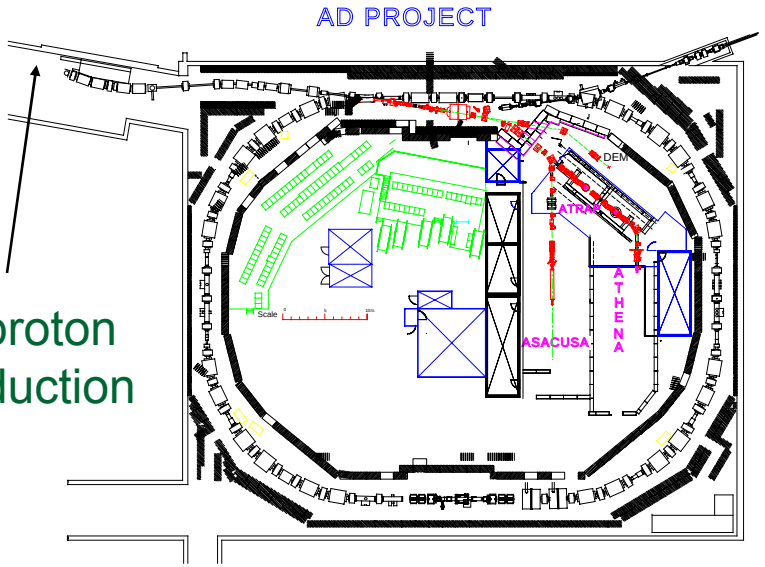
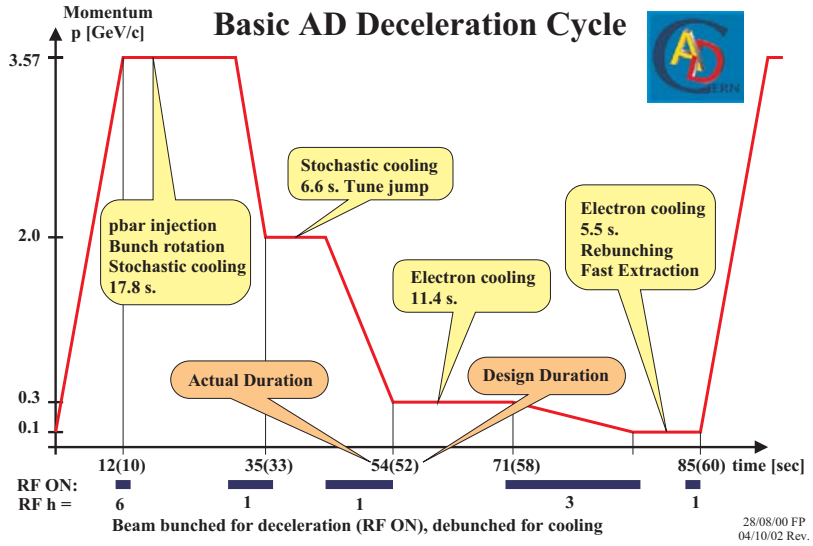
FLAIR - A Next-generation Low-energy Antiproton and Ion Facility

