The Cockcroft Institute
of Accelerator Science and Technology

UNIVERSITY OF LIVERPOOL

The Ultra-low Storage Ring at FLAIR

Prof. Carsten P. Welsch

Fundamental Questions

Do we understand the interaction between matter and antimatter ?

Is CPT valid ?

Is the effect of gravity equal on matter and antimatter ?

What is the structure of antiprotonic atoms and ions?

Do we understand the correlation between electrons in simple systems ?

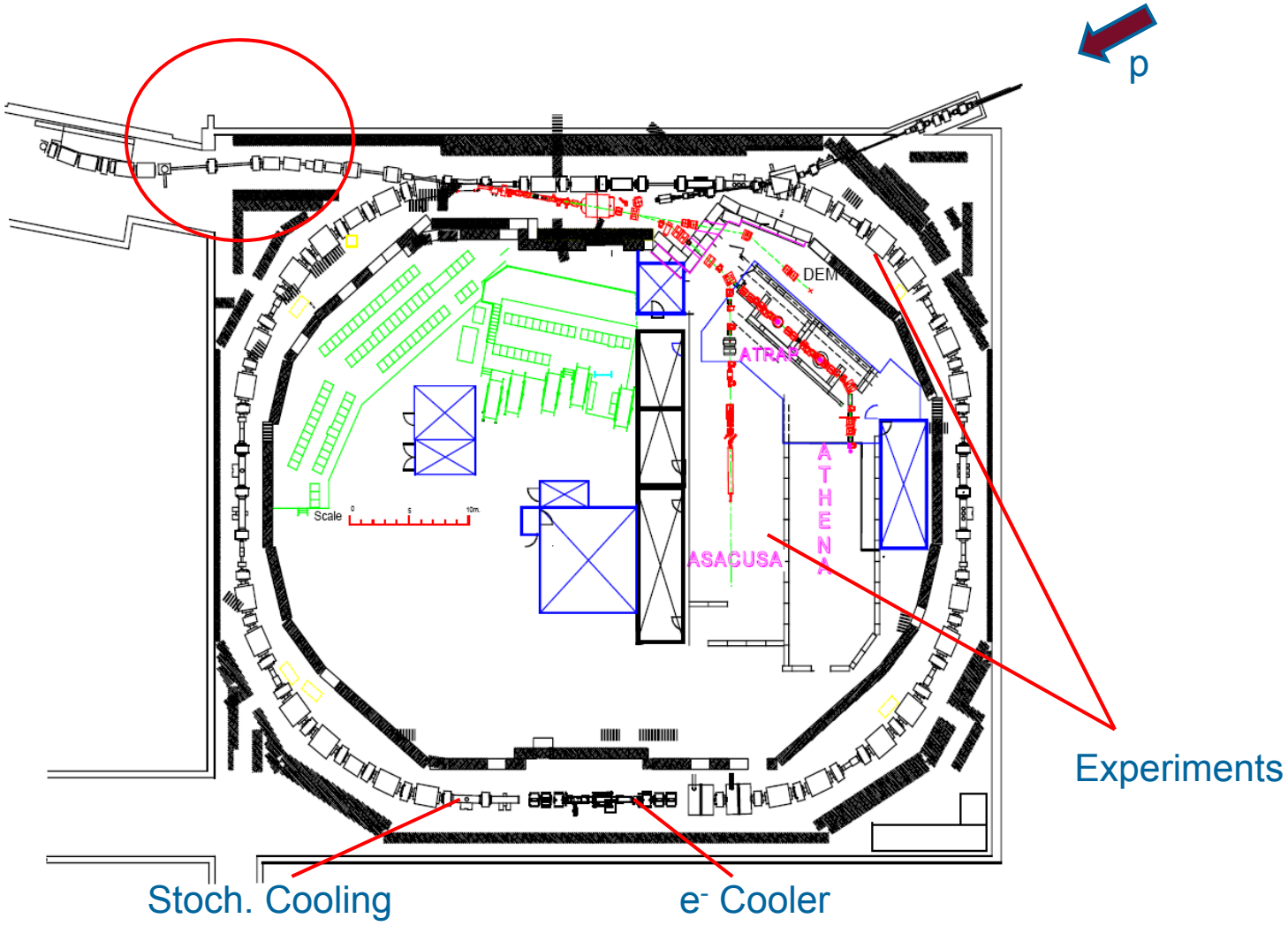
Present Situation: AD @ CERN

Target

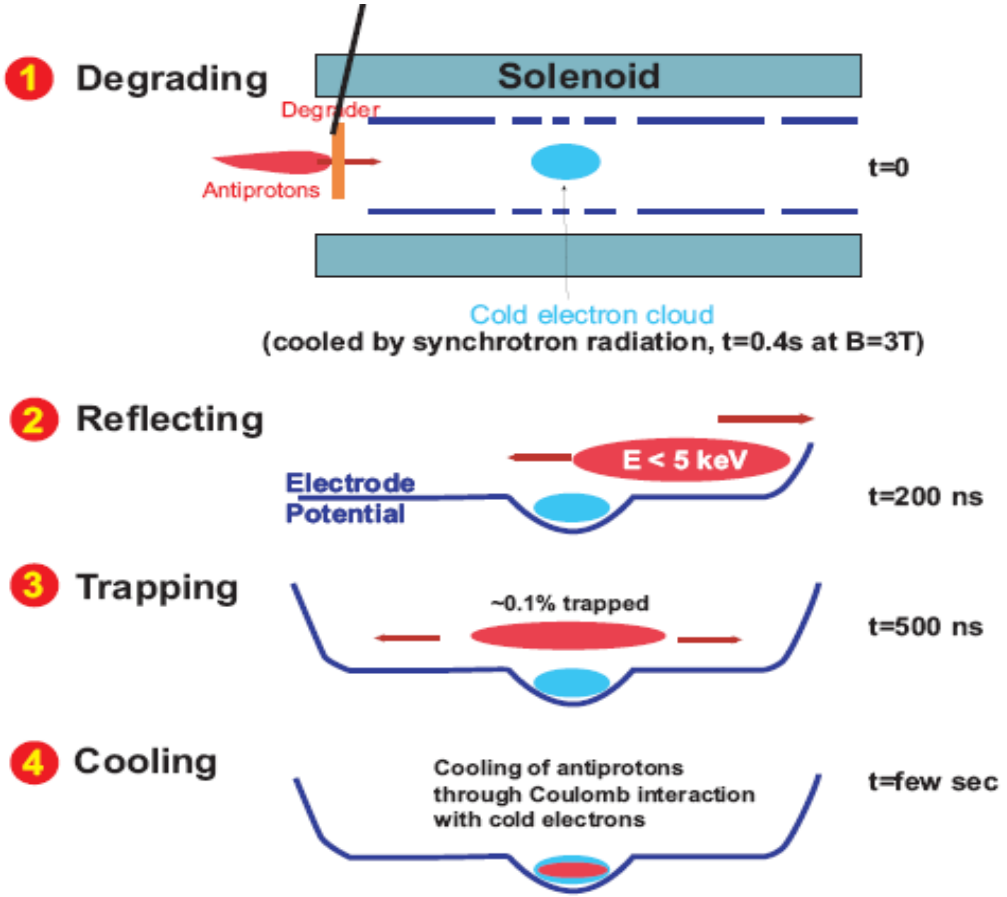
26 GeV/c p

➡ 3.57 GeV/c $\bar{p}$

Yield: $4 \cdot 10^{-6}$



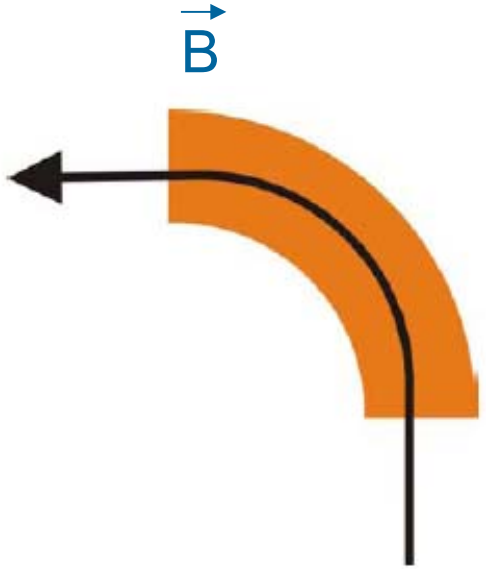
Problem: 5 MeV too high for trapping !

