The Anticyclotron Project

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Outline

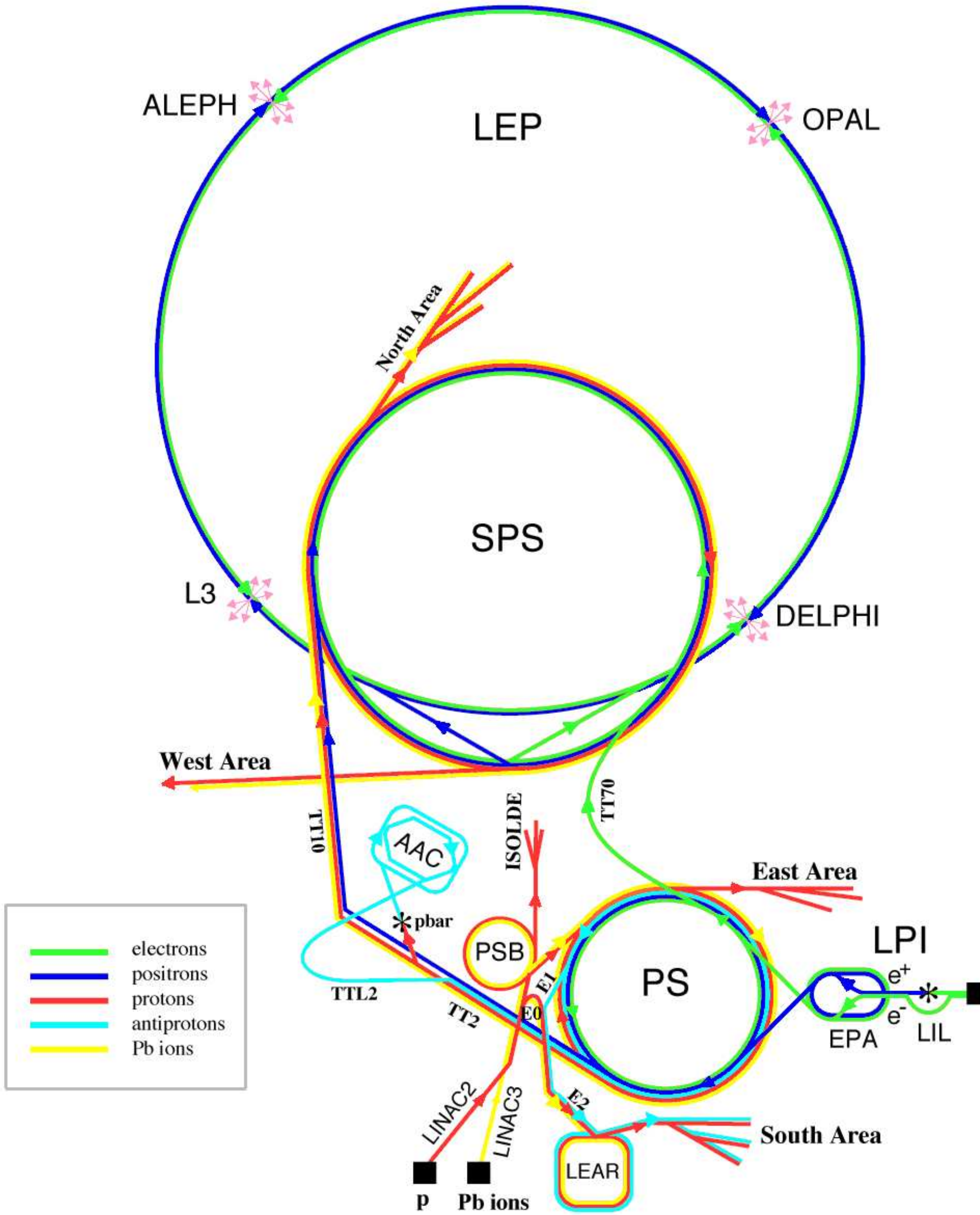
- Historical Introduction
- Cyclotron Trap I
- Anticyclotron Test at LEAR
- Anticyclotron Tests at PSI
- Cyclotron Trap II
- Extracted Muons at PSI

Who should have given this talk?

