TITAN: Building the Penning Trap

TRIUMF ISAC

Vladimir Ryjkov

for the TITAN collaboration

Penning trap mass measurments with high precision ($\delta m/m < 1 \cdot 10^{-8}$), or short half-life ($t_{1/2} \sim 10$ *ms*), or very low yields (*~10-100 ions/s*)

Motivation:

CKM matrix, nuclear astrophysics, nuclear structure far from stability

Outline:

TITAN set-up and individual components

Status & some new ideas

Conclusions

TITAN set-up @ ISAC

ISAC ion beam → **RFQ cooler & buncher** → **EBIT charge breeder** → **m/q selection** → **Penning trap**

RFQ cooler & buncher:

Cool 60 keV ISAC beam with buffer gas.

Covert DC into AC beam, adjust beam energy.

Better transfer efficiency and bunching needed for stacking.

EBIT charge breeder:

Rapid charge breeding.

Operated in pulsed mode.

m/q selection:

Purify beam from isobar contaminants.

Select charge state.

Penning trap:

on mass
nts

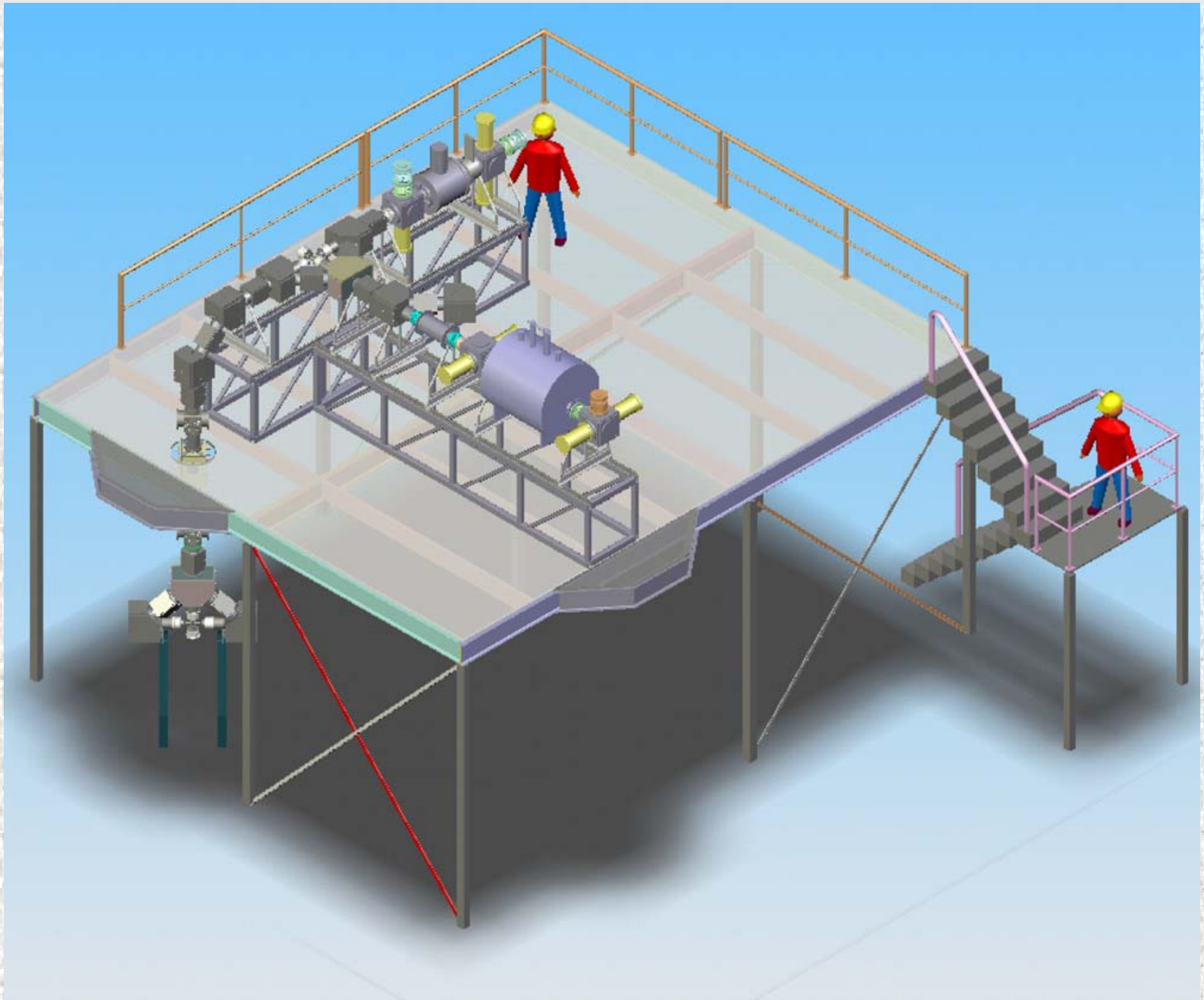
y studies

asurements

Penning trap for cooling of HCI