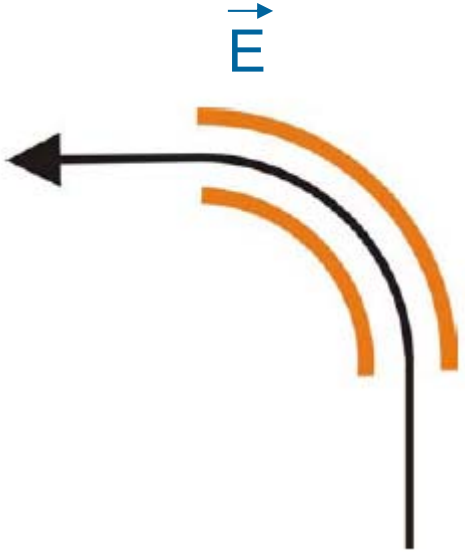


- > 99.9 % of pbars lost in degrader.
  ~ 10.000 pbars/shot
- ASACUSA: RFQ-D
  ~ 2.000.000 pbars/shot

BUT: $\Delta E/E$, $\varepsilon_{x,y}$

Magnetic ↔ Electrostatic





$$\frac{mv^2}{R} = q \cdot v \cdot B$$

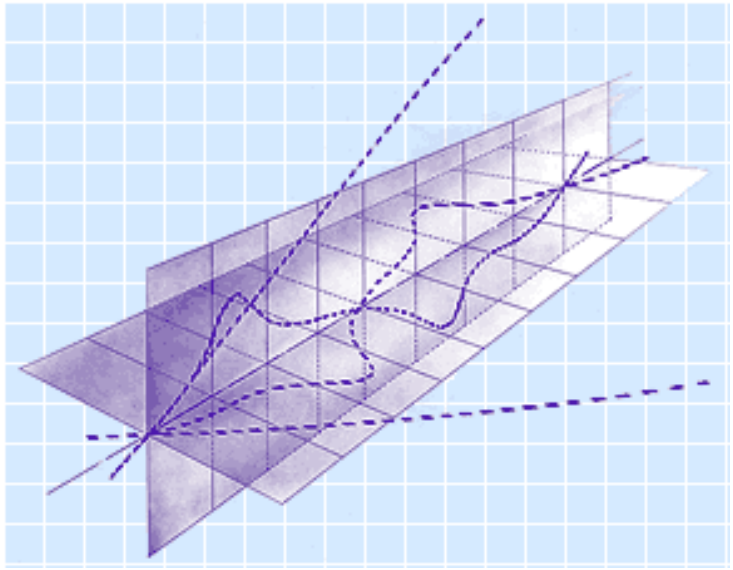
$$R \cdot B = \frac{1}{q} \cdot \sqrt{2 \cdot m \cdot E_{Kin}}$$

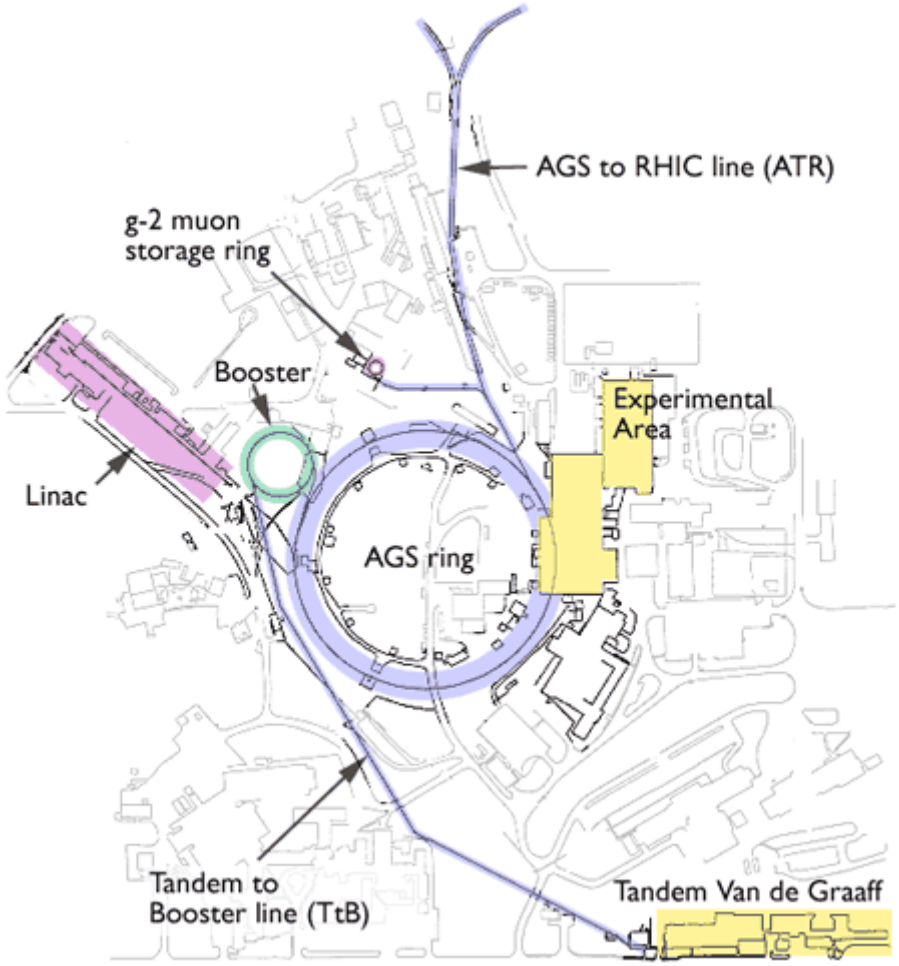
$$\frac{mv^2}{R} = q \cdot E$$

$$R \cdot E = \frac{2 \cdot E_{Kin}}{q}$$

The First Electrostatic Ring

Prototype for the AGS in Brookhaven

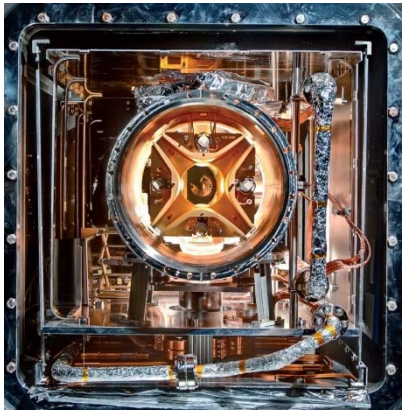




Other Electrostatic Rings

ELISA, Denmark

KEK, Japan

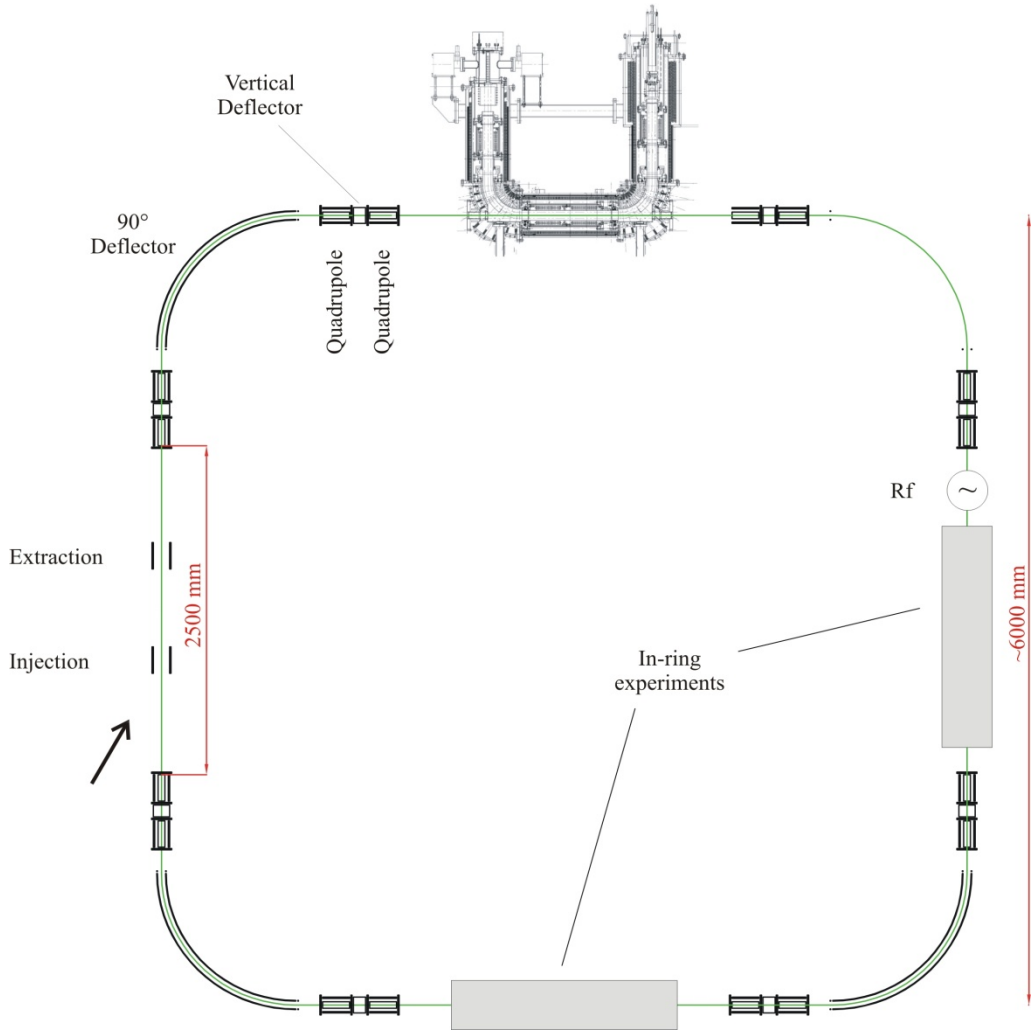


MPIK, Germany

TMU, Japan

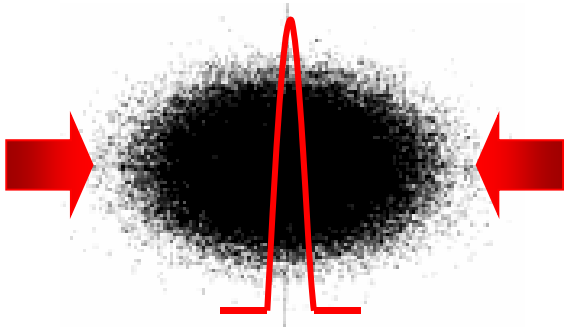
DESIREE, Sweden

USR: First Design in 2005



Welsch, C.P., et al.
Nucl. Instrum. Methods A **546**
405–417 (2005)

