Institute for Structure and Nuclear Astrophysics
Nuclear Science Laboratory

Construction of St. Benedict

M. Brodeur[1], T. Ahn[1], D.W. Bardayan[1], D.P. Burdette[2], J.A. Clark[2], A.T. Gallant[4], J.J. Kolata[1], B. Liu[1], P.D. O'Malley[1], W.S. Porter[1], R. Ringle[5], F. Rivero[1], G. Savard[2], A.A. Valverde[2,3], and R. Zite[1]

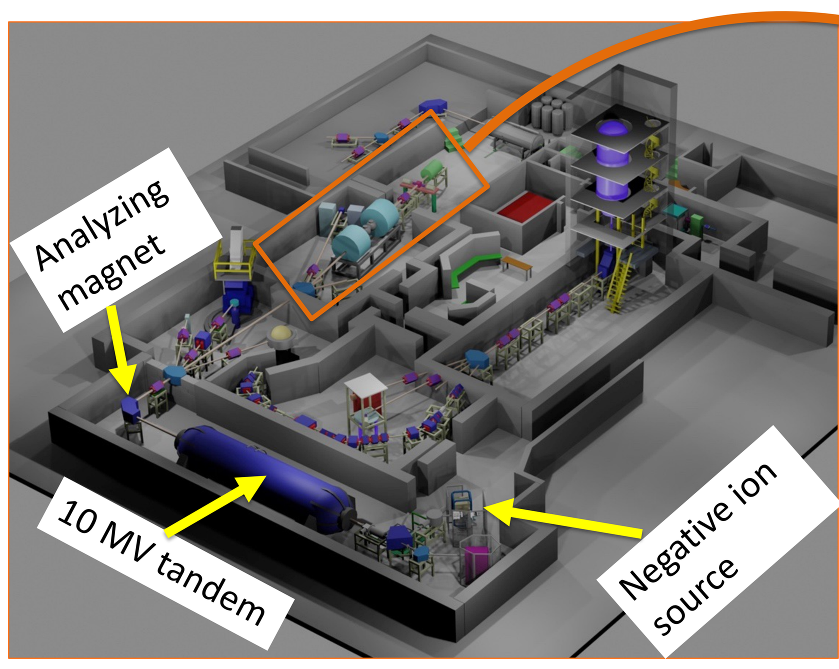
[1]University of Notre Dame, [2]Argonne National Laboratory, [3]University of Manitoba, [4]Lawrence Livermore National Laboratory, [5]Facility for Rare Isotope Beams

Motivation

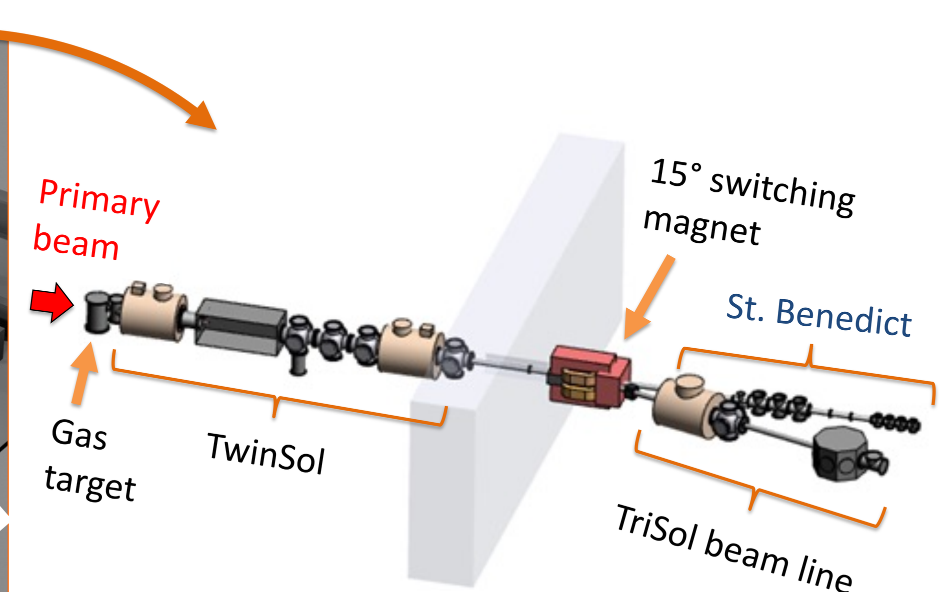
Nuclear beta decays provide a unique avenue for testing the electroweak part of the Standard Model through precision measurements. Physics beyond the Standard Model would manifest itself in these transitions through a variety of possible effects including a non-unitarity of the Cabibbo-Kobayashi-Maskawa quark mixing matrix, scalar or tensor currents, and interactions involving right-handed neutrinos. Probing these various effects in superallowed mixed beta decay transitions can be done through precision measurement of the beta-neutrino angular correlation parameter $a_{\beta\nu}$. As such, we are currently constructing at the Nuclear Science Laboratory (NSL) of the University of Notre Dame, the Superallowed Transition Beta-Neutrino Decay Ion Coincidence Trap (St. Benedict).