CFI (250k CAD)
G.Gwinner (UofM)

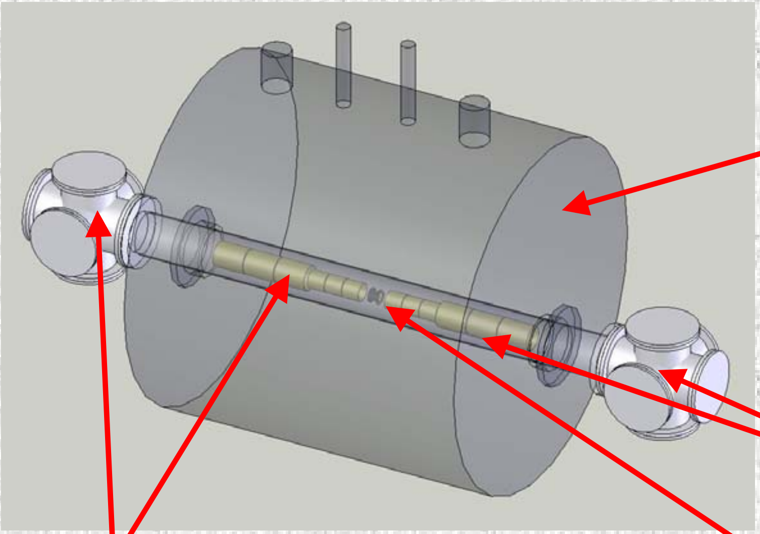
$$\nu_c = \frac{1}{2\pi} \cdot \frac{q}{m} \cdot B \qquad \frac{\delta m}{m} \approx \frac{m}{T_{RF} \cdot q \cdot B \cdot \sqrt{N}}$$

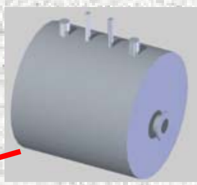
Move to ISAC



Platform (tendering process started) will be prefab. and put into the ISAC hall during shut-down Jan-Mar 2005. TITAN components will move in ~ May 2005.

Penning Trap Components





High homogeneity warm-bore magnet

In final negotiations with magnet manufacturers. Specs:
- Field strength 4T
- Bore size 5 inches
- Homogeneity 1 ppm (2cm * 1 cm)

Ion detection

Ion optics for injection into the Penning trap

- Simulation code for optimizing ion injection/detection will be used to determine the location of the focusing elements based on the parameters of the purchased magnet.

Penning trap

Currently calculating the trap construction that minimizes the field inhomogeneity due to its magnetization.