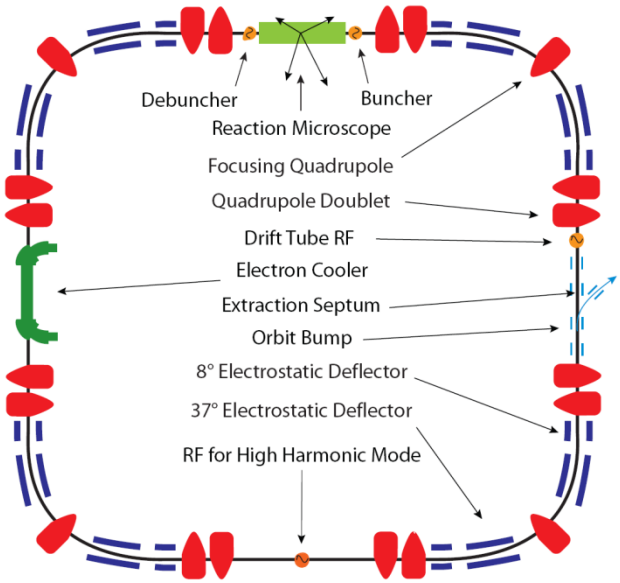
USR – Ring Re-Design



ns Bunching

How to realize nanosecond bunches ?

How to extract the beam ?



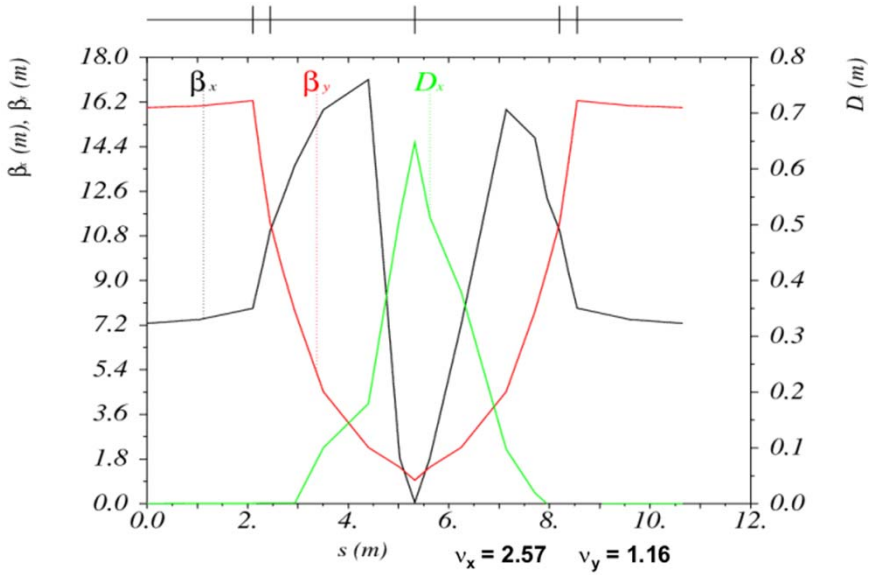
A.I. Papash, et al., Nucl. Instr. Meth. A 620 (2010)
G. Karamysheva et al., Part Phys. Nucl. Letters **8** (2011)
A.I. Papash, et al., Phys. Rev. STAB **16**, 060101 (2013)

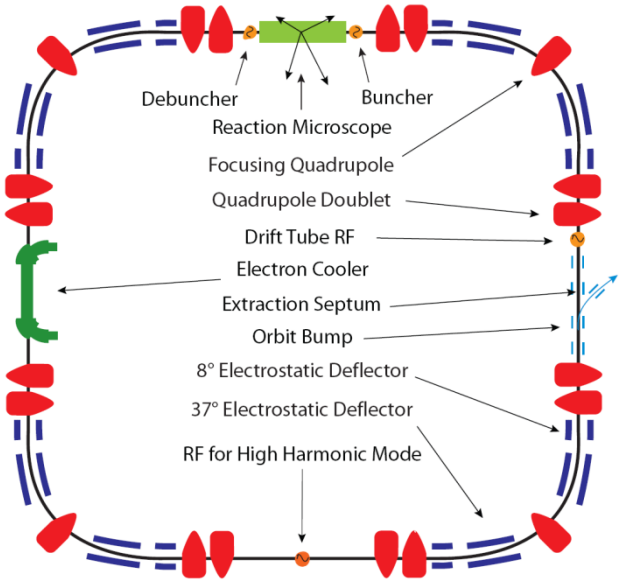
Steps:

- General feasibility
- 1-D simulation
- Full study

Modification to USR Lattice

- "Split-achromat" geometry, new concept

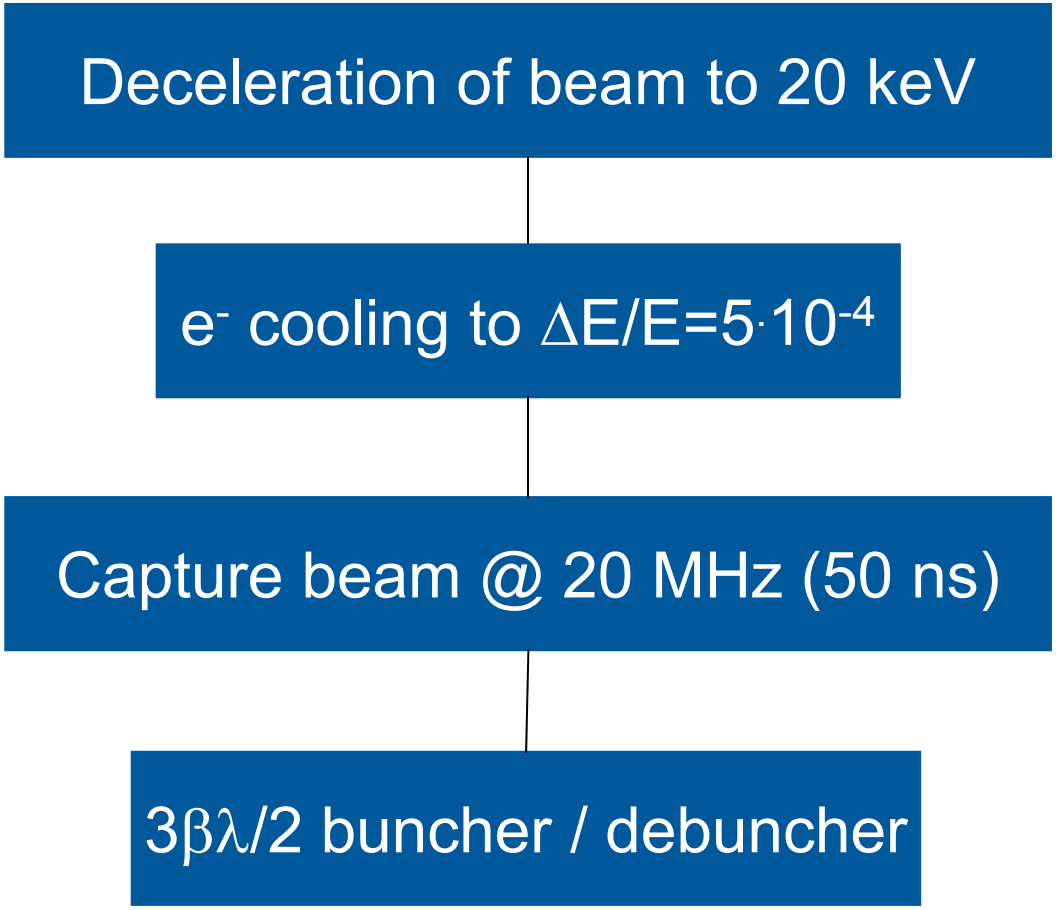




- Achromatic section, D=0 in straights
- D never > 0.6 m.