RIB production at the Nuclear Science Laboratory

The NSL has been producing radioactive ion beams (RIB) since the 1980's. The radioactive nuclei provided to St. Benedict will be produced in-flight using heavy ions on light ions in a gas target and separated using *TwinSol*. St. Benedict will be located at 15° from the new *TriSol* beam line.



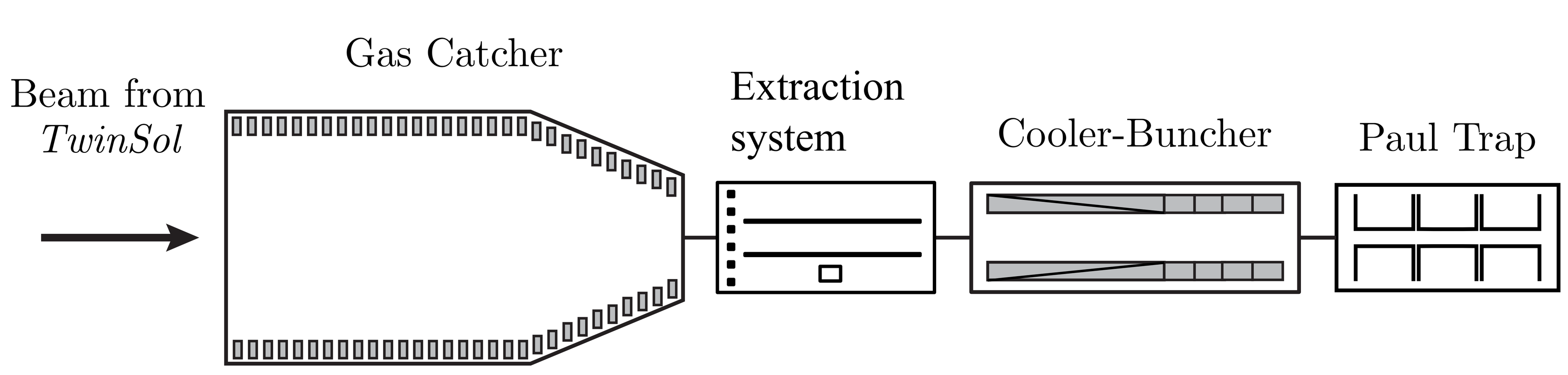
Nuclear Science Laboratory at Notre Dame



St. Benedict at TwinSol

St. Benedict

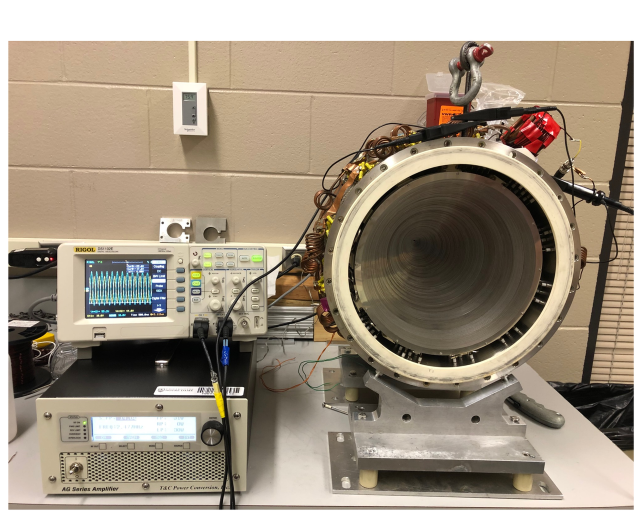
St. Benedict will take a radioactive ion beam produced by *TwinSol*, thermalize it in a large volume gas cell, then transport it through two separate, differentially-pumped, volumes using a radio-frequency carpet and a radio-frequency quadrupole (RFQ) ion guide before injecting it into an RFQ trap to create cool ion bunches for injection into the measurement Paul trap.



