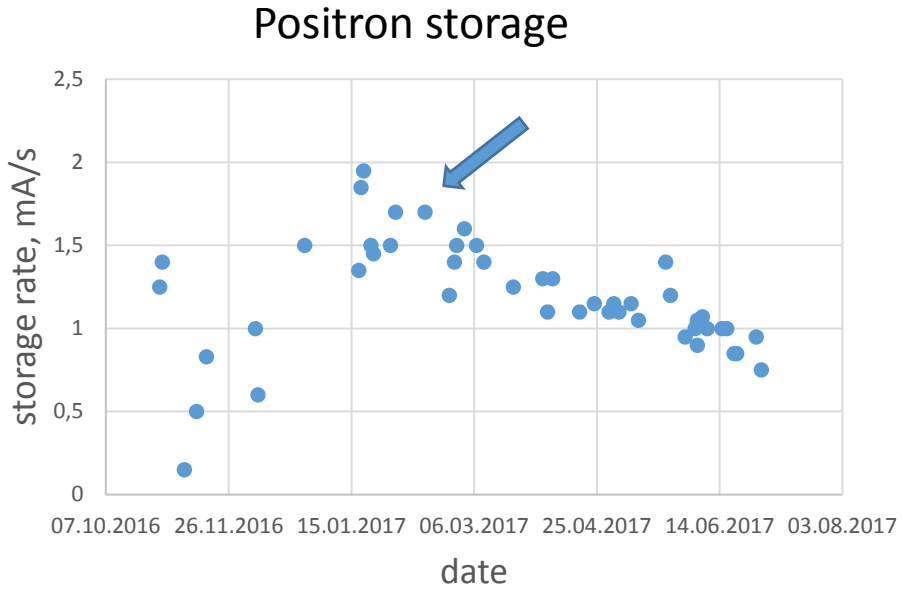


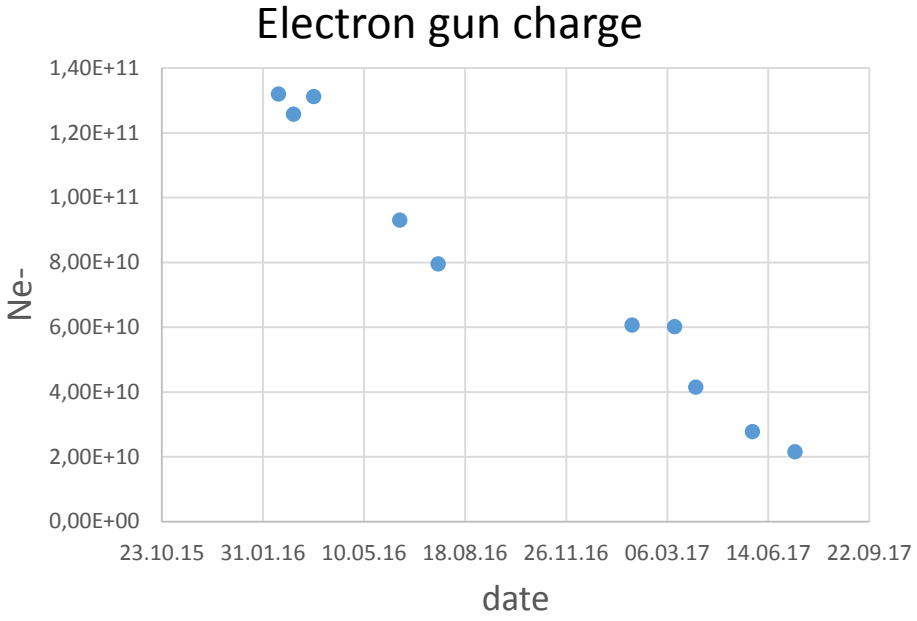



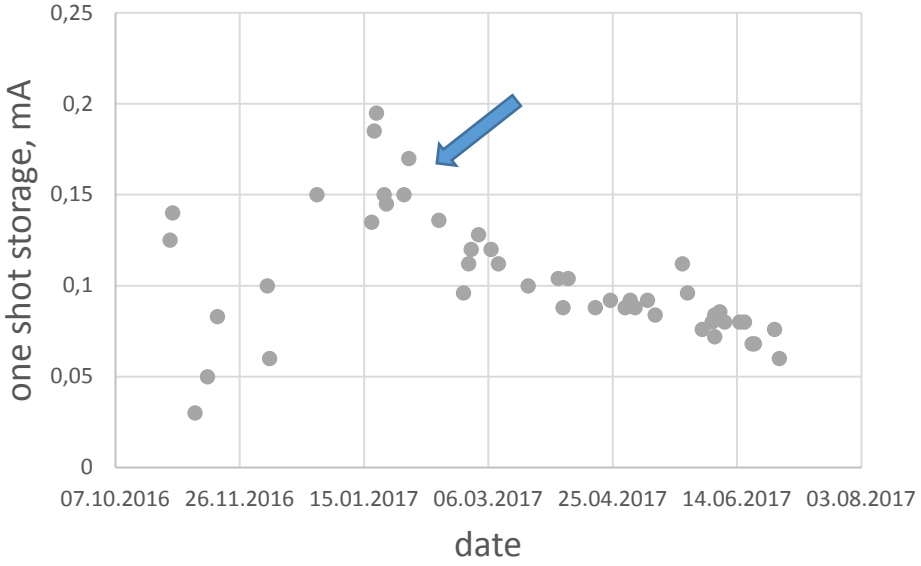


# Injection complex performance lifespan



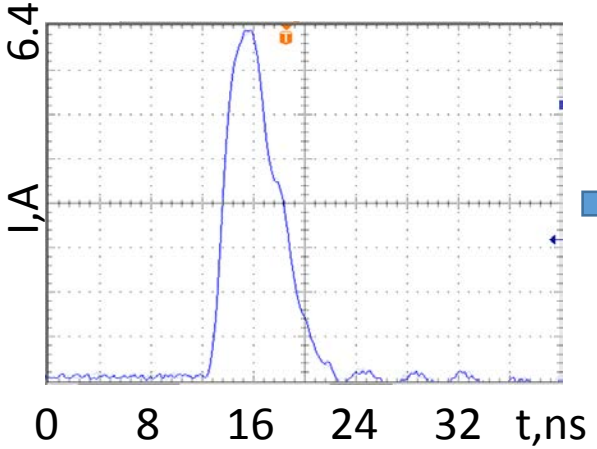



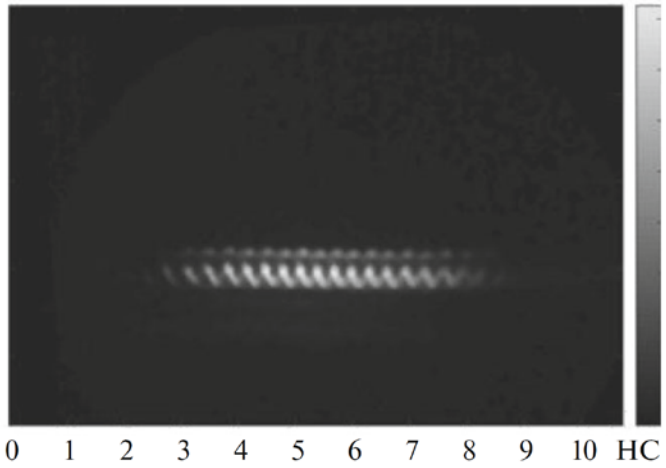

Positron storage rate lifespan
Is better than electron gun one

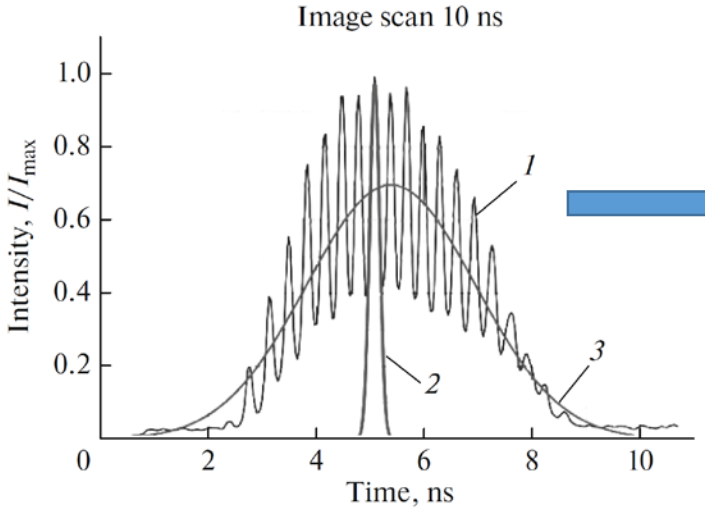
# Damping ring injection efficiency

Gun beam current




Streak camera image of injected beam in damping ring



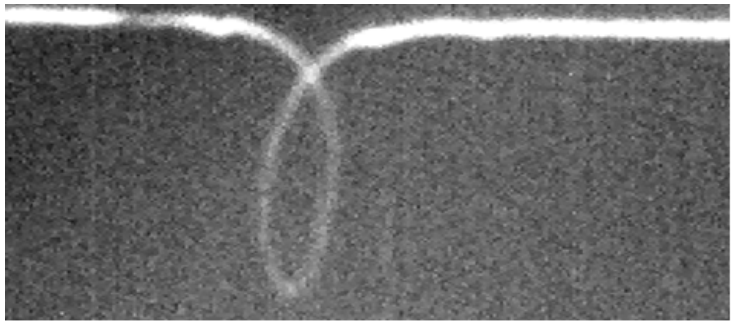

*1* Profile