E. Widmann, University of Tokyo
Chairman, FLAIR steering committee
SPSC Villars meeting,
September 26, 2004

Antiproton Decelerator (AD) at CERN



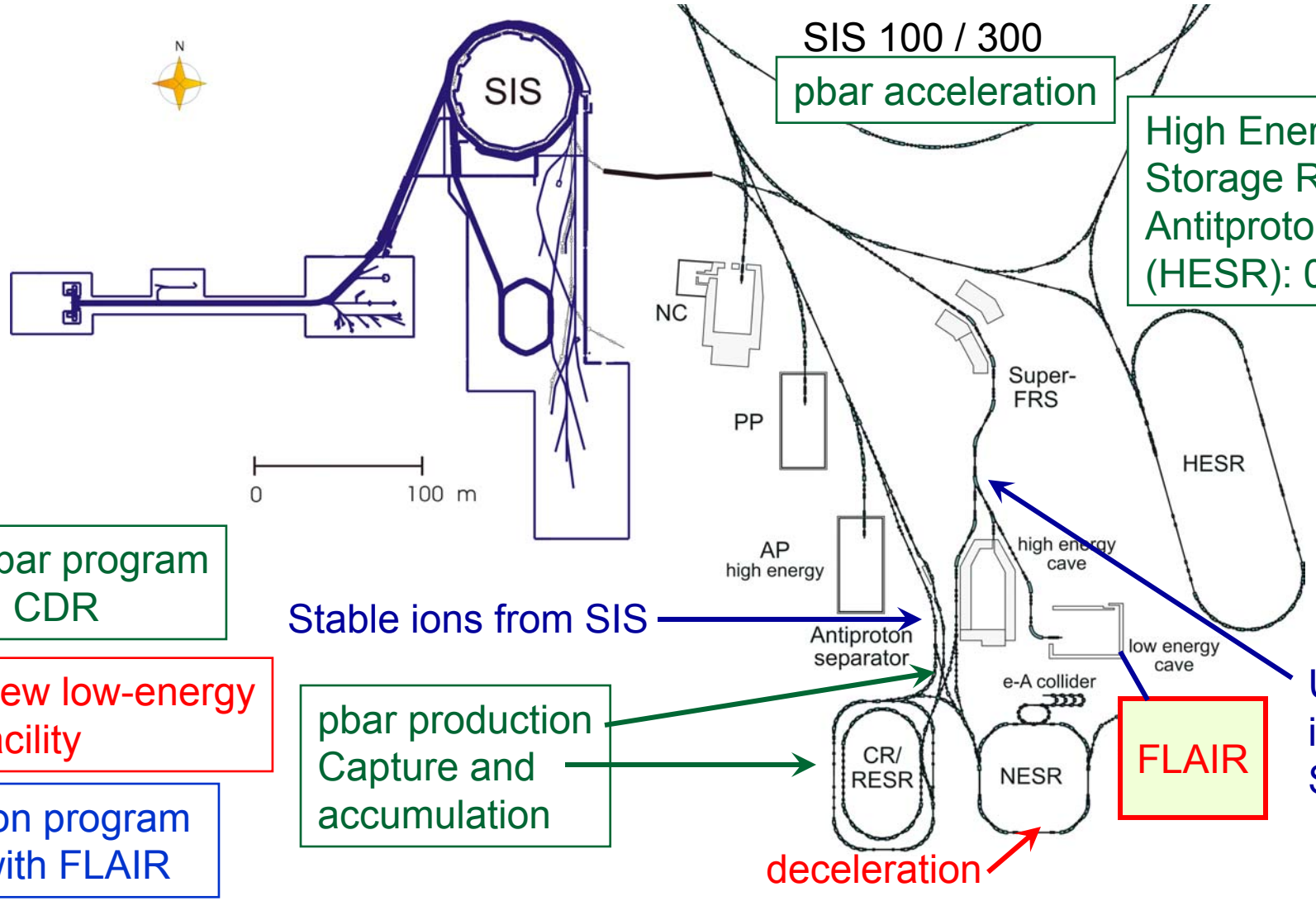


- *Antiproton capture, deceleration, cooling*
  - 100 MeV/c (5.3 MeV)
- *Pulsed extraction*
  - 2-4 x 10^7 antiprotons per pulse of 100 ns length
  - 1 pulse / 85 seconds
- *Antiprotonic atom, Antihydrogen formation and spectroscopy, atomic collisions*

Features of a Next-generation Low-energy Antiproton Facility

Feature	*Solution*
Higher intensity	*Accumulation scheme*
Fast and slow extraction	*Coincidence experiments (nuclear physics)*
Cooled beams down to < 500 keV	*Storage rings*
Availability of pbar and RI	*FAIR @ Darmstadt*

FLAIR and the FAIR @ Darmstadt



FLAIR – A Facility for Low-energy Antiproton and Ion Research @ FAIR

- *NESR*
  - Pbar & Ions
    30 – 400 MeV
- *LSR*
  - Standard ring
  - Min. 300 keV
- *USR*
  - Electrostatic
  - Min. 20 keV
- *HITRAP*
  - pbar and ions
  - Stopped & ext-tracted @ 5 keV