Leo Simons (PSI), Franz Kottmann (ETH),
John Eades (CERN)

Historical Introduction: LEAR

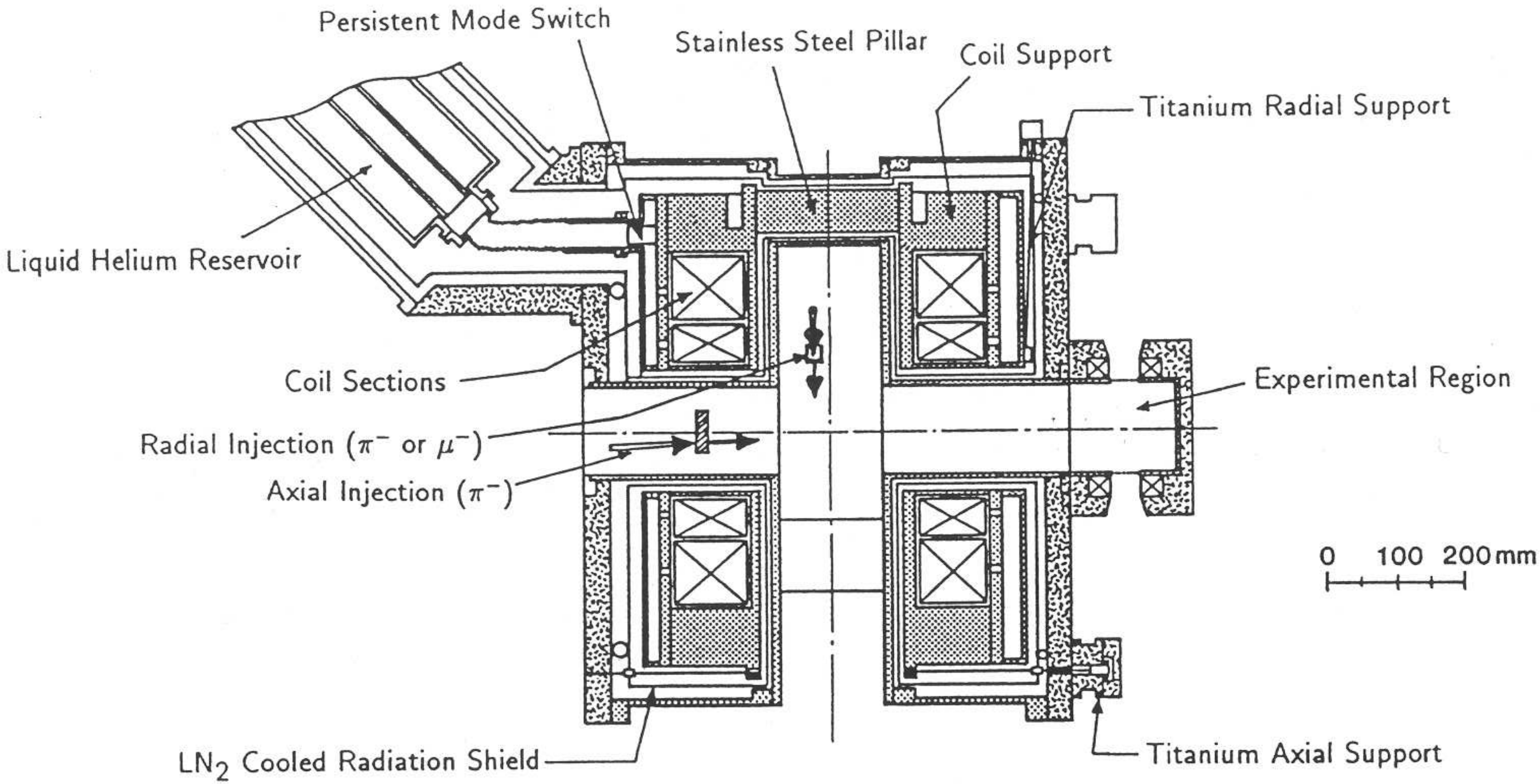
- ULEAP Workshops at CERN (John Eades): 1989-90
- Proposals for ultra low energy $\bar{p}$ beam:
  - 1981: PS189 proposal with ELENA
  - 1985: PS189 with RFQD
  - 1989-91: Anticyclotron (AC) tests (gravity measurement)
- Both RFQD and AC gave up by 1991 (no LEAR beam below 100 MeV/c)



Historical Introduction: present

- Proposals for ultra low energy $\bar{p}$ beam at AD
  - ASACUSA's RFQD: it works!
  - ELENA proposed (again?)
- The AC at PSI
  - 1991-94: AC tested for muons
  - 2000: Slow muon beam with new CT-AC
- Maybe AC revives for $\bar{p}$?