Requirements for the trap magnet

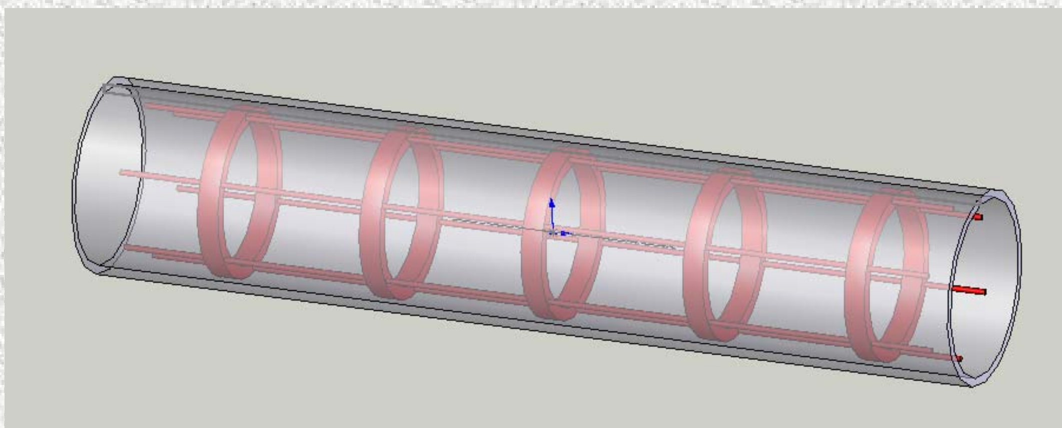
1. Measurement accuracy of 10^{-8}
   - drift <100ppb/hr
   - high magnetic field homogeneity
   - active shielding from external interference
2. Possibility of baking the vacuum system in bore and future cryogenic setup
   - Magnet bore diameter >5in (127mm)
3. Reduce the influence on the polarized beamline
   - Active stray field shielding
4. Low loss cryostat (refills disturb the measurement, and are costly)

Placing the ion trap inside the bore

1. Assemble the trap structure (the "ribs") in vertical orientation

2. Insert the structure into the vacuum chamber tube vertically

3. Place the ion chamber + trap structure inside the horizontal magnet bore and align to magnetic field



Penning trap design

1. The magnetic field inhomogeneity at the trap center due to the magnetization of the trap has to be removed.

2. Use as little insulator material as possible
   - Only have to reduce the magnetization influence due to metal electrodes
   - Increase pumping speed

3. Ring and cap electrodes are to be monolythic (one piece). The quadrupolar excitation is to be created by the guard electrodes (each split into 4 pieces).

Cooling the HCI for the measurement

The ions from EBIT could have significant energy spread (~100eV/q) and emittance. In order to have precision measurement we need to “shrink” the ions phase space – cool it. And it needs to be fast (<0.1s time scale).

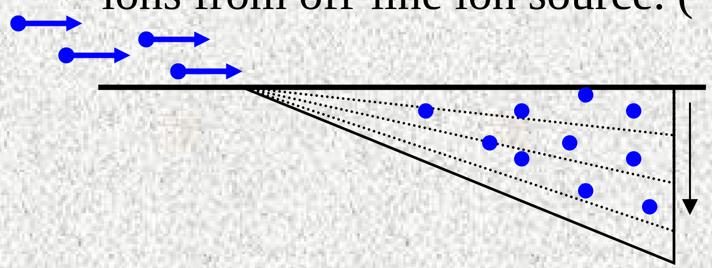
- Resistive cooling
  - Is fast enough (0.1s scale) only at cryogenic circuit temperatures
  - Needs to be tuned for specific ion’s mass-to-charge ratio
- Electron cooling (HITRAP)
  - Works very well for bringing the HCI ions to intermediate energies (~100eV/q) but at lower energies the ion recombination rate increases
- **Sympathetic cooling!** (cooling ions with ions)

New cooling method for HCI

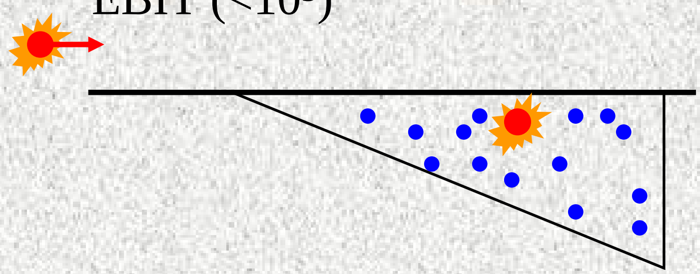
The energy spread and emittance of the ions extracted from EBIT can be large (approx 50eV/q). Need to be cooled before measurement in the Penning trap.