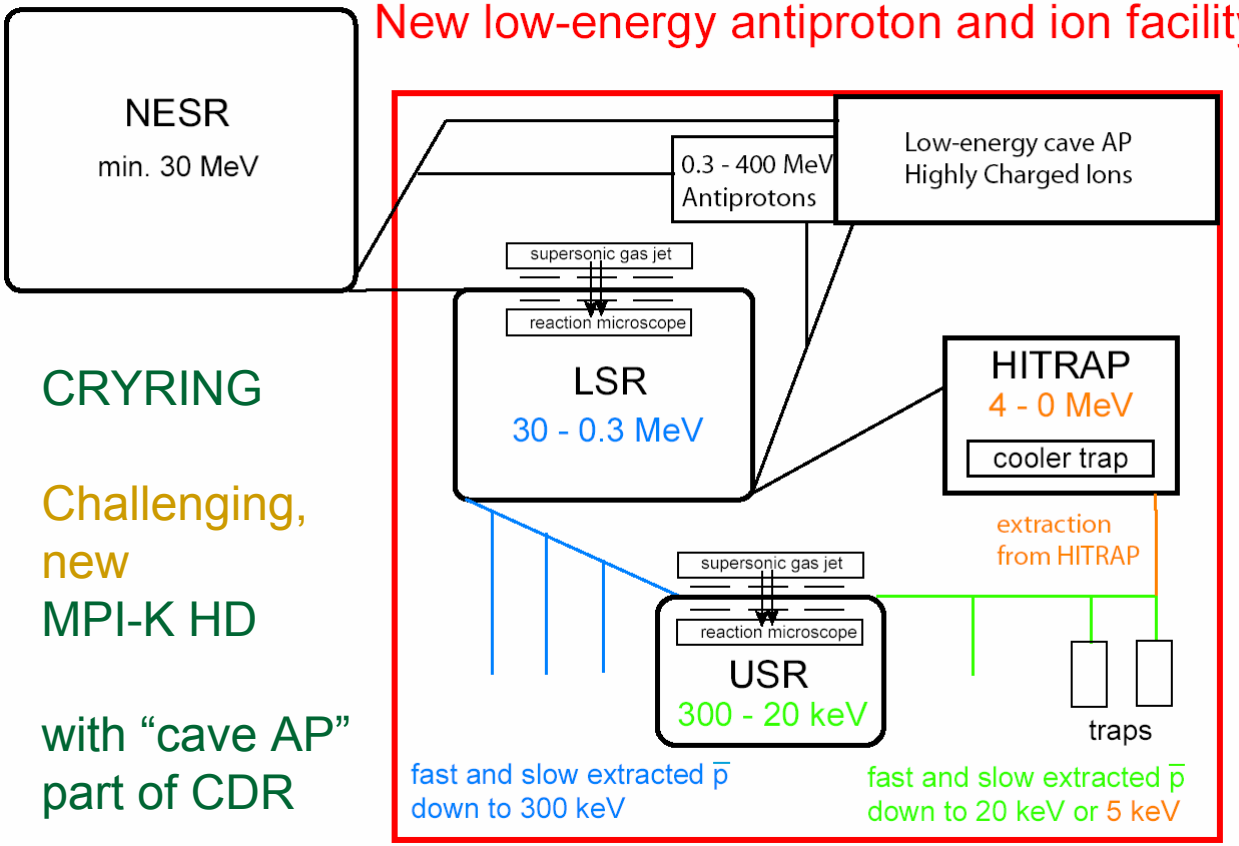
www-linux.gsi.de/~flair

CRYRING

Challenging, new MPI-K HD

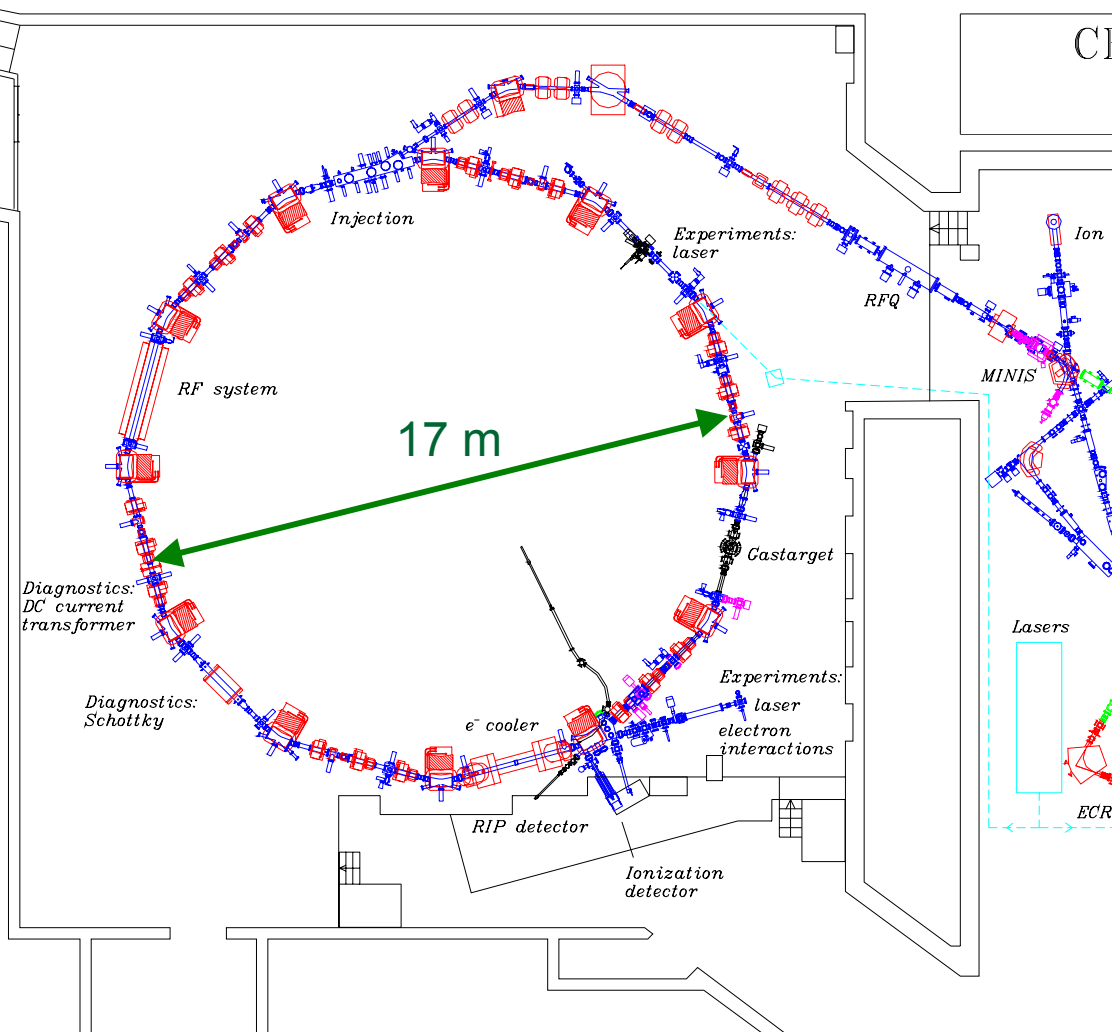
with "cave AP" part of CDR

New low-energy antiproton and ion facility



Factor 100 more pbar trapped or stopped in gas targets than now

Features of CRYRING

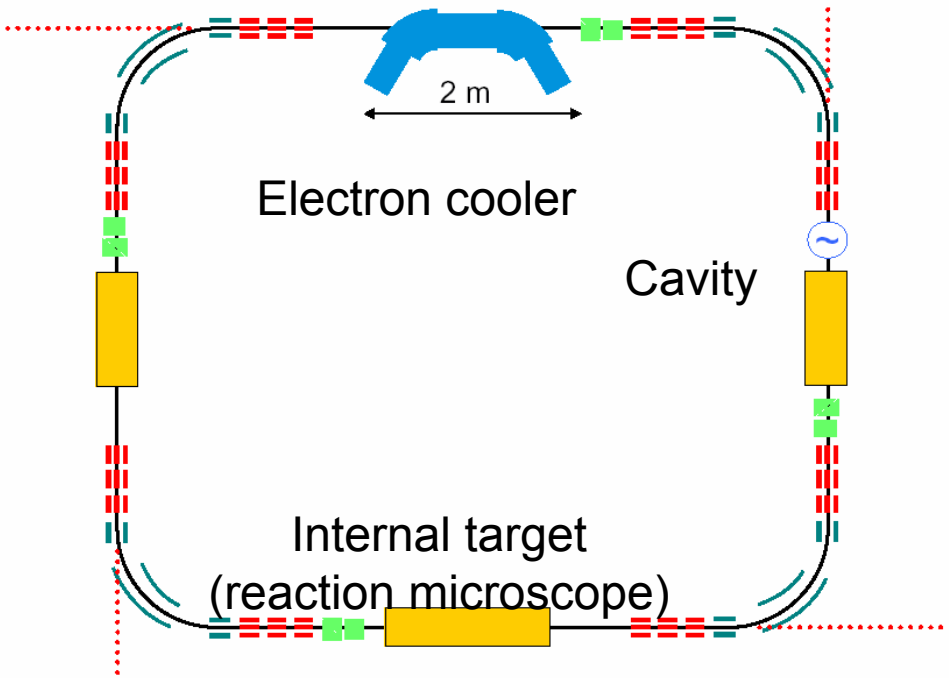


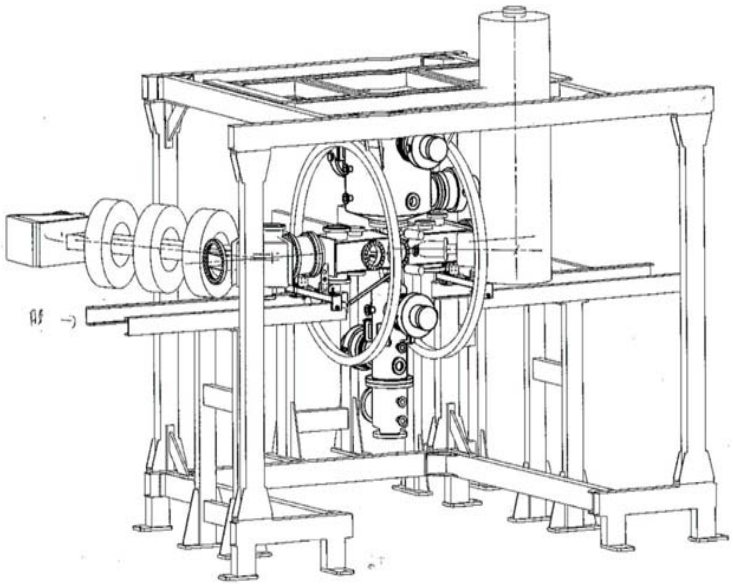
- 300 keV – 96 MeV (q/A=1)
- Fast ramping (7 T/s)
- Regular changes of polarity
- Good vacuum (<10^{-11} torr)