Cyclotron Trap

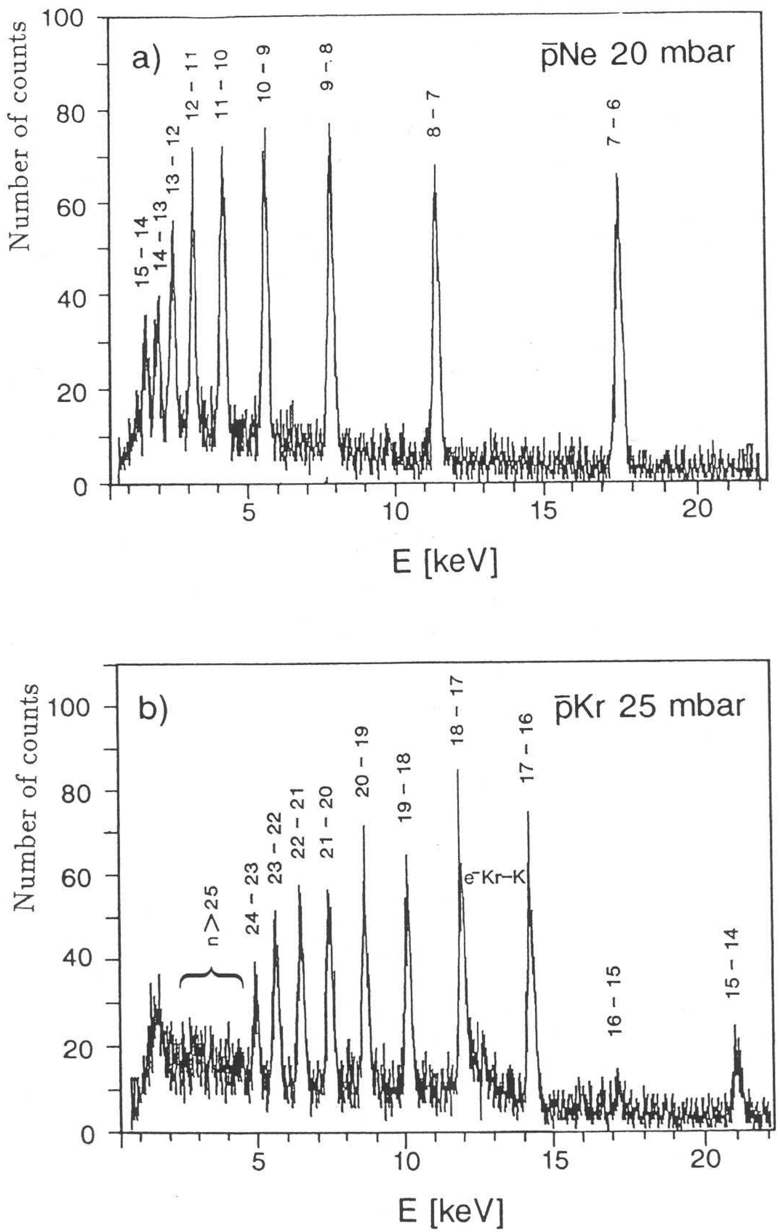


Low pressure (mbar) gas target in SC inverse cyclotron

Inject charged particles at max radius through foil

Cyclotron motion, slowing down in gas

Field shape: stop in middle, detector in bore hole



PS-175 at LEAR

Missing X-ray transitions

⇕

Auger transitions of remaining electrons

Naked exotic atoms

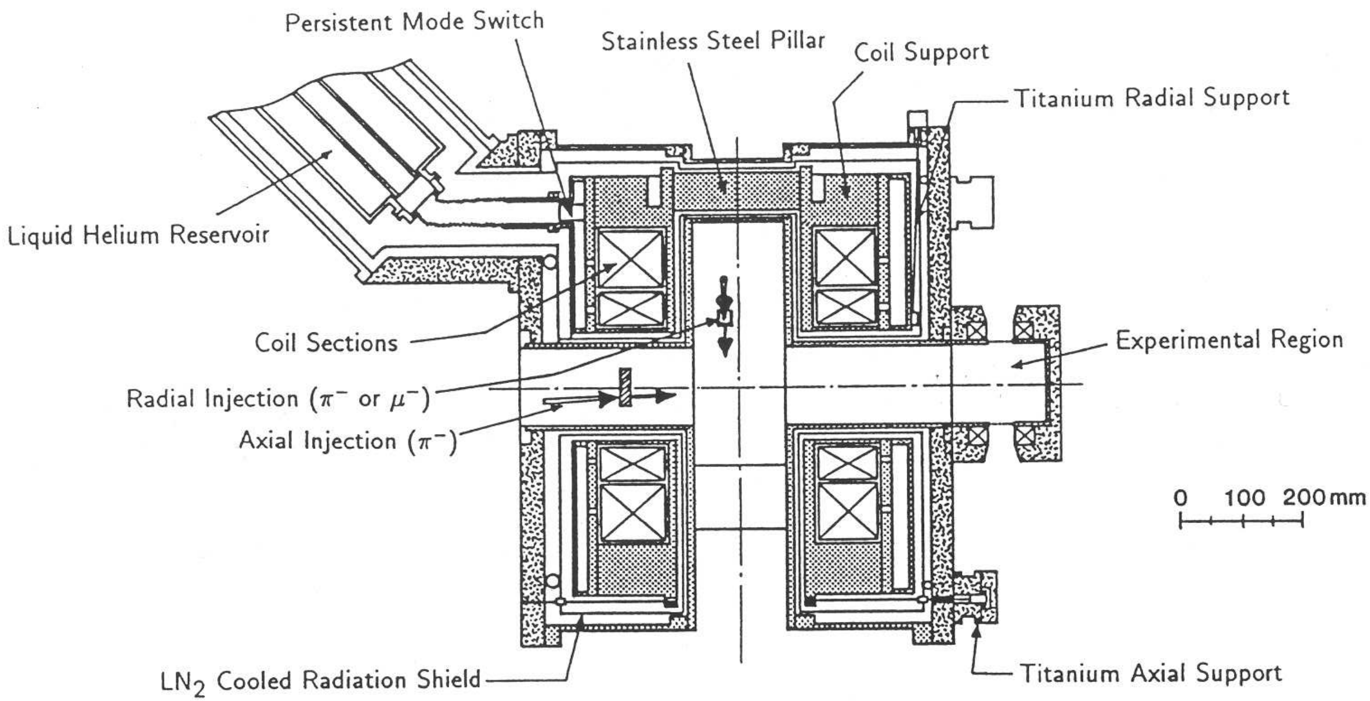
L. M. Simons:

Physica Scripta **T22** (1988) 90.

K. Heitlinger et al.:

Z. Phys. A **342** (1992) 359.

Anticyclotron at LEAR



Inject 61 MeV$/c$ $\bar{\mathrm{p}}$ at high radius off median plane