PROPOSAL: cool the HCI with protons or SCI in a special Penning trap

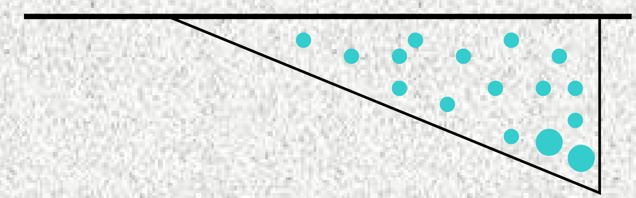
1. Load the cooling trap with “cold” ions from off-line ion source. (~10^7)



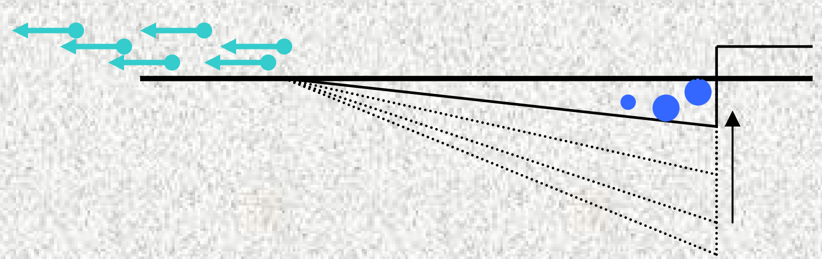
2. Inject the “hot” ions from the EBIT (<10^3)