*2* HWHW = 0.11 ns, 2*Sigma = 0.09 ns
*3* HWHW = 1.84 ns, 2*Sigma = 1.56 ns

Extra 40% lost

subharmonic buncher use

Beam probe image, single bunch mode

+40% lost
Before linac

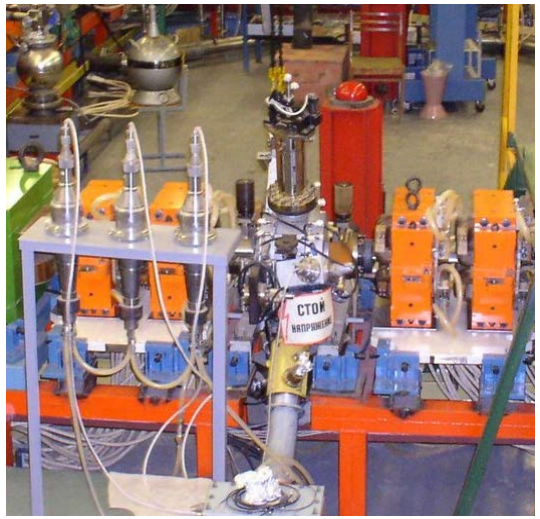


Another solution:
Use lower frequency cavity

# Damping ring 1st harmonic cavity

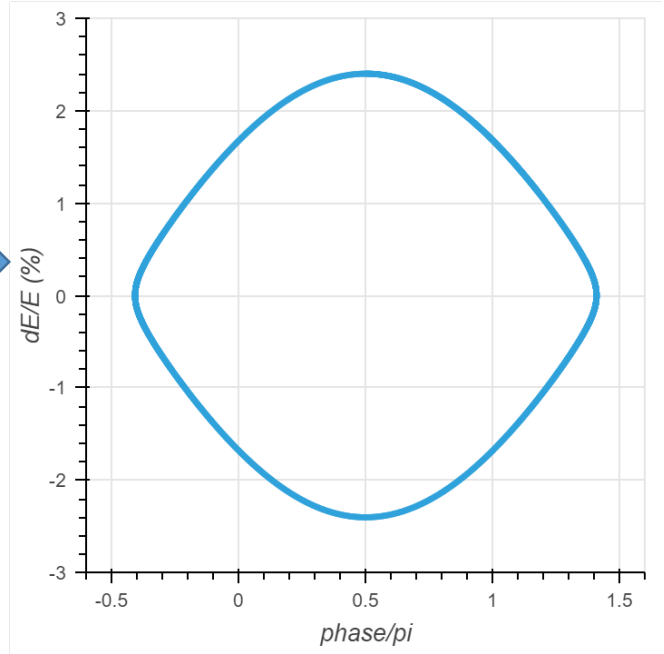
Up to 16/17 season

700 MHz cavity
q=64
$U_{max}$=300 kV
$\sigma_{bunch}$=8 mm



New 10.94MHz cavity
q=1
$U_{max}$=10 kV
$\sigma_{bunch}$=16 cm

Damping ring separatrix




Separatrix width: 2.4%
As in old project with
2 x 400 kV 700MHz cavity

# Achievements, possibilities

Achieved parameters

| Linacs | | Damping Ring | |
|---|---|---|---|
| Max. e+ energy | 420 MeV | Max. e+ current | 200 mA |
| e- production rate | $3 \cdot 10^{10}$/pulse | Max. e- current | 200 mA |
| e+ production rate | $6.3 \cdot 10^{9}$/pulse | Storage rate for e- | $10^{10}$/pulse |
| Operating energy | 395 MeV | Storage rate for e+ | $2.5 \cdot 10^{8}$/s @12.5Hz |
| Particles switching time | 5 s | Energy for e+ & e- | 395 MeV |