Cyclotron & betatron motion, slowing down in gas

Slow $\bar{\mathrm{p}}$ at axis, electrostatic extractor in bore hole

extraction into Penning trap

L. M. Simons, Physica Scripta **T22**, 90 (1988).

J. Eades, L. M. Simons: Nucl. Instr. Meth. **A278** (1989) 368.

Anticyclotron test at LEAR

Anticyclotron test at LEAR: P118T, 1990-91

Pisa, Genova, PSI, CERN, Budapest

We could not extract the antiprotons

Mapped $\overline{\mathrm{p}}$ trajectories with radially moving scintillator

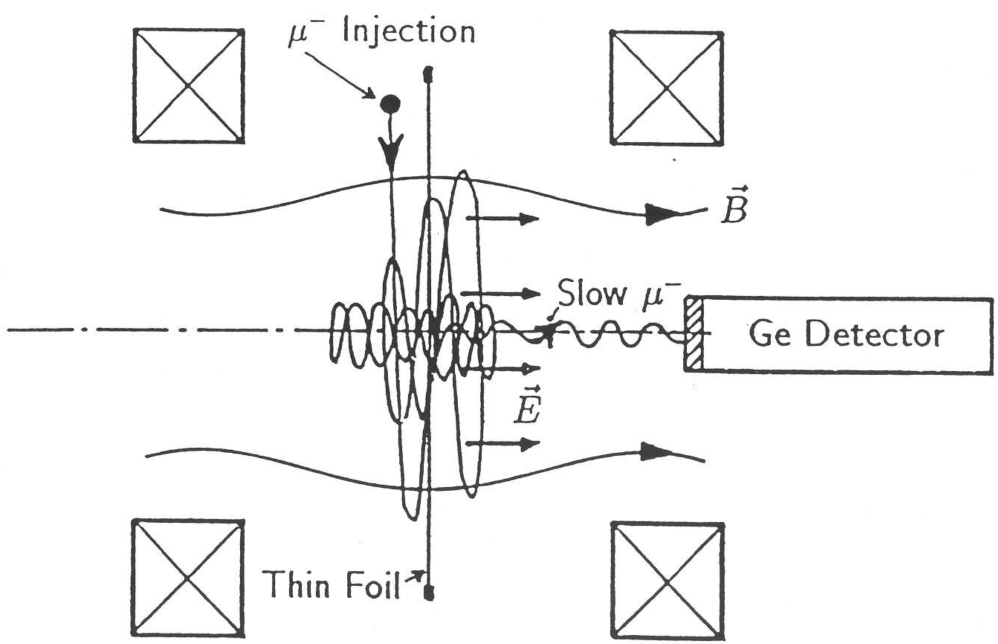
Simulations (GEANT3): large emittance at injection