- Electron cooling
- Extraction foreseen in design
- Room for internal targets
- Low-energy injector with ions source
  - Commissioning / tests
  - Physics with ions
- Exists and works
- To stop operation at MSL within ~2 years
- Many features result in large size

In-ring Collision Studies

- *Electrostatic storage ring:* ***USR***
- *First ever variable energy electrostatic ring*

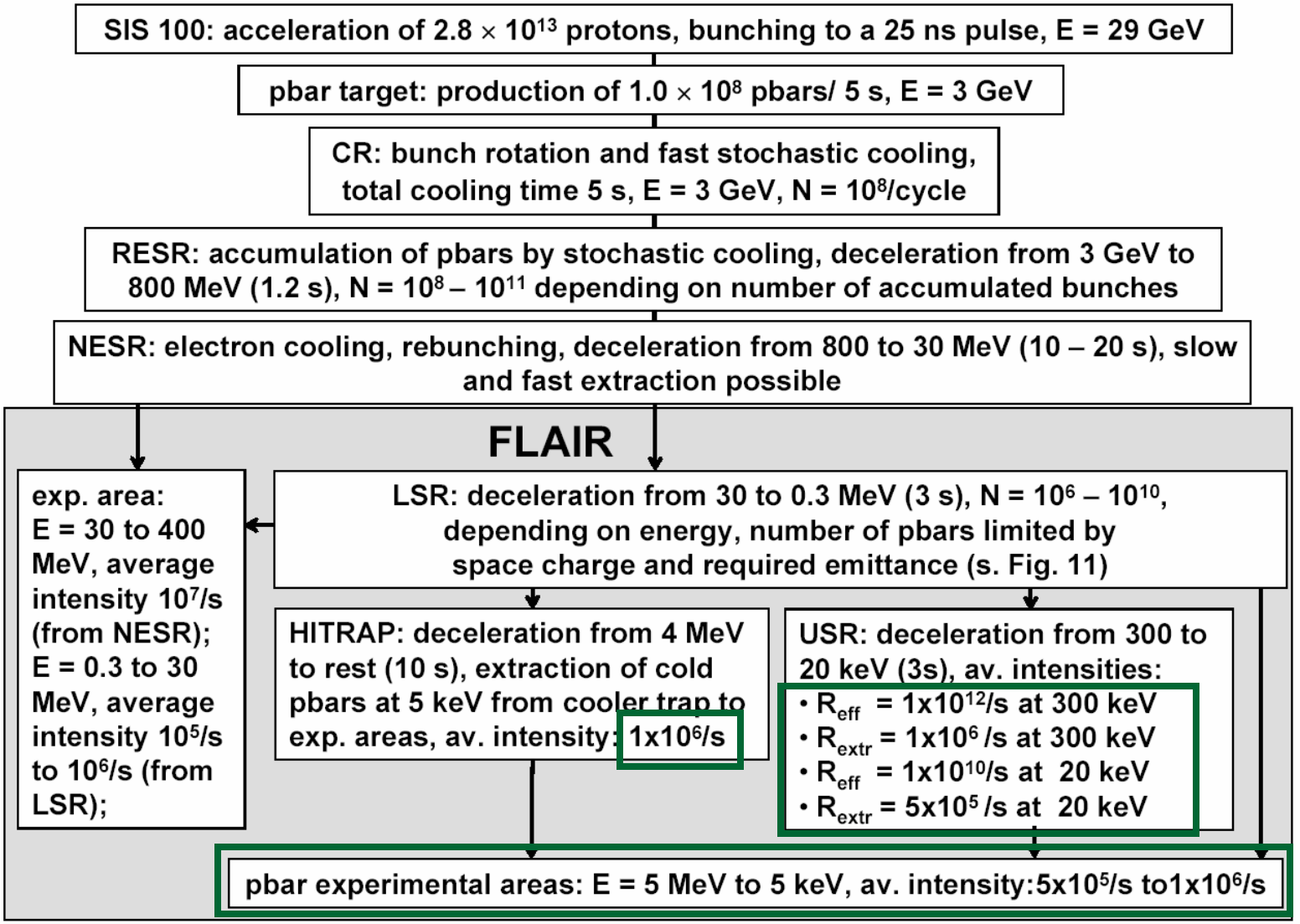
- *Reaction Microscope for fully differential collision measurements*