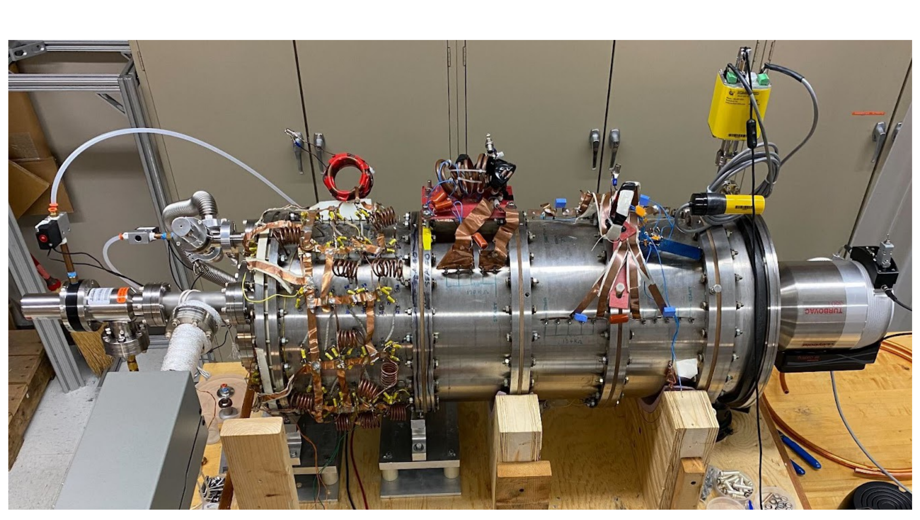
Major components of St. Benedict: gas catcher, extraction system, cooler-buncher and Paul trap.

Gas catcher

The St. Benedict gas catcher will stop the 10-40 MeV beam from TwinSol. The beam will first lose most of its energy by passing through a thin degrader and aluminum window. It then thermalize the ions via collision with helium at ~100 mbar. A combination of a potential gradient and radiofrequency applied on co-centric electrodes will transport the ions towards a nozzle.
The gas catcher was built at Argonne National Laboratory. The catcher DC and RF has been tested and it has been pumped down to below 2x10^{-8} torr.