Later: stochastic cooling was not set up
for $p(\overline{\mathrm{p}}) \sim 60 - 70$ MeV$/c$

Success with muon extraction at PSI
with much worse injected beam

D. Horváth et al., Nucl. Instr. Meth. B **85** (1994) 736–740.

Muon Anticyclotron at PSI



Muons:
continuous beam
with large beam spot
and emittance

Slowing down in
$\Downarrow$
thin Formvar foil
(in median plane)

Extraction possible with
no vacuum separation

P. DeCecco et al., Nucl. Instr. Meth. A **394** (1997) 287.

Anticyclotron I for μ^- and $\overline{\mathrm{p}}$

Property	μ^- at PSI (measured)	$\overline{\mathrm{p}}$ at LEAR (expected)
Beam momentum	30 MeV/c	61 MeV/c
— energy	4 MeV	2 MeV
— emittance	300 mm mrad	30 mm mrad
— $\frac{\Delta p}{p}$	1%	0.1%
— focus on window	22×9 mm^2	1×1 mm^2
— contamination	10^3 e$^-$/μ^-(πE1)	none
— intensity (cont.)	3×10^6 μ^-/s	3×10^6 $\overline{\mathrm{p}}$/s
— — (bunched)	none	3×10^8 $\overline{\mathrm{p}}$/100 ns