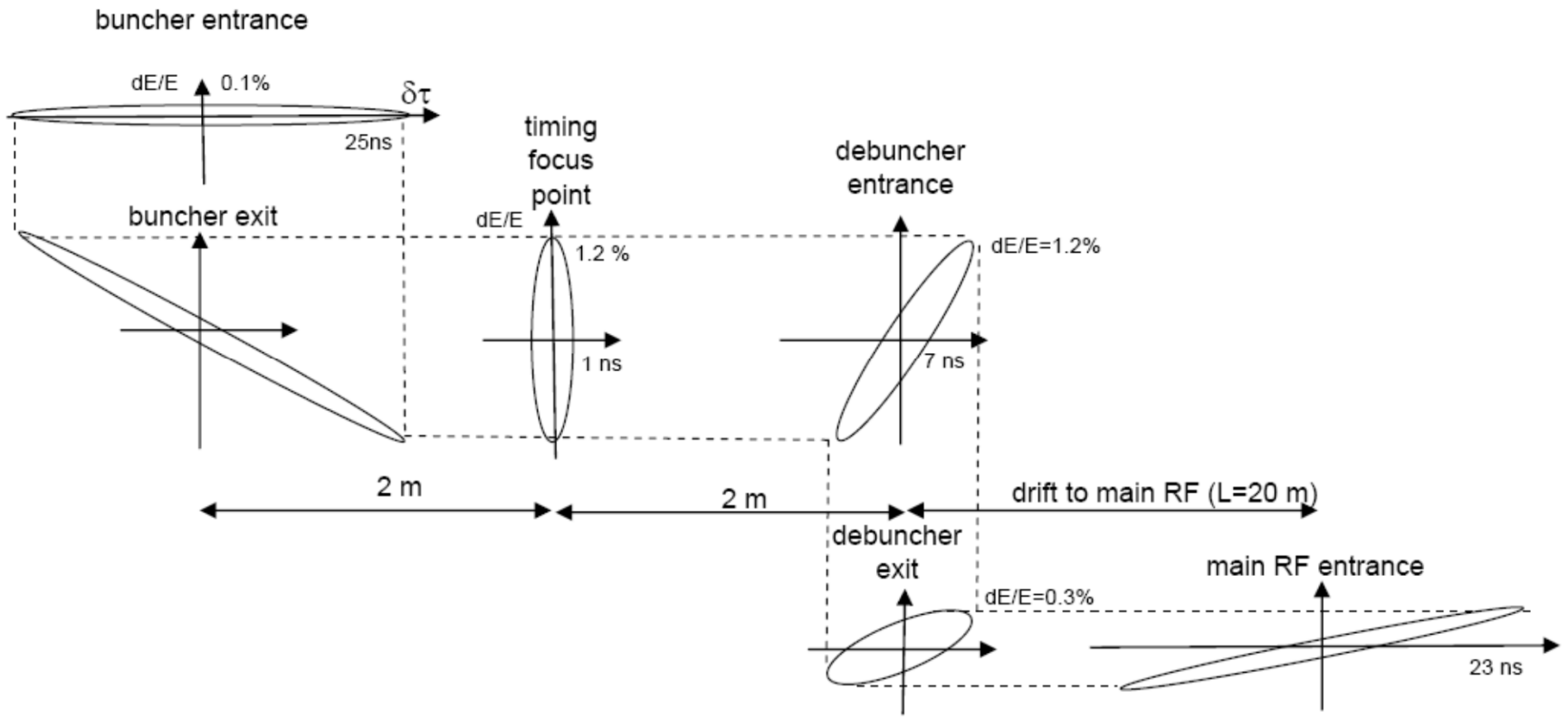
Proc. PAC (2009
C.P. Welsch et al., Hyp. Inter. (2014).

Staged approach



A. Papash, C.P. Welsch, Part Phys. Nucl. Letters **3** (2009)

Evolution in Phase Space

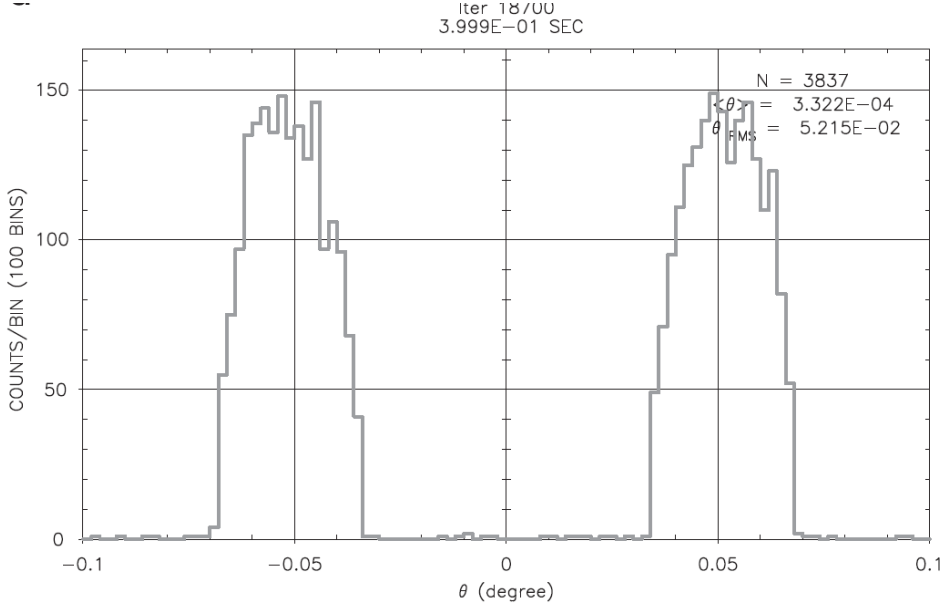


Crucial: Dispersion in straight section !

A.I. Papash, C.P. Welsch, PPNL 6 (3) (2009)
A.I. Papash, C.P. Welsch, Nucl. Instr. Meth. A 620 (2010)

Alternative: Higher harmonic split

- 20, 40, 80, 160 MHz split into smaller rf buckets
- Minimize losses (overall efficiency is ~30 %)

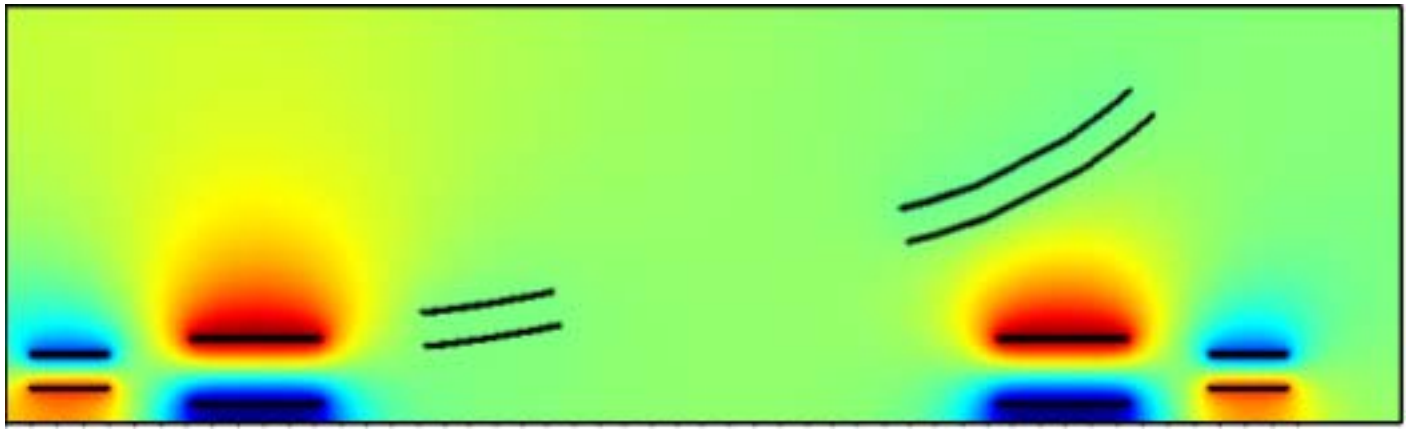


- Problem: Inter-bunch spacing ! Use chopper.