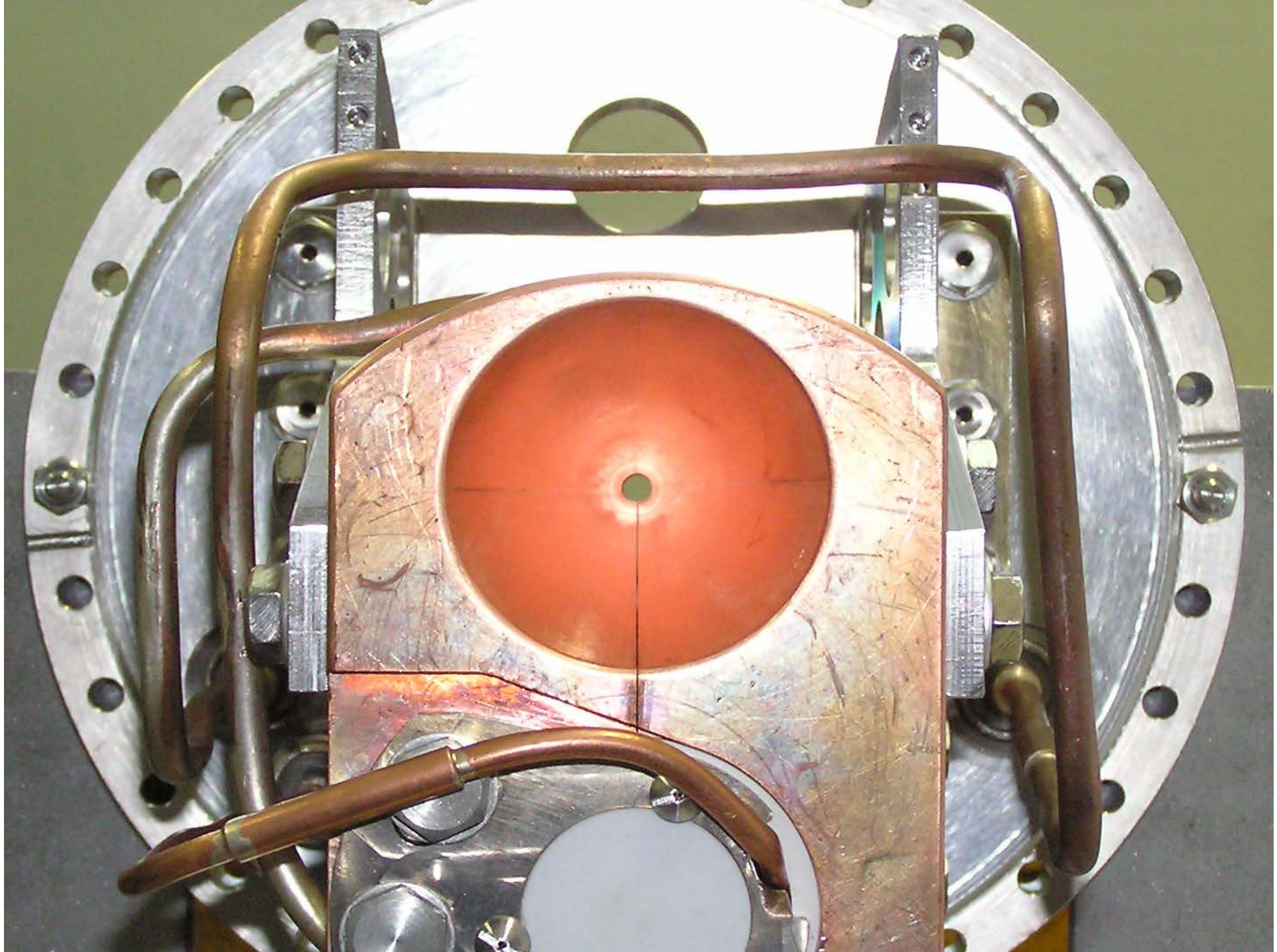
Ways to increase charge productivity

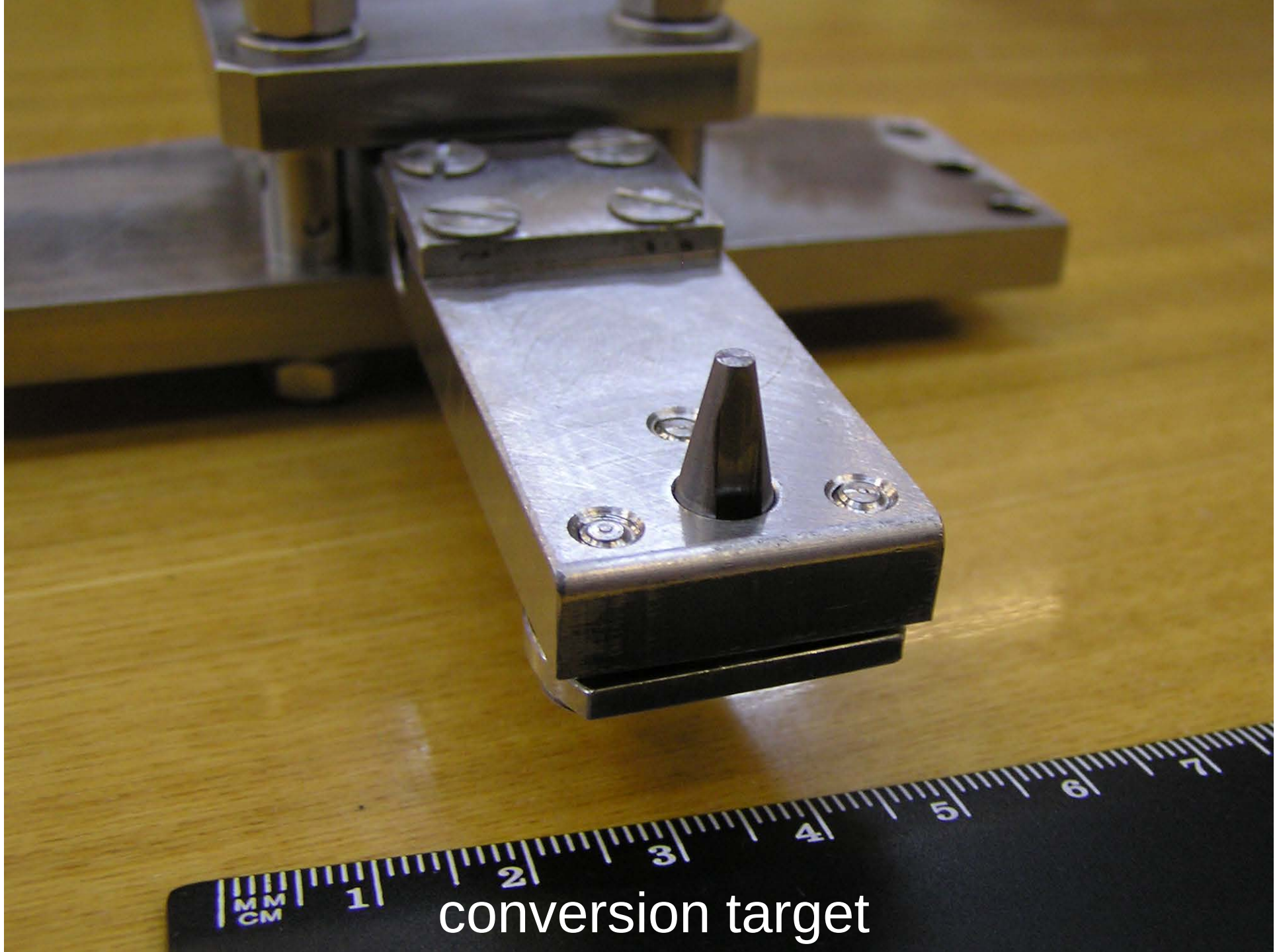
| Action | Potential gain |
|---|---|
| Switch to 10.91 MHz RF station | 1.8 (installed) |
| Increase gun pulse duration with 10.91 MHz RF | 2 |
| Increase operating energy to maximum | 1.5 |
| Increase repetition rate (with energy increase) | 1.5-2 |
| Linac single bunch mode with 700 MHz RF | 2 |
| Install debuncher | 1.5 |