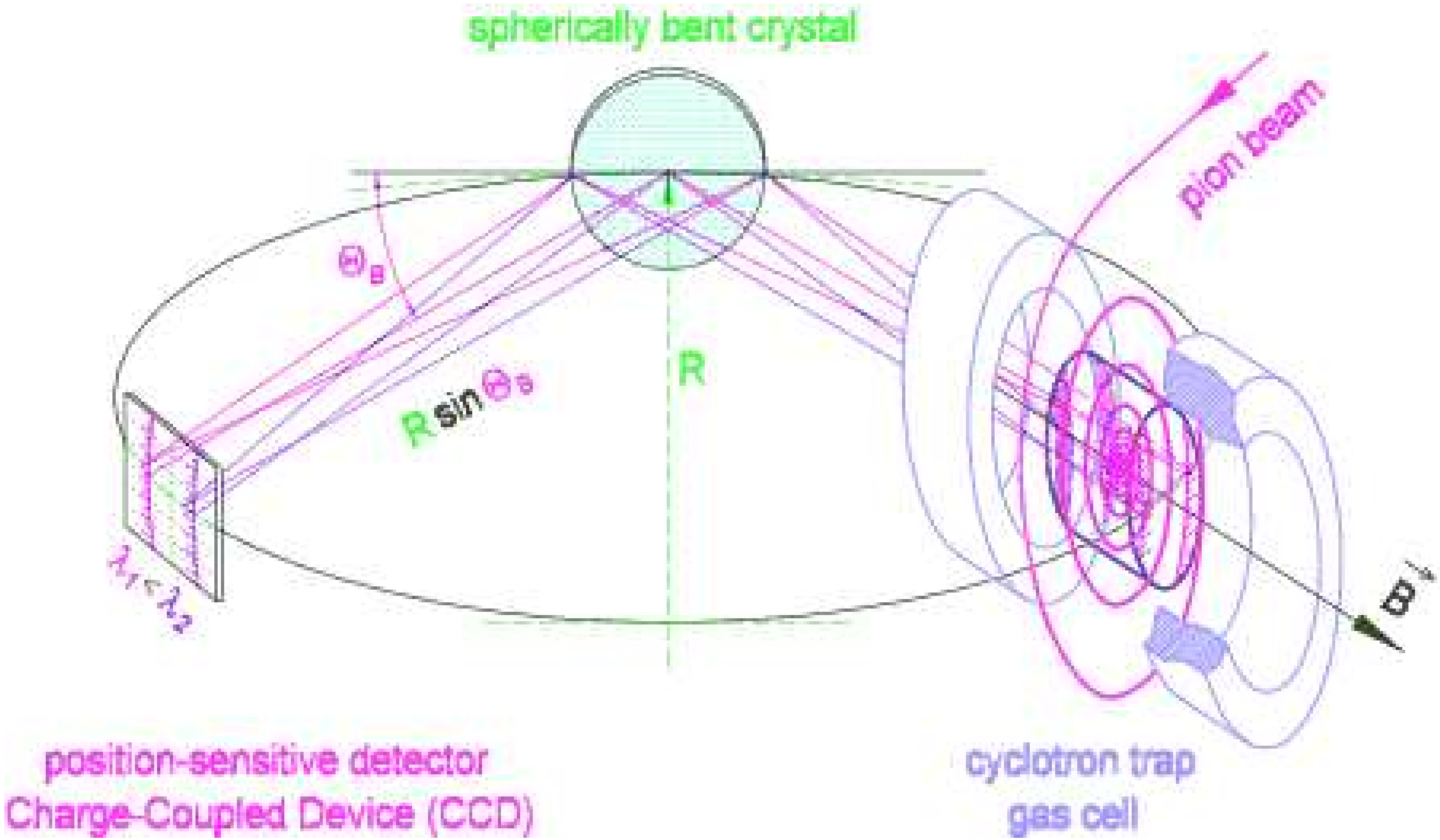
Anticyclotron I for μ^- and $\bar{p}$

Property	μ^- at PSI (measured)	$\bar{p}$ at LEAR (expected)
Moderator medium	4 μm Mylar foil	0.3 mbar H_2
Injection eff.	15%	100%
Stopping eff.	17% (→20%)	20 – 30%
Extraction eff.	2% (→5%)	75%
MeV→keV conv. eff.	0.05 % (→0.15%)	15 – 22%
Extracted energies	5 - 25 keV	7 - 10 keV
Extracted intensity	2×10^4 μ^-/s (πE5)	6×10^6 $\bar{p}$/shot