A.I. Papash, C.P. Welsch, Nucl. Instr. Meth. A 620 (2010)

USR - slow/fast Extraction

Goal: Combined system, providing highly-flexible extraction



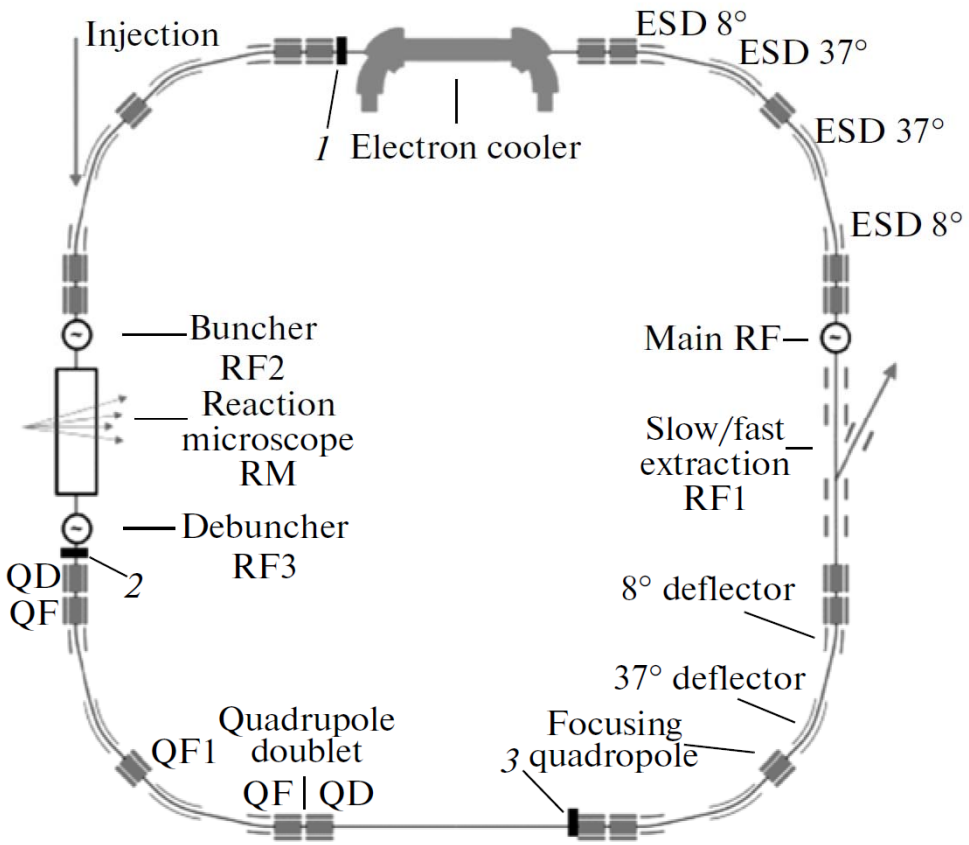
Motivation: Nuclear physics-type experiments.

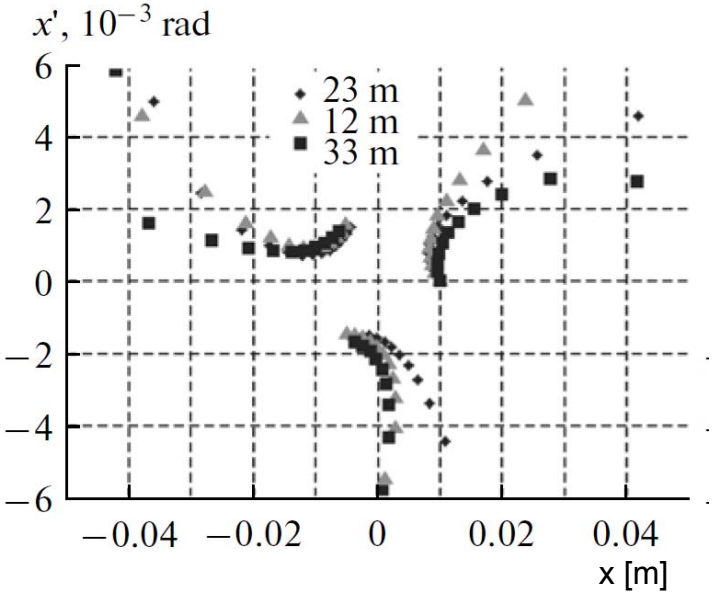
➡ First time in electrostatic ring !

Used: Comsol, benchmarked against OPERA results.

G. Karamysheva, A.I. Papash, C.P. Welsch, Part Phys. Nucl. Letters **8** (2011)

Sextupole Integration

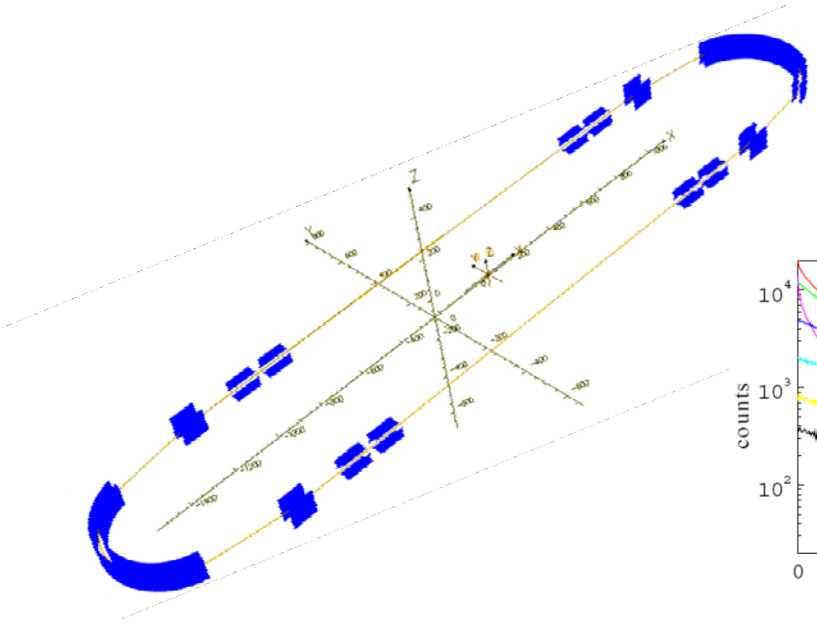


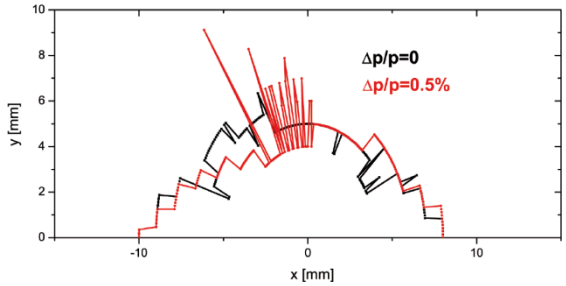


G. Karamysheva, A.I. Papash, C.P. Welsch, Part Phys. Nucl. Letters **8** (2011)

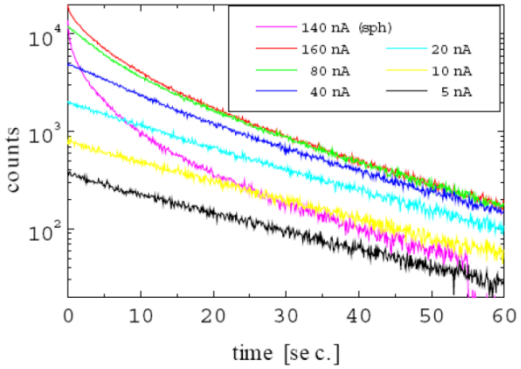
USR – Advanced Studies

- Full 3D ring model, detailed studies (OPERA, MAD-X)
- Explained life time, Δp/p, etc.