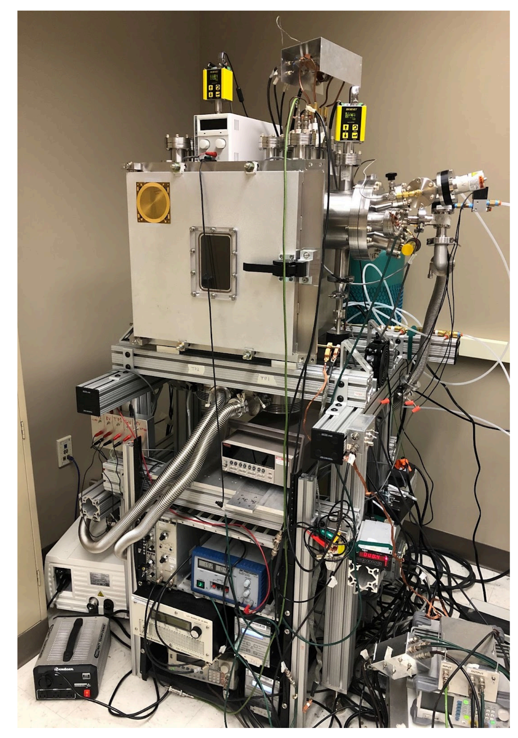
Setup to test RF on the cone section



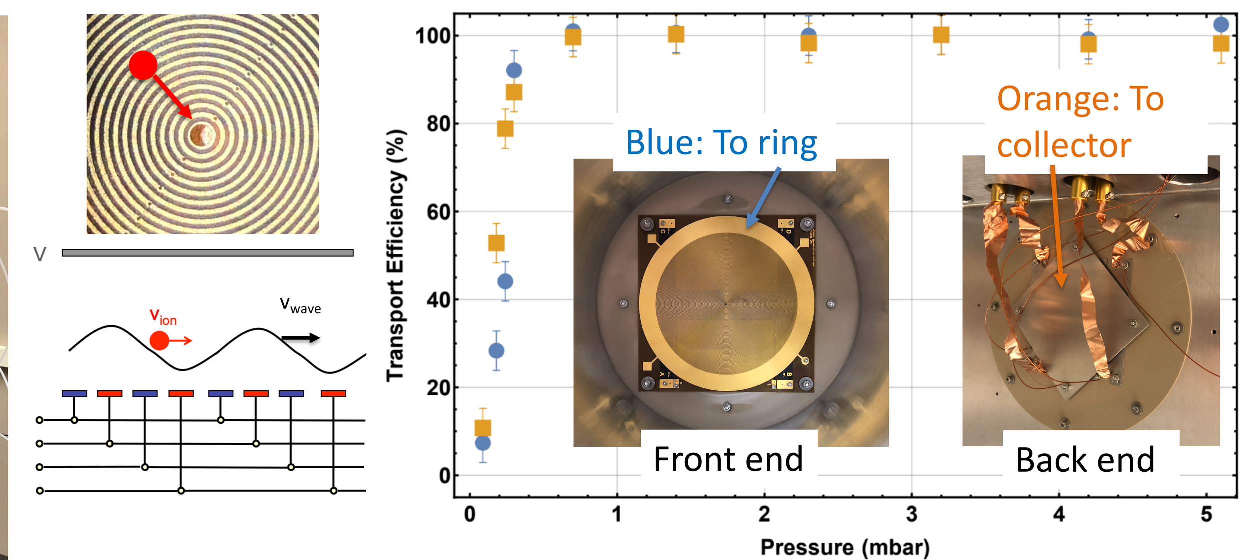
Setup to pressure-test the gas catcher

Extraction system

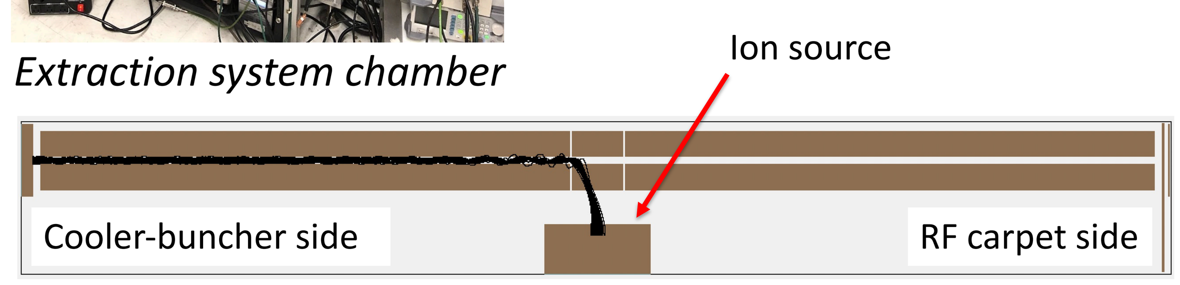
Upon leaving the gas catcher, the ions will be guided through two differentially-pumped chambers. First, a RF carpet will transport the ions using the ion surfing method at ~3 mbar up to a second chamber housing a RFQ ion guide at a pressure of ~2x10^{-3} mbar. RF carpet achieved ~100% transport efficiency for P > 0.75 mbar. The ion guide will include an off-line ion source with sideway injection.