D. Horváth et al., Nucl. Instr. Meth. B **85** (1994) 736–740.

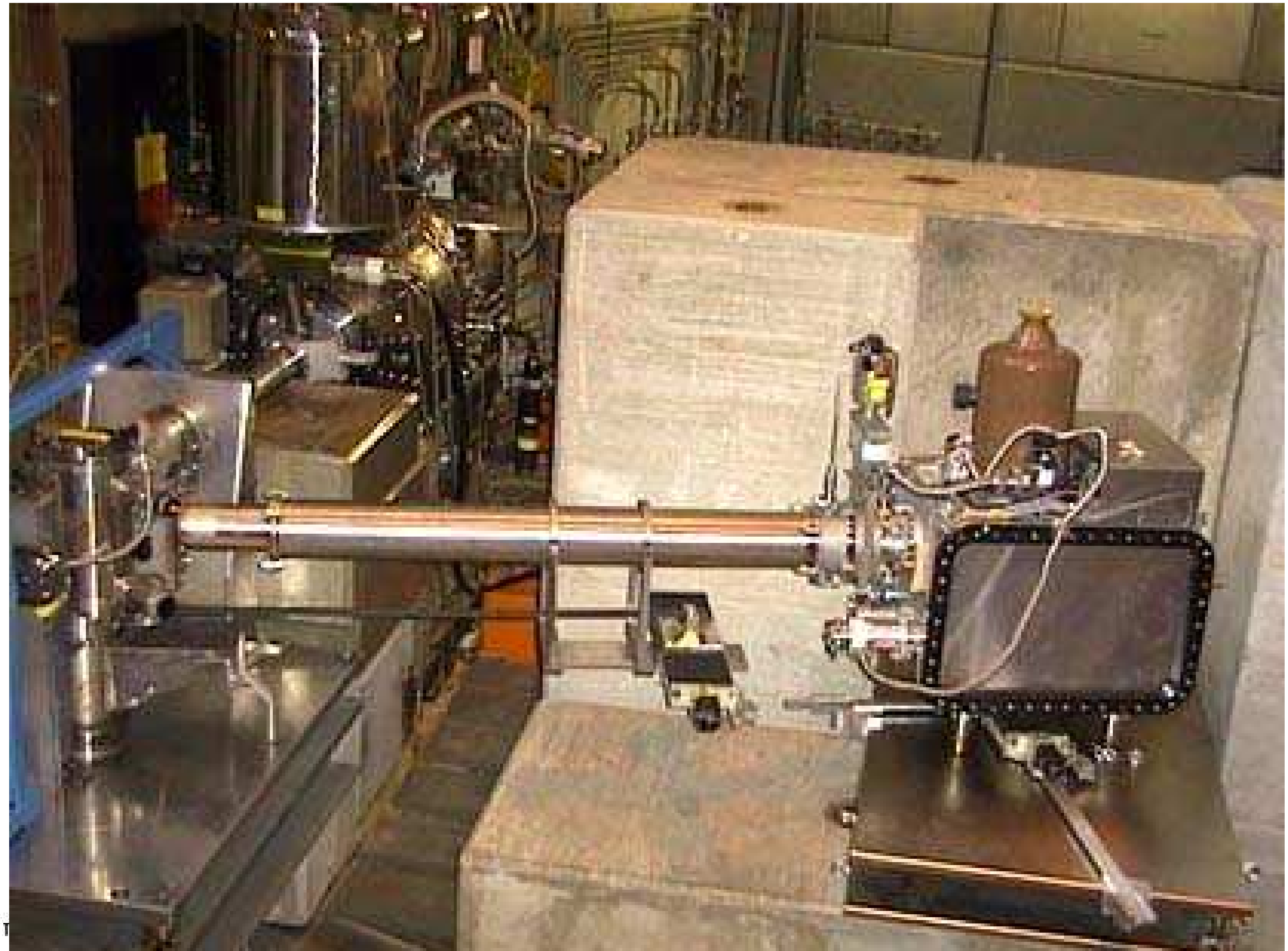
PAUL SCHERRER INSTITUT PSI

Pionic Hydrogen Expt at PSI



D. Gotta: Prog. Part. Nucl. Phys. 52 (2004) 133.

Pionic Hydrogen Expt at PSI



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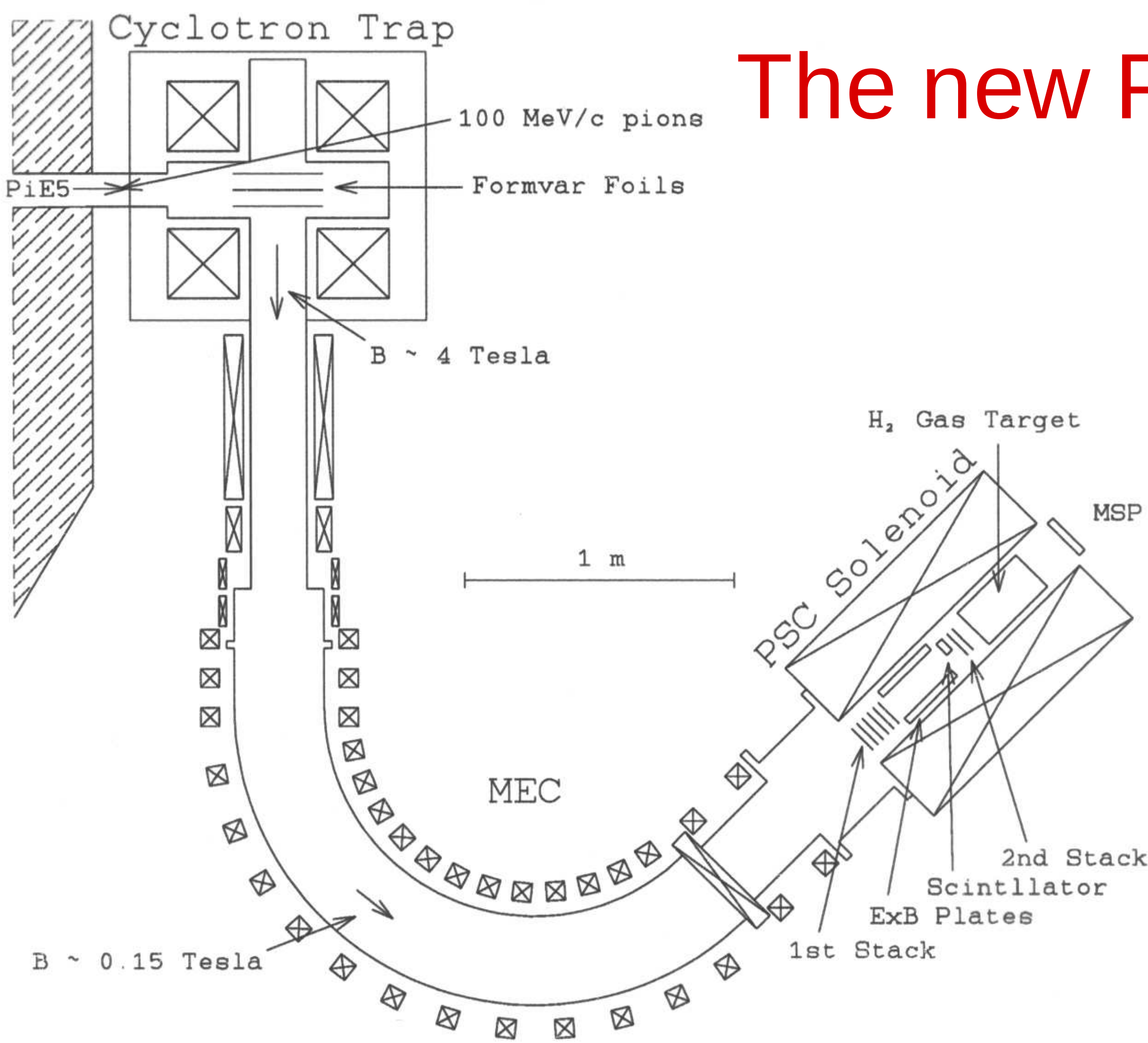
Slow Muon Beam at PSI