Similar (cryogenic!) ring under R&D at MPI-K Heidelberg for molecular physics

Rates @ FLAIR


SIS 100: acceleration of 2.8 × 10^13 protons, bunching to a 25 ns pulse, E = 29 GeV
pbar target: production of 1.0 × 10^8 pbars/ 5 s, E = 3 GeV
CR: bunch rotation and fast stochastic cooling, total cooling time 5 s, E = 3 GeV, N = 10^8/cycle
RESR: accumulation of pbars by stochastic cooling, deceleration from 3 GeV to 800 MeV (1.2 s), N = 10^8 – 10^11 depending on number of accumulated bunches
NESR: electron cooling, rebunching, deceleration from 800 to 30 MeV (10 – 20 s), slow and fast extraction possible
FLAIR
exp. area: E = 30 to 400 MeV, average intensity 10^7/s (from NESR); E = 0.3 to 30 MeV, average intensity 10^5/s to 10^6/s (from LSR);
LSR: deceleration from 30 to 0.3 MeV (3 s), N = 10^6 – 10^10, depending on energy, number of pbars limited by space charge and required emittance (s. Fig. 11)
HITRAP: deceleration from 4 MeV to rest (10 s), extraction of cold pbars at 5 keV from cooler trap to exp. areas, av. intensity: 1x10^6/s
USR: deceleration from 300 to 20 keV (3s), av. intensities:
• R_eff = 1x10^12/s at 300 keV
• R_extr = 1x10^6 /s at 300 keV
• R_eff = 1x10^10/s at 20 keV
• R_extr = 5x10^5 /s at 20 keV
pbar experimental areas: E = 5 MeV to 5 keV, av. intensity:5x10^5/s to1x10^6/s