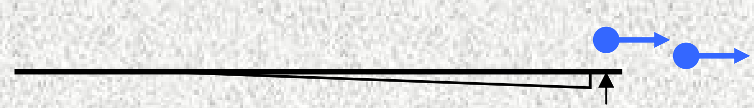
3. Thermalization



4. Light ion separation/evap. cooling

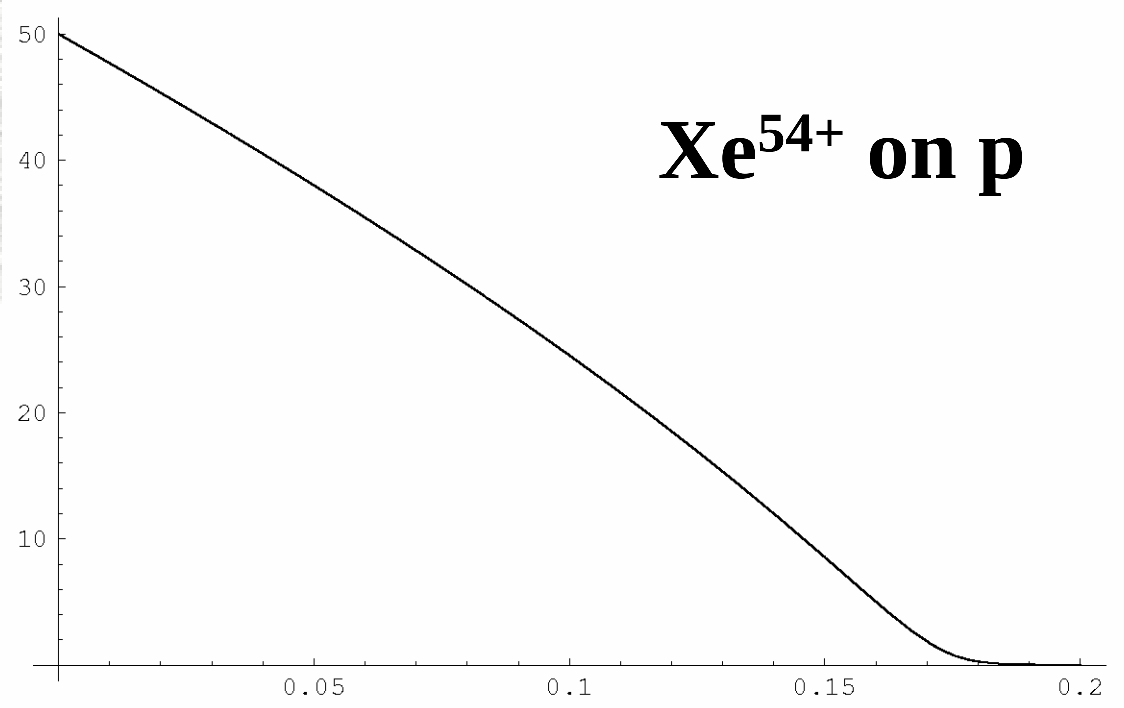


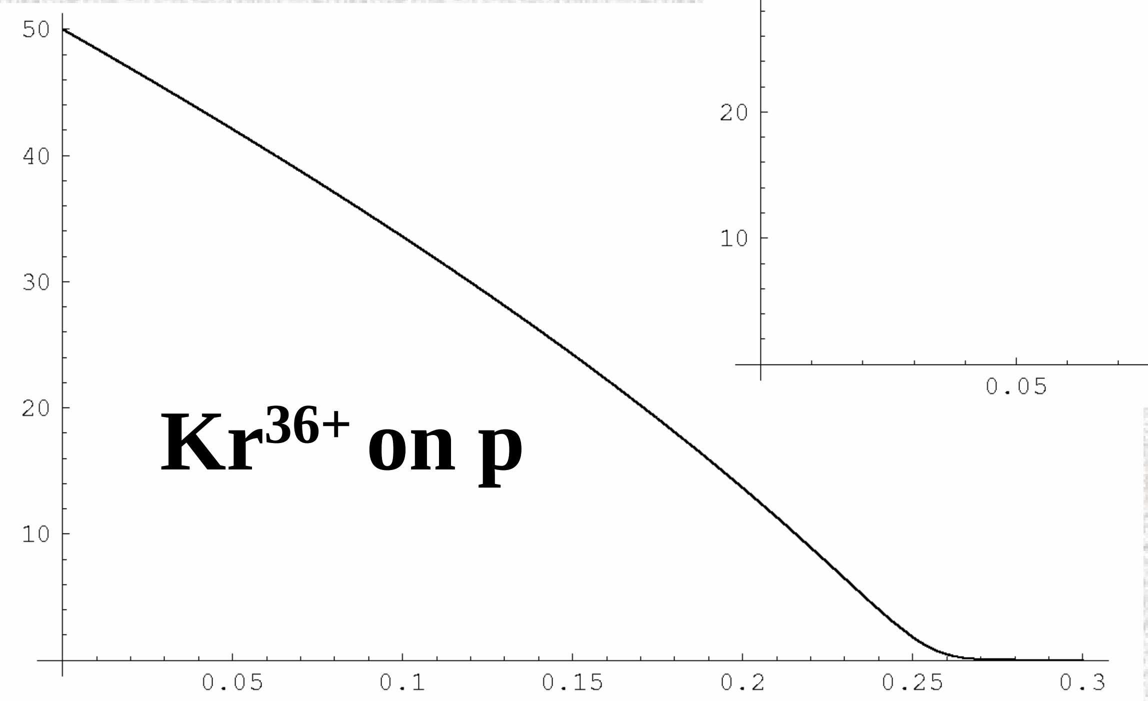
5. Send HCI into the measurement trap



Calculations show that for Kr^{36+} the thermalization time is around 100ms (factor 20 faster than electron cooling and no recombination losses!)

Calculation examples (Spitzer formula)





Looks feasible, and is worth trying out.

Penning trap plan

1. Order the magnet.
2. Conduct systematic injection simulations with the B-field of the purchased magnet to determine the parameters of injection optics.
3. Do simulations for the HCI cooling scheme: cool ion injection from the ion source, thermalization, separation and ejection.
4. With the help of the design office produce final mechanical design for the trap. Send it to workshop for manufacture.

Collaboration

Local:

TRIUMF Jens Dilling, Pierre Bricault, Joseph Vaz(post-doc), Günther Sikler(post-doc), Vladimir Ryjkov (post-doc)

UBC M. Smith, M. Brodeur (grad. student)

The Canadian Universities:

McGill Bob Moore, John Crawford, Fritz Buchinger, Jonathan Lee, L. Blomeley

U.of Manitoba Kumar Sharma, Gerald Gwinner M. Froese, Z.Ke U.of Calgary Rob Thompson
U.of Windsor Gordon Drake York U William Van Wijngaarden, G. Noble (grad. student)

Worldwide:

GSI Darmstadt Jürgen Kluge MPI-K Heidelberg Jose Crespo, Joachim Ullrich, C. Osborne (grad. student) U Mainz Günther Werth

U of Surrey Phil Walker MSU Georg Bollen Texas A&M Hans Schüssler

CERN/Mainz Klaus Blaum

TRIUMF support: Controls group, Kicker group, Design office, Workshop, Vacuum, etc…