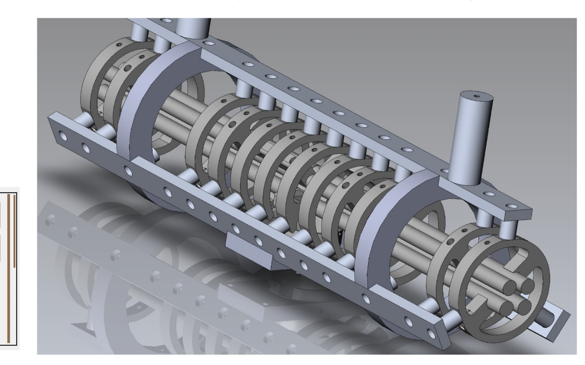
Extraction system chamber



Transport efficiency for ion surfing in 0-5 mbar pressure range



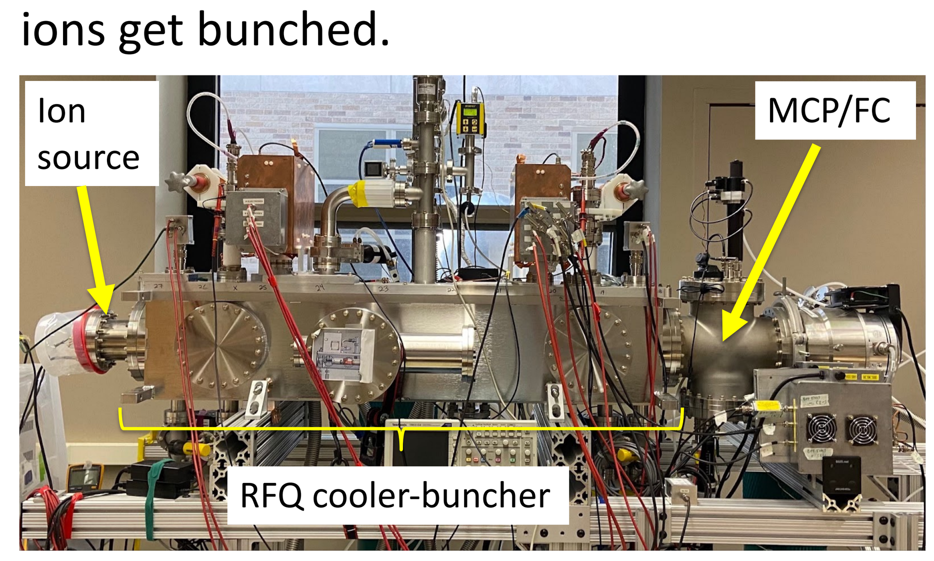
Sideway injection of beam from ion source in the RFQ ion guide



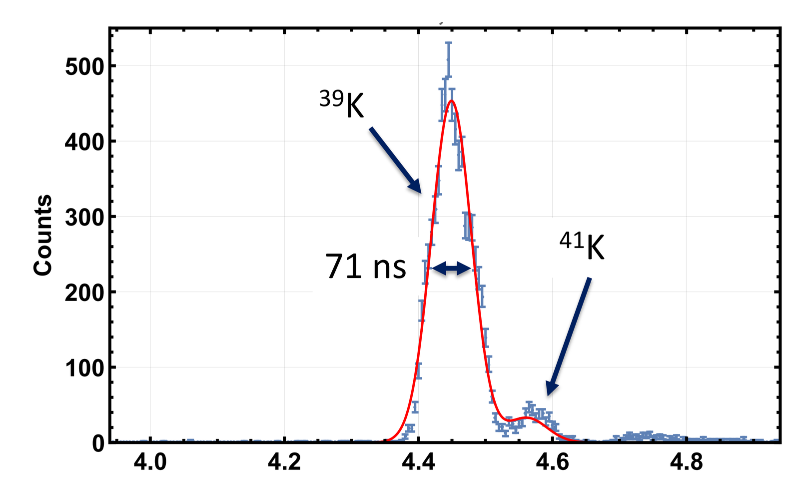
Design of ion guide

Cooler and buncher

The St. Benedict cooler and buncher coverts the continuous beam from the extraction system in cooled bunches with a <100 ns FWHM. This device follows the design of the FRIB EBIT cooler and buncher.
Off-line commissioning with a potassium source has been completed and showed that ~80% of the beam from the source gets in the RFQ. The totality of those ions then get transported to the end of the device. Similarly, ~100% of the transmitted ions get bunched.