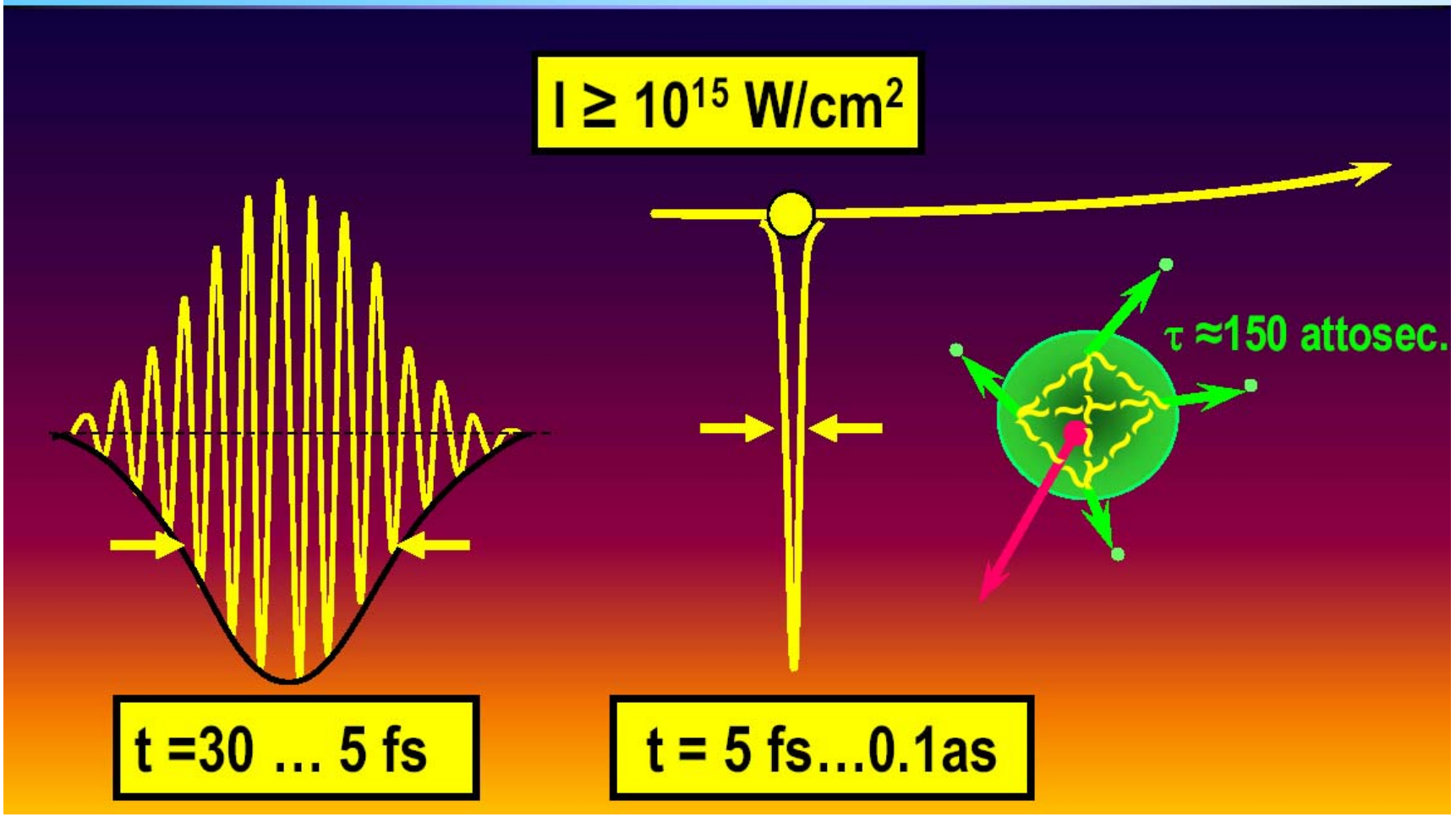
FLAIR Physics Topics with Antiprotons

- *Spectroscopy for tests of CPT and QED*
  - Antiprotonic atoms (pbar-He, pbar-p), antihydrogen
- *Atomic collisions*
  - Sub-femtosecond correlated dynamics: ionization, energy loss, antimatter-matter collisions
- *Antiprotons as hadronic probes*
  - X-rays of light antiprotonic atoms: low-energy QCD
  - X-rays of neutron-rich nuclei: nuclear structure (halo)
  - Antineutron interaction
  - Strangeness –2 production
- *Medical applications: tumor therapy*

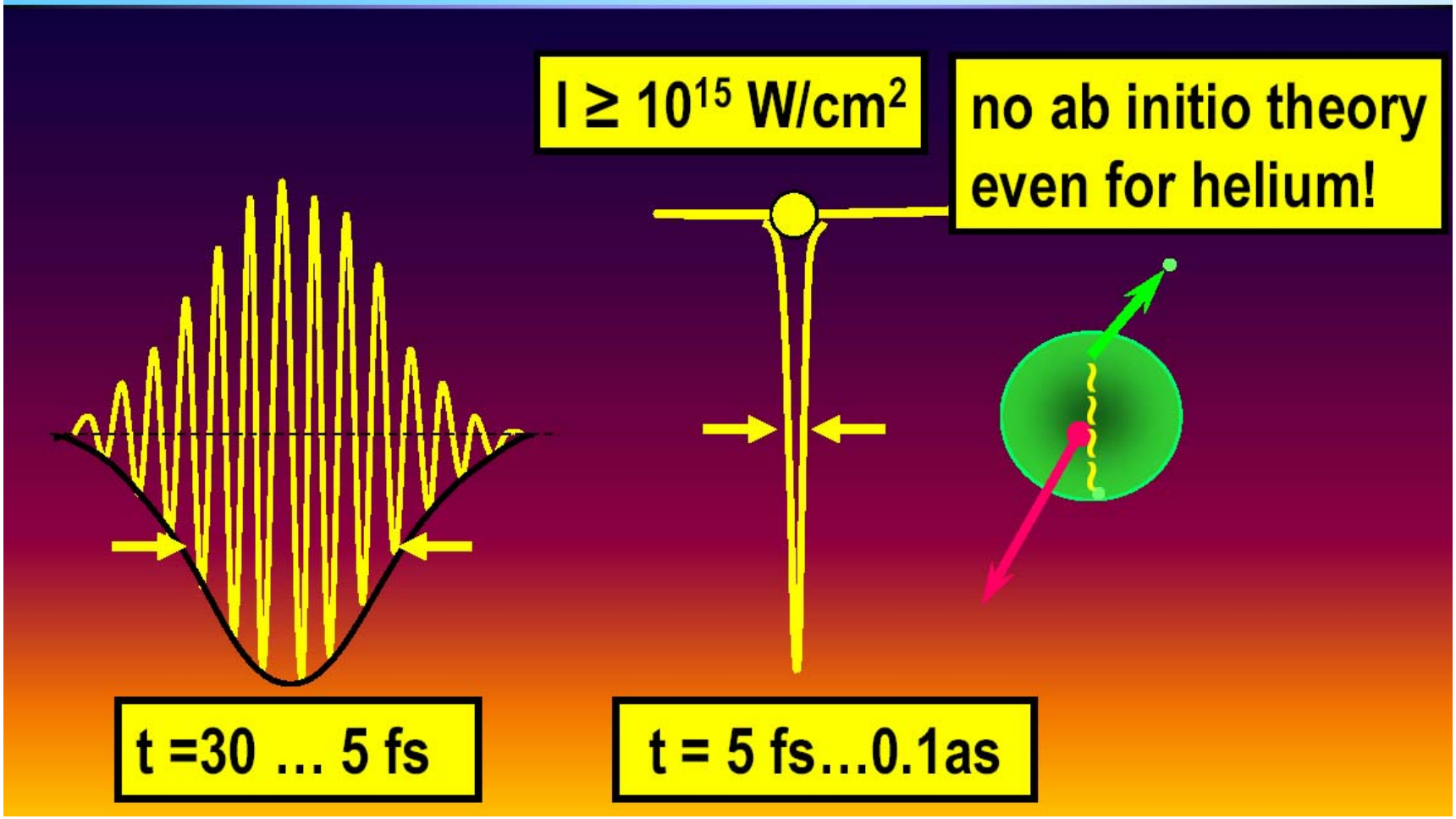
Features of FLAIR

- Low-energy, high-brilliance beams for effective stopping
- High effective collision rates with USR: fully kinematic measurements
- Continuous beams: only possible @ FLAIR
- availability of radio-active ions offers synergies
- High energies, high intensities, slow extraction