Thank you for attention

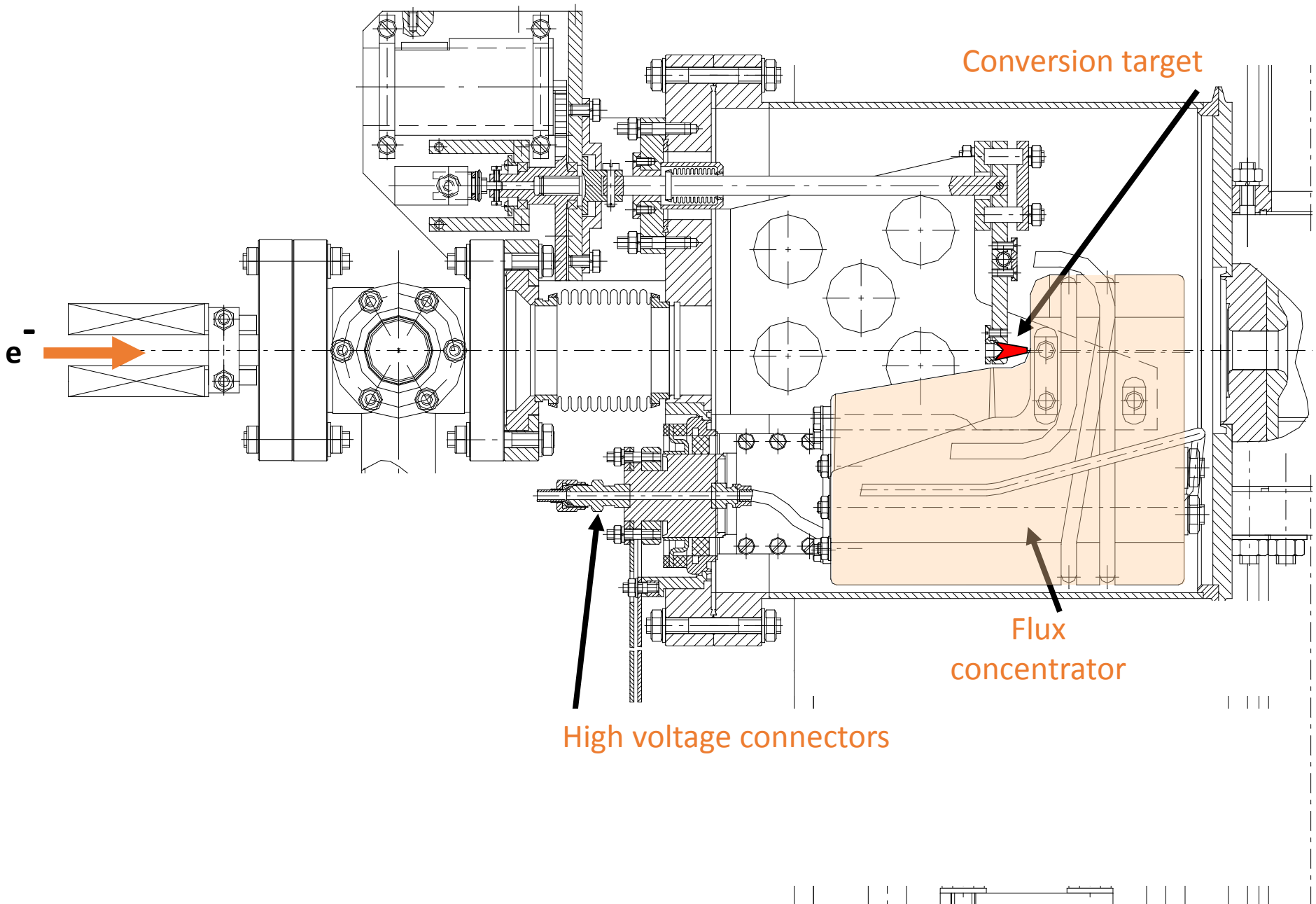
Flux concentrator

**Магнит-концентратор форинжектора ВЭПП-5**




conversion target

# IC conversion system



# Currents Comparison

| | Current, mA | | | | |
|---|---|---|---|---|---|
| | **VEPP-5 DR** | **BEP** | **VEPP-2000** | **VEPP-3** | **VEPP-4** |
| N \ П,m | 27,40 | 22,35 | 24,18 | 74,39 | 366,1 |
| 1,00E+09 | 1,75 | 2,15 | 1,99 | 0,65 | 0,13 |
| 5,00E+09 | 8,76 | 10,74 | 9,93 | 3,23 | 0,66 |
| 1,00E+10 | 17,52 | 21,48 | 19,85 | 6,45 | 1,31 |
| 5,00E+10 | 87,59 | 107,38 | 99,26 | 32,26 | 6,56 |
| 1,00E+11 | 175,18 | 214,77 | 198,51 | 64,52 | 13,11 |