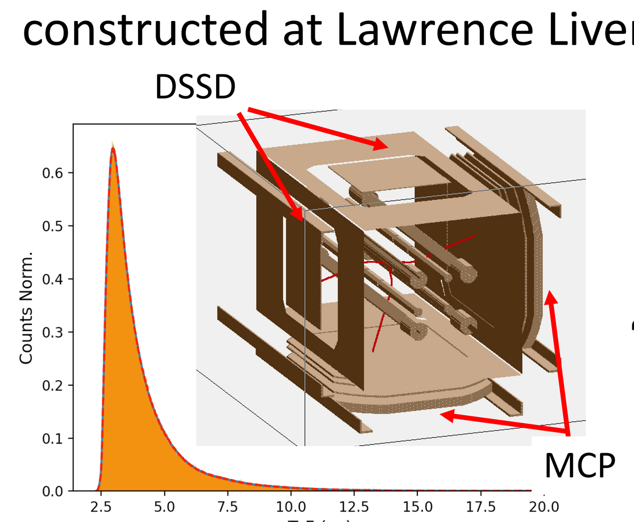
Setup for off-line commissioning of the cooler



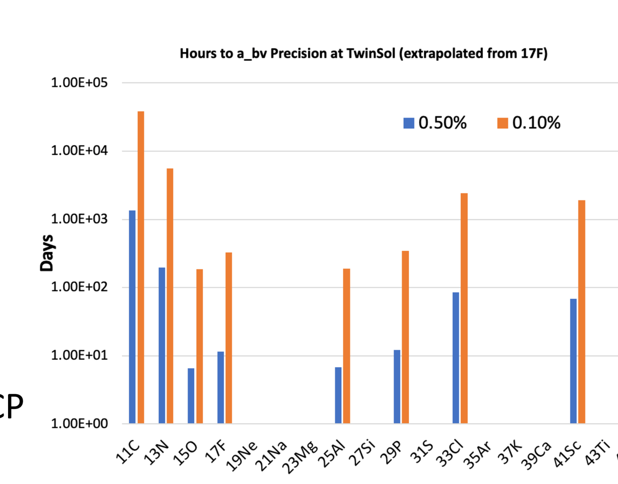
Typical TOF of extracted ion bunch

Paul trap

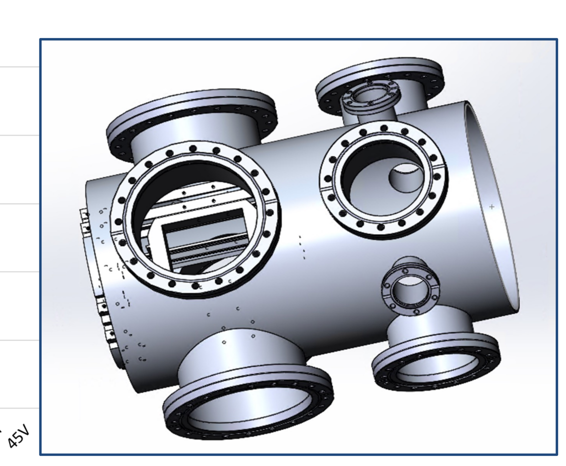
The St. Benedict Paul trap will hold ions in free space and will be surrounded by two position-sensitive MCP and two DSSD detectors backed by plastic scintillator and photomultiplier tubes. The wanted $a_{\beta\nu}$ will be obtained by fitting the time-of-flight spectra of the recoil. Simulations indicate that a $\Delta a/a$ = 0.5% can be achieved within 2 weeks for ^{15}O, ^{17}F, ^{25}Al, and ^{29}P. The Paul trap has been designed and constructed at Lawrence Livermore National Laboratory.



TOF distribution for ^{17}F decay



Measurement time to given $\Delta a/a$



Paul trap in its chamber

Conclusion

- St. Benedict aims to measure $a_{\beta\nu}$ in superallowed mixed transitions.
- It will comprise 4 major components: gas catcher, extraction system, cooler-buncher, and Paul trap.
- All components are either individually commissioned or under construction.
- A precision of $\Delta a/a$ = 0.5% can be achieved within 2 weeks for ^{15}O, ^{17}F, ^{25}Al, and ^{29}P based on measured rates at *TwinSol*.

UNIVERSITY OF NOTRE DAME