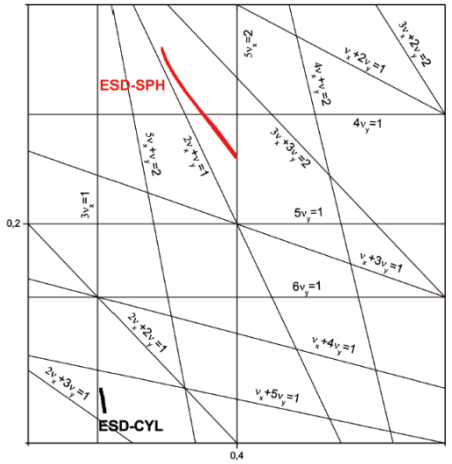




Dynamic Aperture



Beam Loss

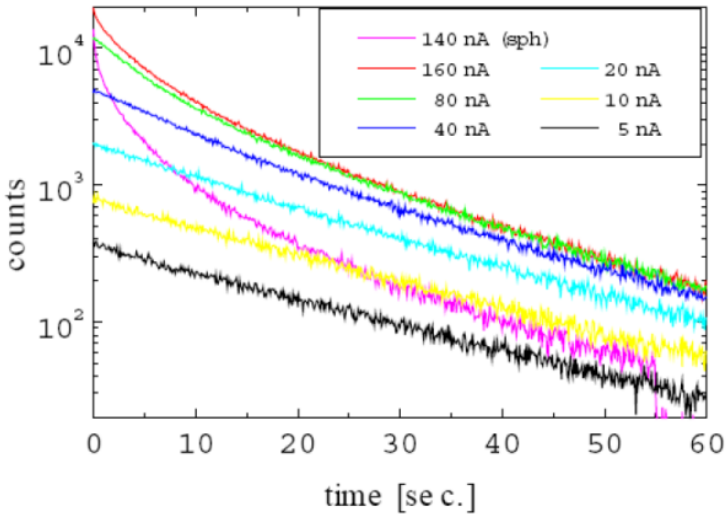


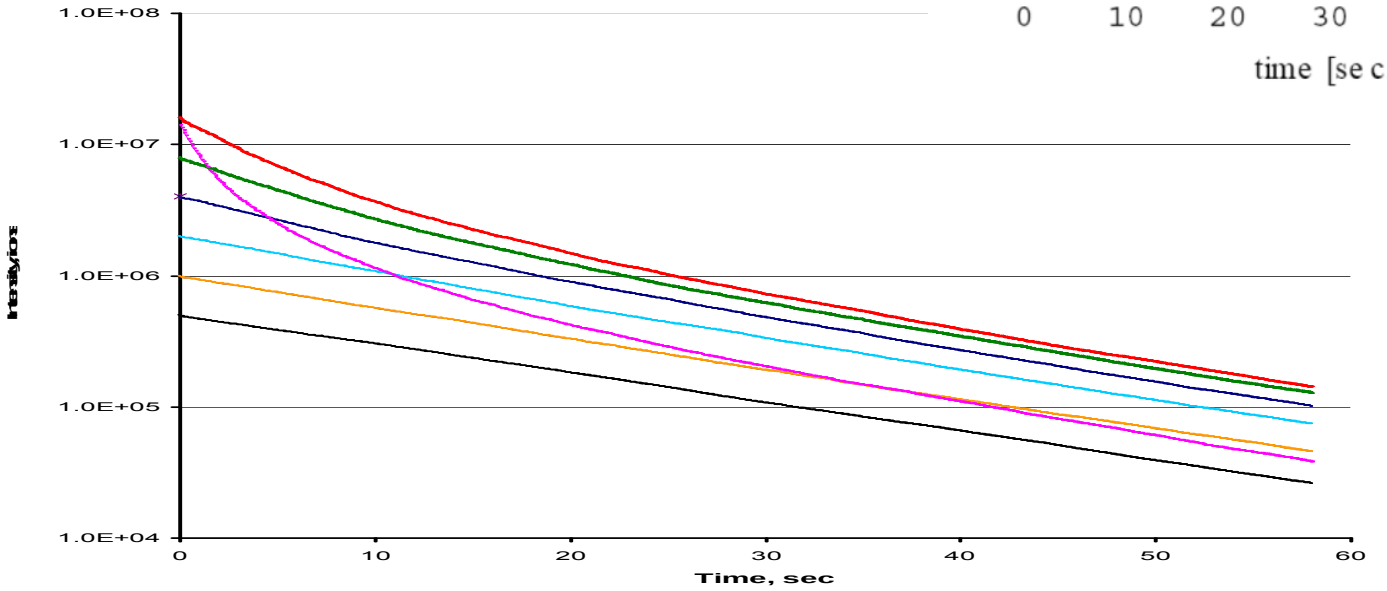
Tune Shift

O. Gorda, A.I. Papash, C.P. Welsch, Proc. IPAC (2010)
A.I. Papash, et al., Proc. IPAC (2011)

Beam Dynamics

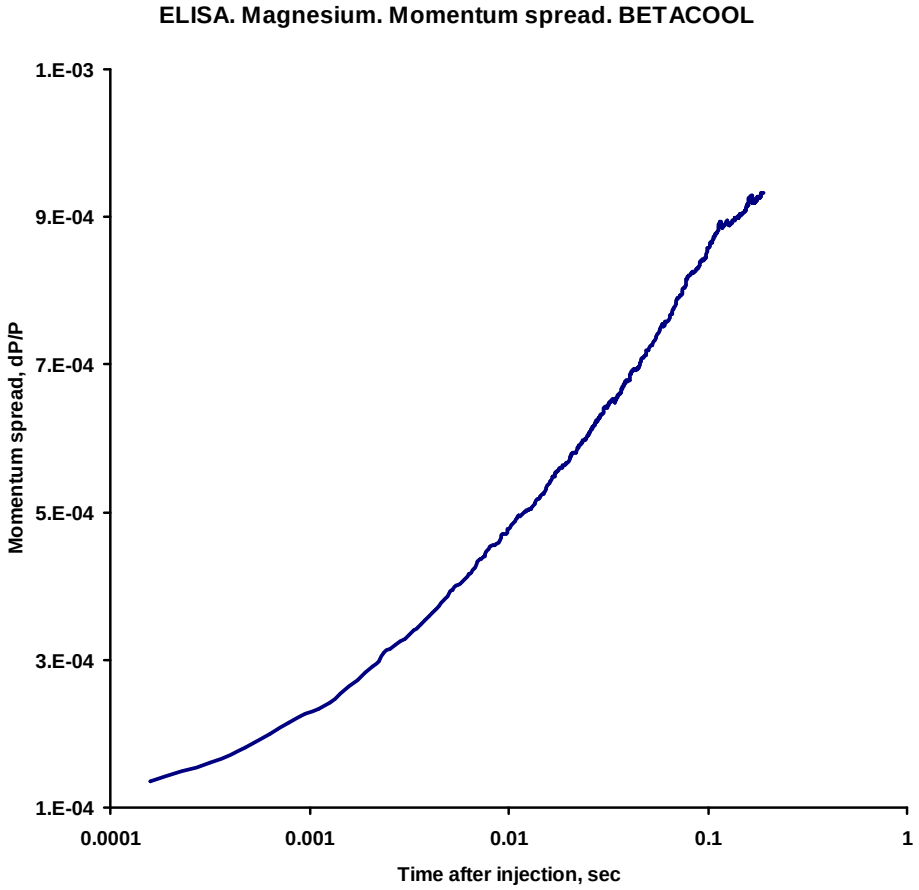
- Used ELISA for benchmarking



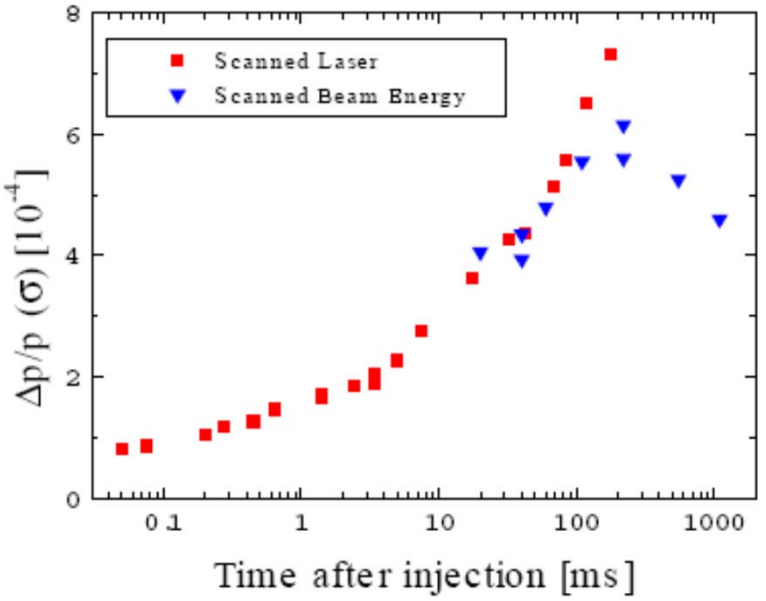


A. Papash, A. Smirnov, C.P. Welsch, *Phys. Rev. STAB 16, 060101 (2013)*

Momentum Spread

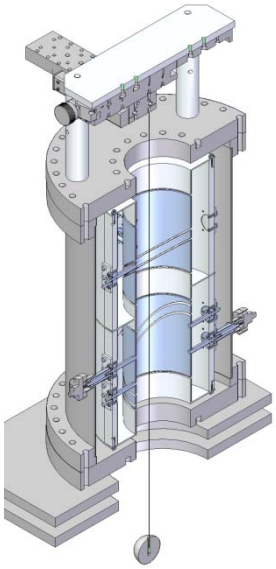


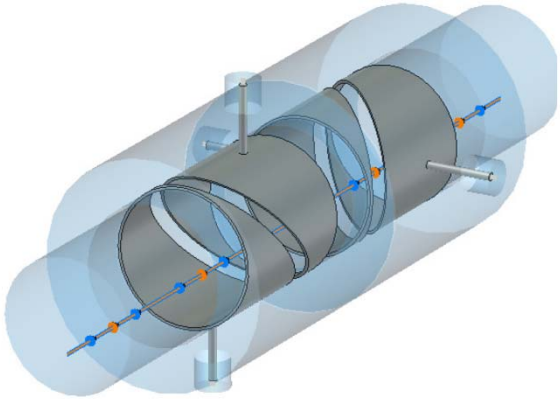
A. Papash, A. Smirnov, C.P. Welsch, *Phys. Rev. STAB 16, 060101 (2013)*