The new PSI anticyclotron

Axial π^- injection

$p(\pi^-) = 100$ MeV$/c$

2×10^8/s, $B = 4$ T

$\pi^- \to \mu^-$ in flight

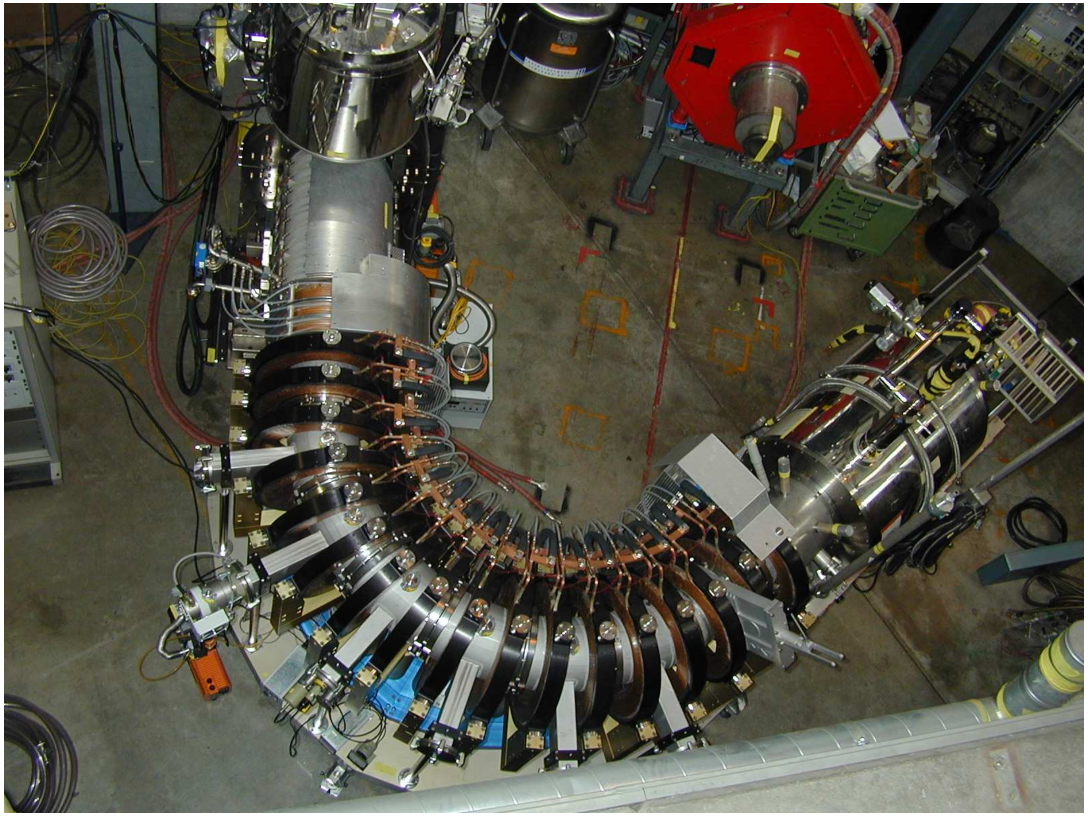
μ^- MeV $\Rightarrow$ keV in foils

Extraction in E_{axial}

$B_{\text{transport}} = 0.15$ T cleans beam of e$^-$

F. Kottmann et al.: Hyperfine Interactions **138** (2001) 55.

Slow Muon Beam at PSI



Arrival:

$E(\mu^-) = 10 - 50$ keV

$\varnothing$ 3 cm

$\sim 10^4$/s μ^- in Be foil

H_2 target

in $B = 5$ T solenoid

100 μ^- stops/s in

$p(H_2) = 2$ mbar H_2

(limited by laser expt)

F. Kottmann et al.: Hyperfine Interactions **138** (2001) 55.

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Conclusion

- The anticyclotron project failed at LEAR
- ... probably due to poor beam cooling
- It works at PSI with muons
- ... of much worse beam characteristics
- It could be as efficient as an RFQD
- ... but much smaller, cheaper and easier to operate