Sub-Femtosecond Correlated Dynamics Probed with Antiprotons

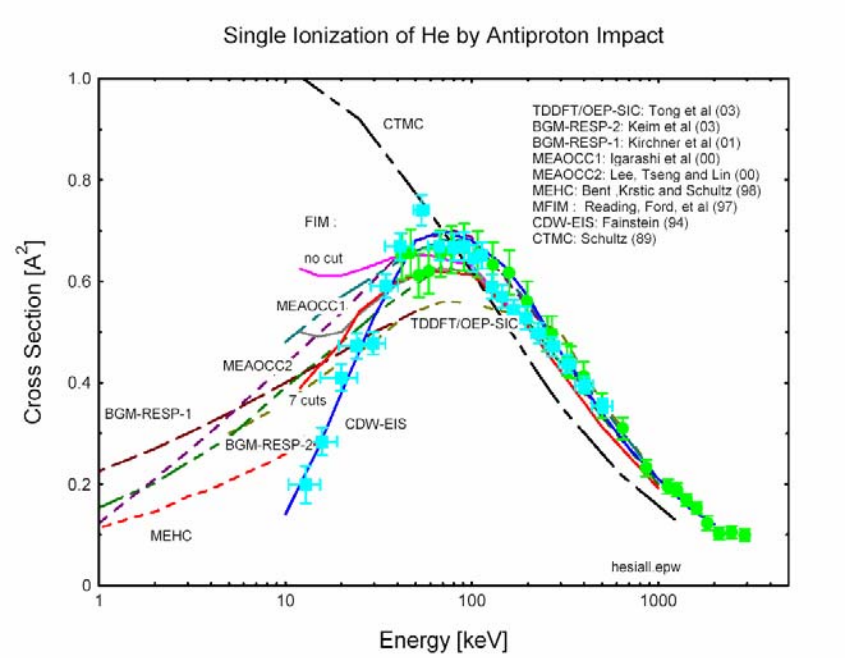


Sub-Femtosecond Correlated Dynamics Probed with Antiprotons

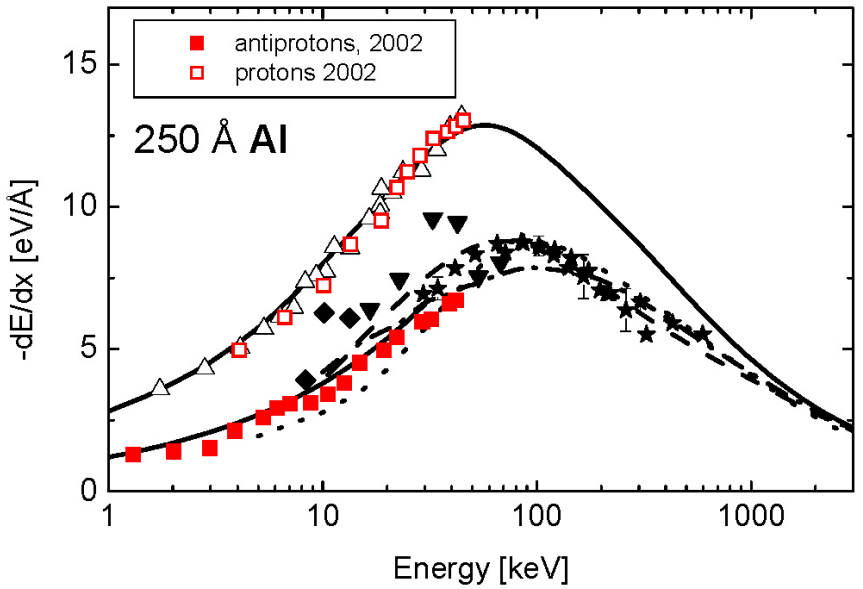


Atomic Collision Physics with USR

- *Ionization in single collision by slow antiprotons*



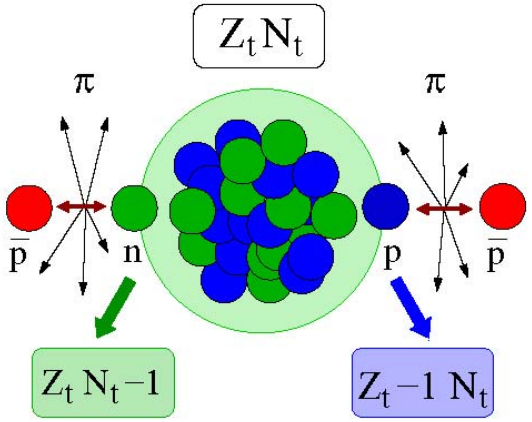
- *Energy loss*



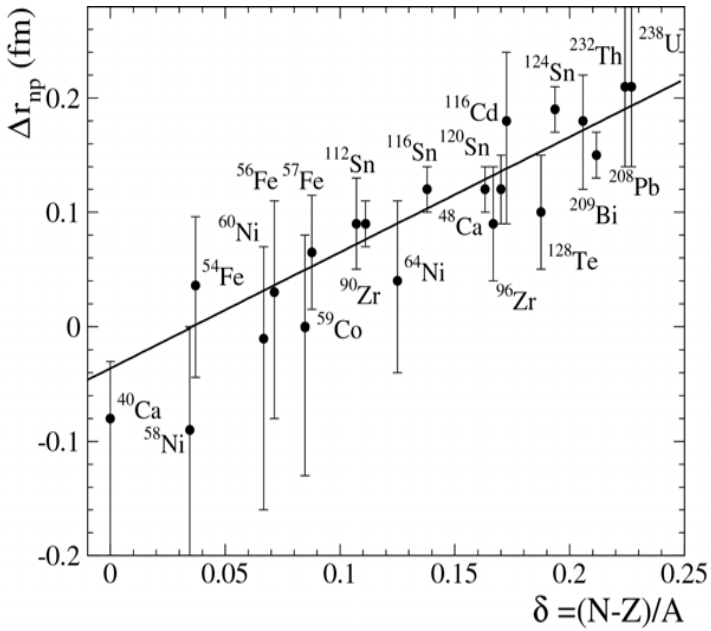
- *Benchmark system for theory*
  - Antiproton does not suffer from charge screening
- *Kinematically complete measurements possible with an internal target in a storage ring*