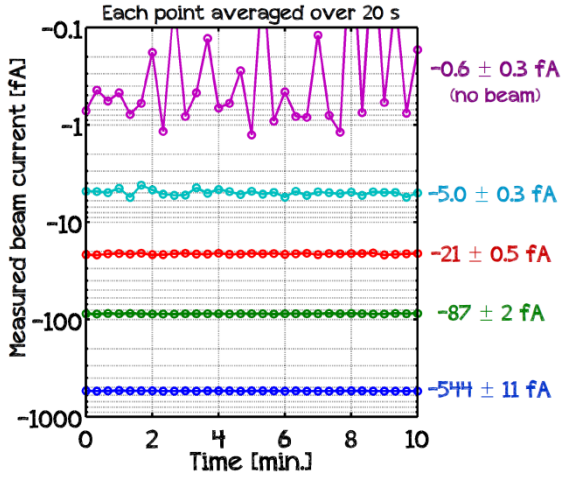


S.P.Moller. „Intensity Limitations of the Electrostatic Storage Ring ELISA“. Proc. of EPAC-2000. p.788-790

USR – Diagnostics



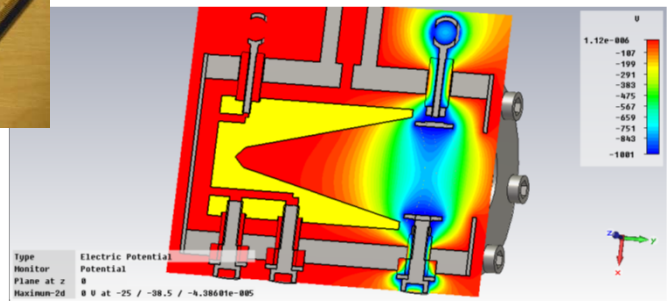




J. Harasimowicz, et al.,
Hyperfine Interact. (2009)

J. Harasimowicz, et al.,
Rev. Sc. Instr. **81** (9) (2010)

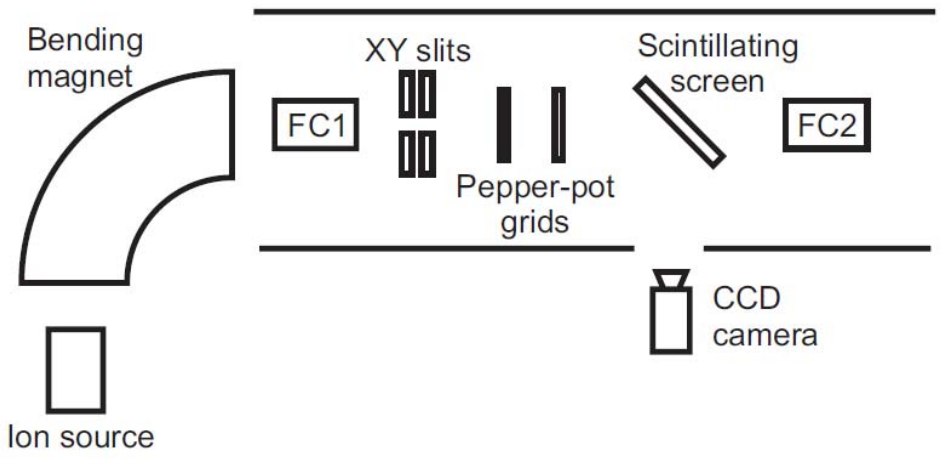
J. Harasimowicz, et al.,
Phys. Rev. STAB **16** (2013)

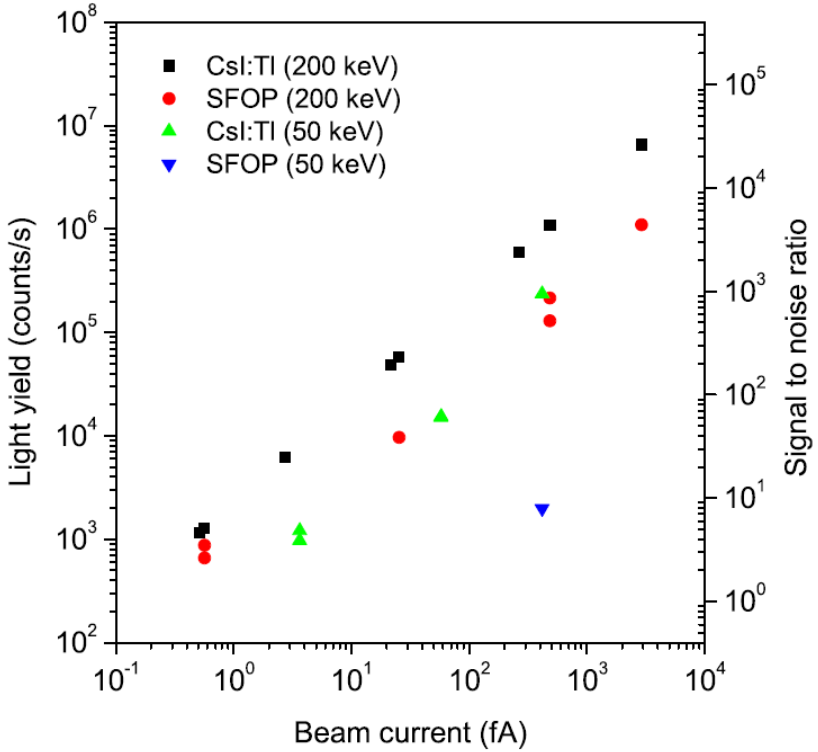


- Position
- Profile
- Intensity
- AEgIS Setup

Screen Studies

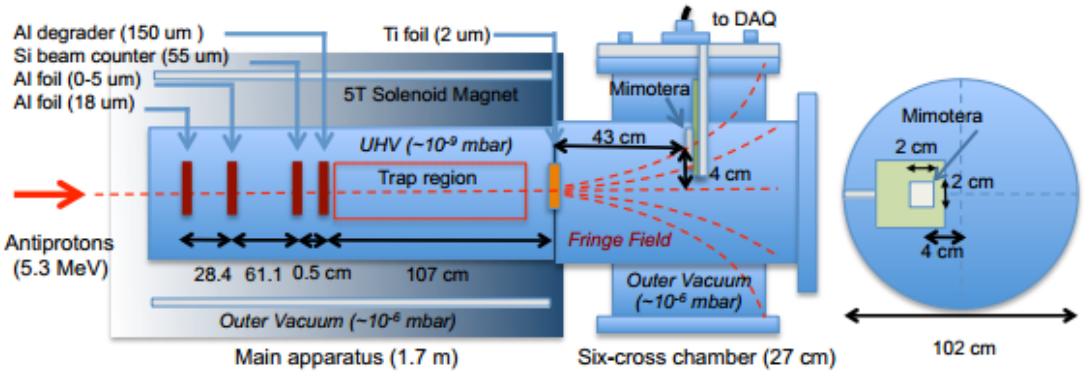
- Realized in close collaboration with INFN-LNS



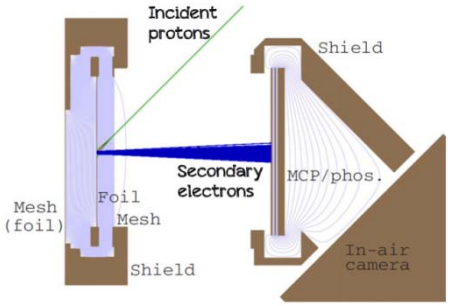


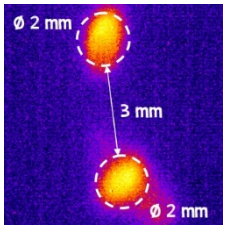
J. Harasimowicz, et al., Rev. Sc. Instr. **81** (9) (2010)
J. Harasimowicz, et al., Phys. Rev. STAB **16** (2013)

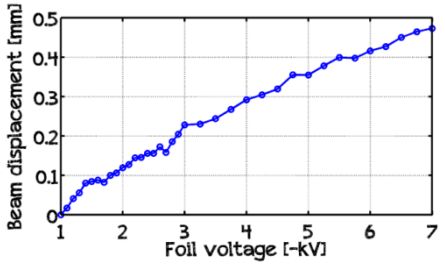
Screens, SEM – AD installation



- Alternative transverse monitor;
- Improve existing designs;
- Measurements with 200 keV proton beams at INFN and pbars @ AEgIS
- Benchmarked simulations.