Nuclear Periphery with $\bar{p}$ Atoms (DC)

determination of the **halo factor** (f_{halo})



PS209 @ LEAR

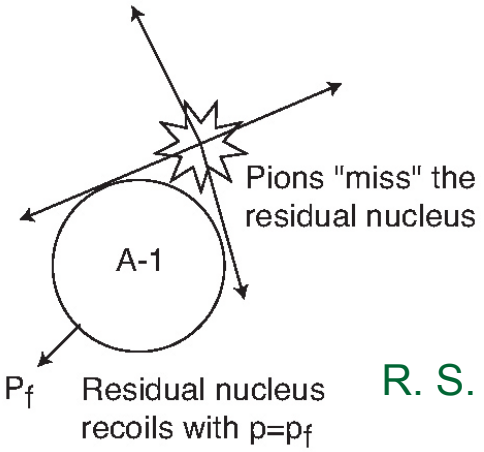


- *Exotic atom formation -> cascade ->*
  - Annihilation with outermost nucleons (<r>+ 2 fm)
- *Measurement of neutron halo parameters*
  - Radiochemical method, X-rays + model calculations
- *Neutron diffuseness increases with neutron excess*
- *Extension to unstable nuclei interesting*

A. Trzcinska, J. Jastrzebski et al. PRL 87 (082501) 2001

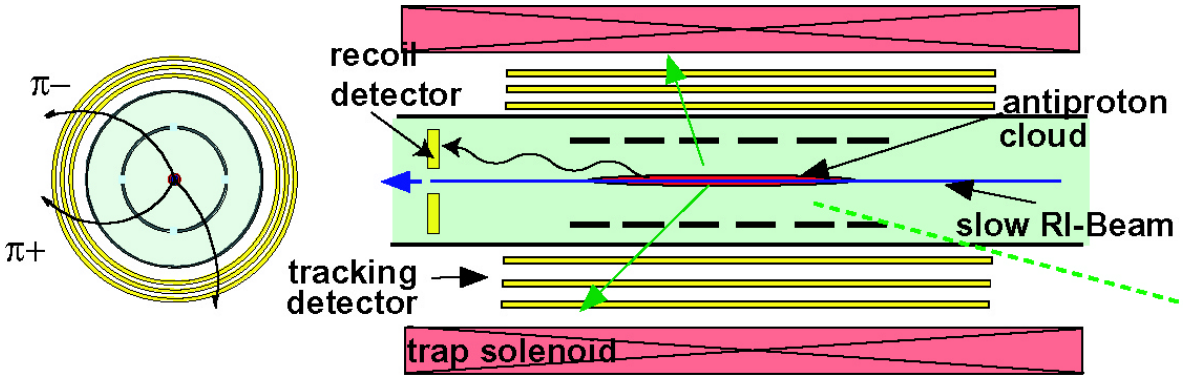
$\bar{p}$-RI in Traps for Nuclear Structure Study

- *$\bar{p}$ annihilates with outer-most nucleon*

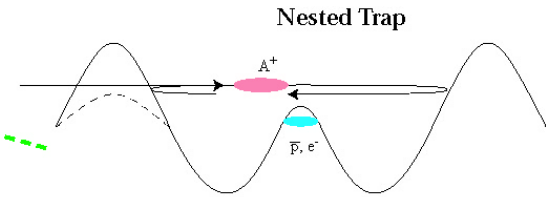


R. S. Hayano (Tokyo)

- *Momentum distribution of recoil nuclei*
  - Wave function of outer-most nucleon
- *Charged pion multiplicity*
  - Distinguish annihilation on p and n
  - Halo factors



M. Wada, Y. Yamazaki (Tokyo)
Nested Penning trap



FLAIR Community

- *Austria (Vienna IMEP, TU)*
- *Canada (York)*
- *Denmark (Aarhus U, ISA)*
- *France (P. & M. Curie, Paris)*
- *Germany (GSI, Dresden, Frankfurt, Freiburg, München, Giessen, Heidelberg, Jülich, Mainz, Tübingen)*
- *Hungary (Budapest, Debrezen U, ATOMKI)*
- *Italy (Bologna, Firenze, Genova, Torino)*
- *Japan (Tokyo, Saitama (RIKEN))*
- *Netherlands (Amsterdam U, FOM)*
- *Poland (Warsaw U, Soltan Inst.)*
- *Russia (Moscow, St. Petersburg)*
- *Sweden (Stockholm U, Manne Siegbahn Laboratory)*
- *United Kingdom (Swansea)*
- *USA (Albuquerque, Harvard, pbar Medical, Texas A&M)*

47 institutions, 14 countries

Summary and status of FLAIR

- *Cooled antiprotons at 20 keV will revolutionize low-energy antiproton physics*
- *DC beams enable nuclear and particle physics type experiments (not possible at AD)*
- *Availability of radioactive ion beams (RIB) offers new synergies*
- *Status of FLAIR*
  - LoI was approved in March 2004
  - Technical proposal due January 15, 2005
  - "final approval" follows (hopefully), 1st beam 2012 (?)
  - Funding still needs to be secured (total 15-20 MEuro)
- *Continuation of AD program in the mean time is essential!*