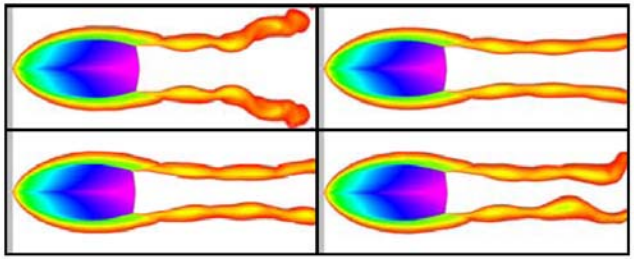




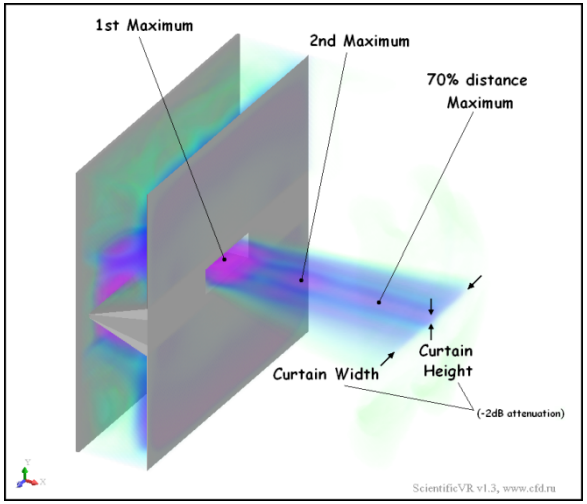


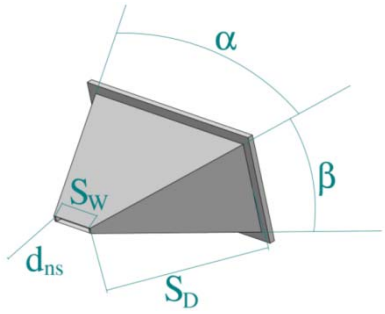
A. Sosa, et al., Hyp. Inter. (2014)
S. Aghiona, et al., JINST 8 P08013 (2013).

Numerical Investigations with GDT



- System optimization and trends analysis

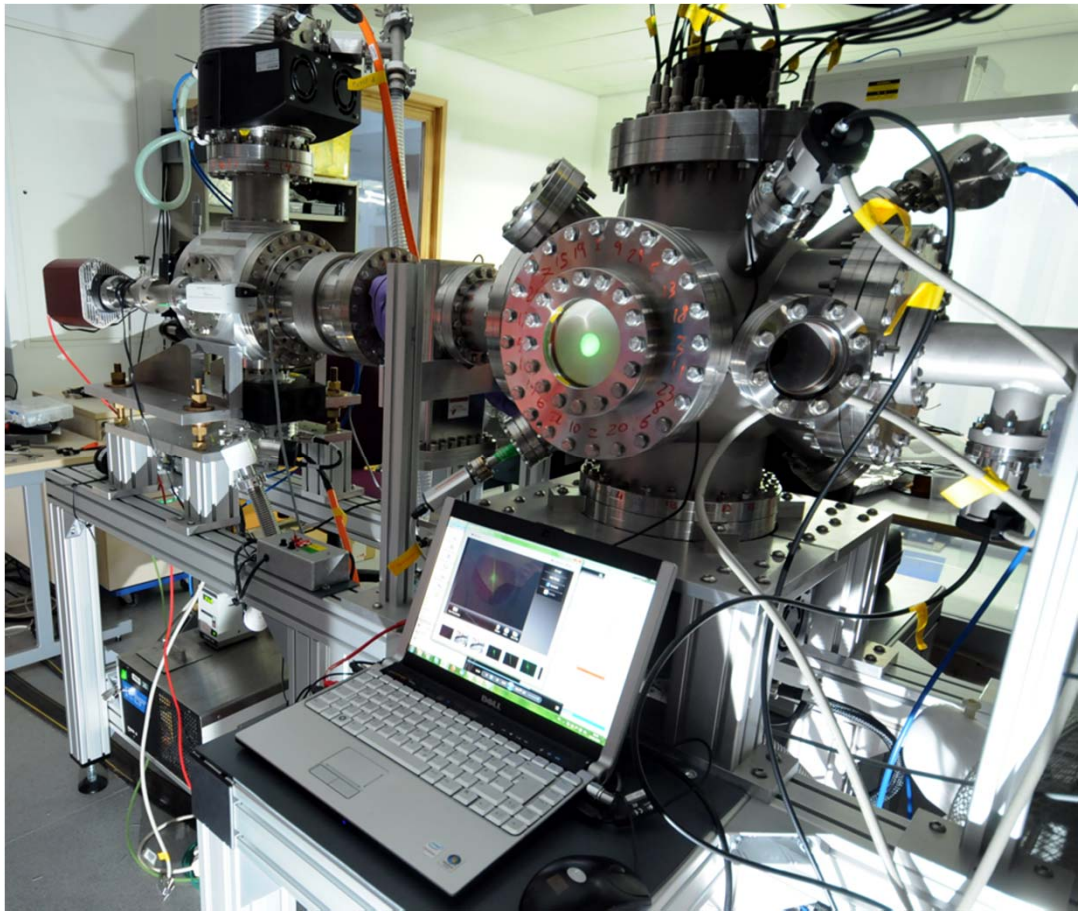




	Mach N.	D	W
α	↘	↘	↗
β	↘	⌒	→
SW	↘	↘	↗
SD	α	⌒	⌒
Dist	⌒	α, β	α, β

M. Putignano et al., Nucl. Instr. Meth. A (2012)

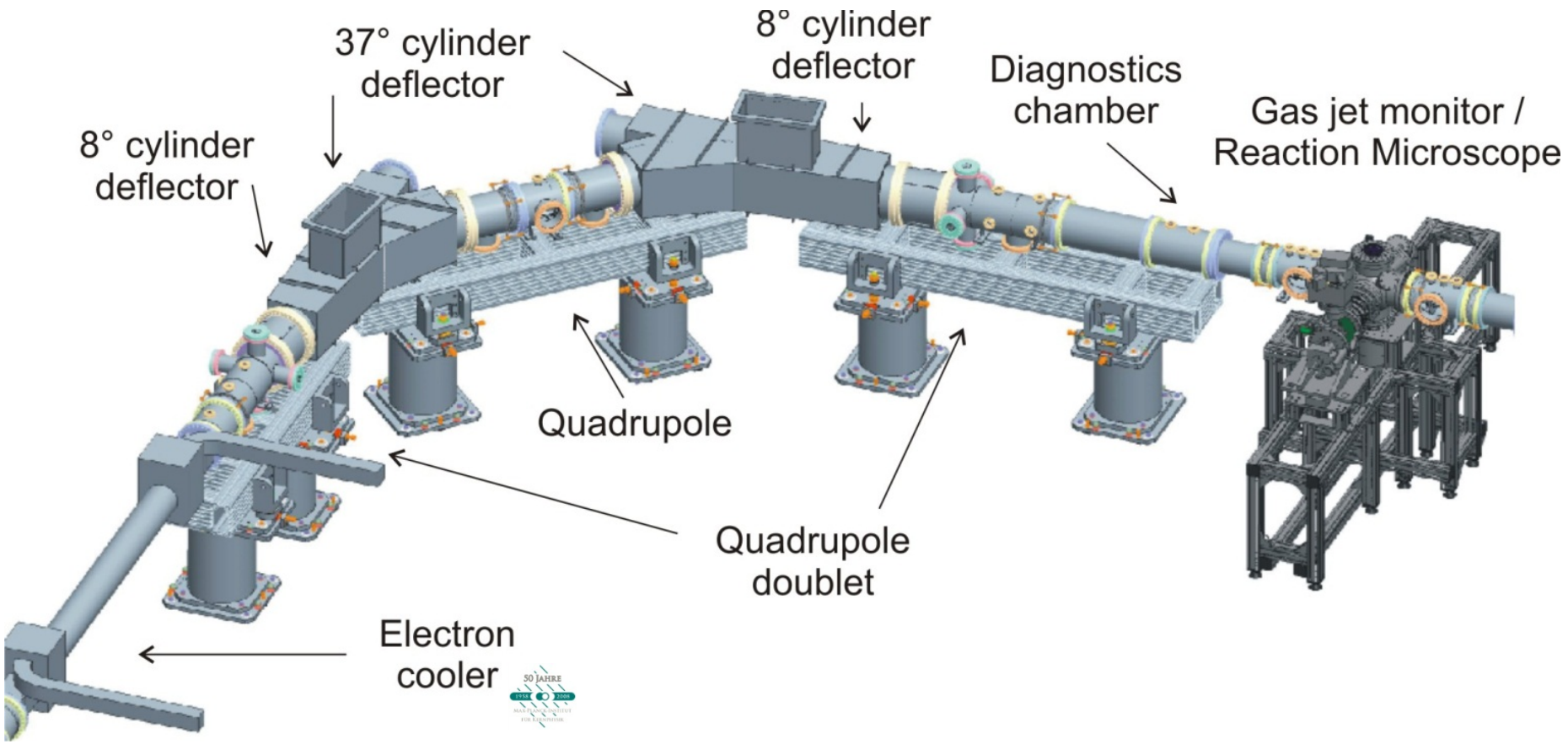
Profile Measurement and Collision Experiments: Prototype Setup



- Proof-of-principle setup @ CI;
- Gas jet and IPM;
- Designed for use with low energy antiproton beams:
  - Profile Monitor
  - Collision studies.

M. Putignano, C.P. Welsch, Nucl. Instr. Meth. A 667 (2012)
V. Tzoganis, C.P. Welsch, Apl. Phys. Letters (2014).

USR - Technical Design



Conclusion

- USR ring design, incl. mechanical design, done - TDR to be written up;
- Improved understanding of beam dynamics and help develop dedicated simulation tools;
- Beam instrumentation prototypes developed and tested with beam.

Many thanks for your attention !