Some words about the BPM's

- 10 electrode sets to be delivered for finishing facility (4 finished)
- Size of project was pretty overwhelming (>11000 wires)
- Wires survived airplane transport from Japan, should be robust.
- Many issues encountered for UHV and baking compatibility, being repaired at CERN (lost connection, probably pin soldering).
- Interesting to see what the failure mode was.
- Preamplifier (electronics) appears to be okay in terms of robustness (2018-2019 operation), 10+4 sets now delivered, remaining 90 ready by April 2020 if you tell us it's okay.
- VME64x modules are all delivered including spares.
- 11 repaired bellows delivered.
- Pneumatic in/out boards being constructed (not a big issue).
- After this, the responsibility of ASACUSA is finished, and moved into the capable hands of the CERN specialists!

Antiprotonic helium physics motivations:

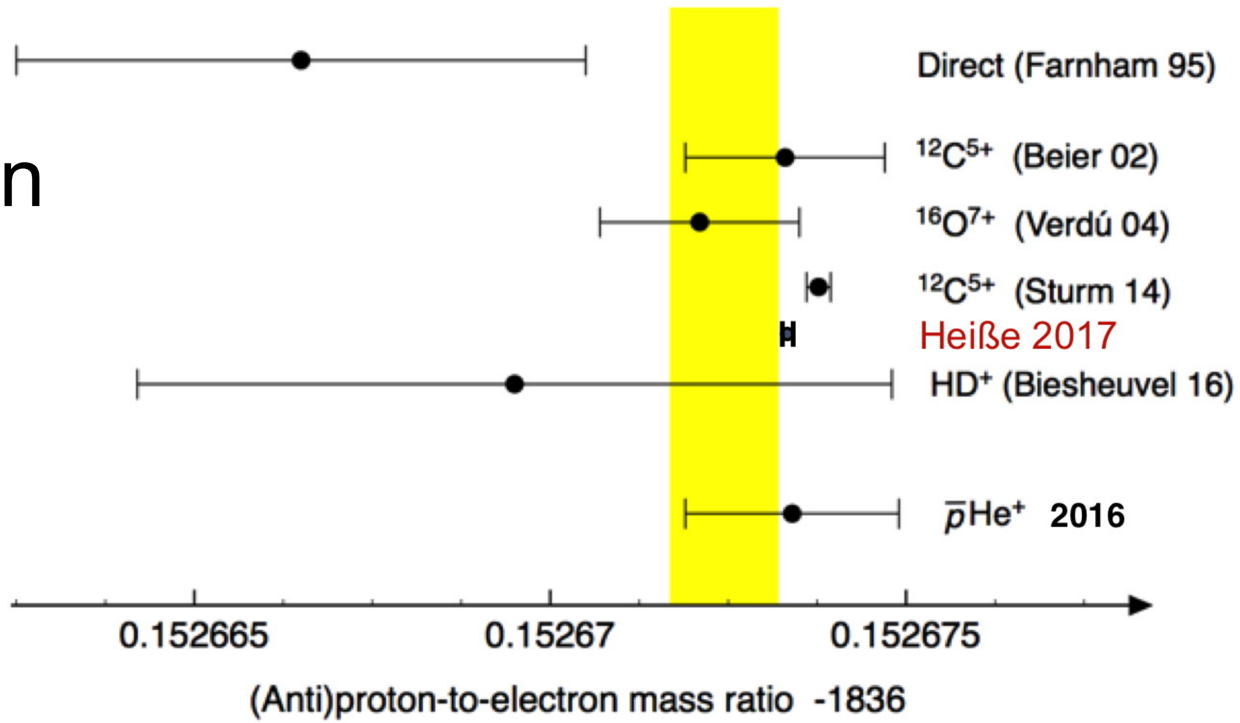
- (Probably) experiment that most benefits from ELENA.
- Tests of three-body QED calculations at 10^{-11} precision
- Determination of the antiproton-to-electron mass ratio
- Tests of CPT symmetry in a bound hadron-antihadron system
- Fifth forces at Angstrom length scales

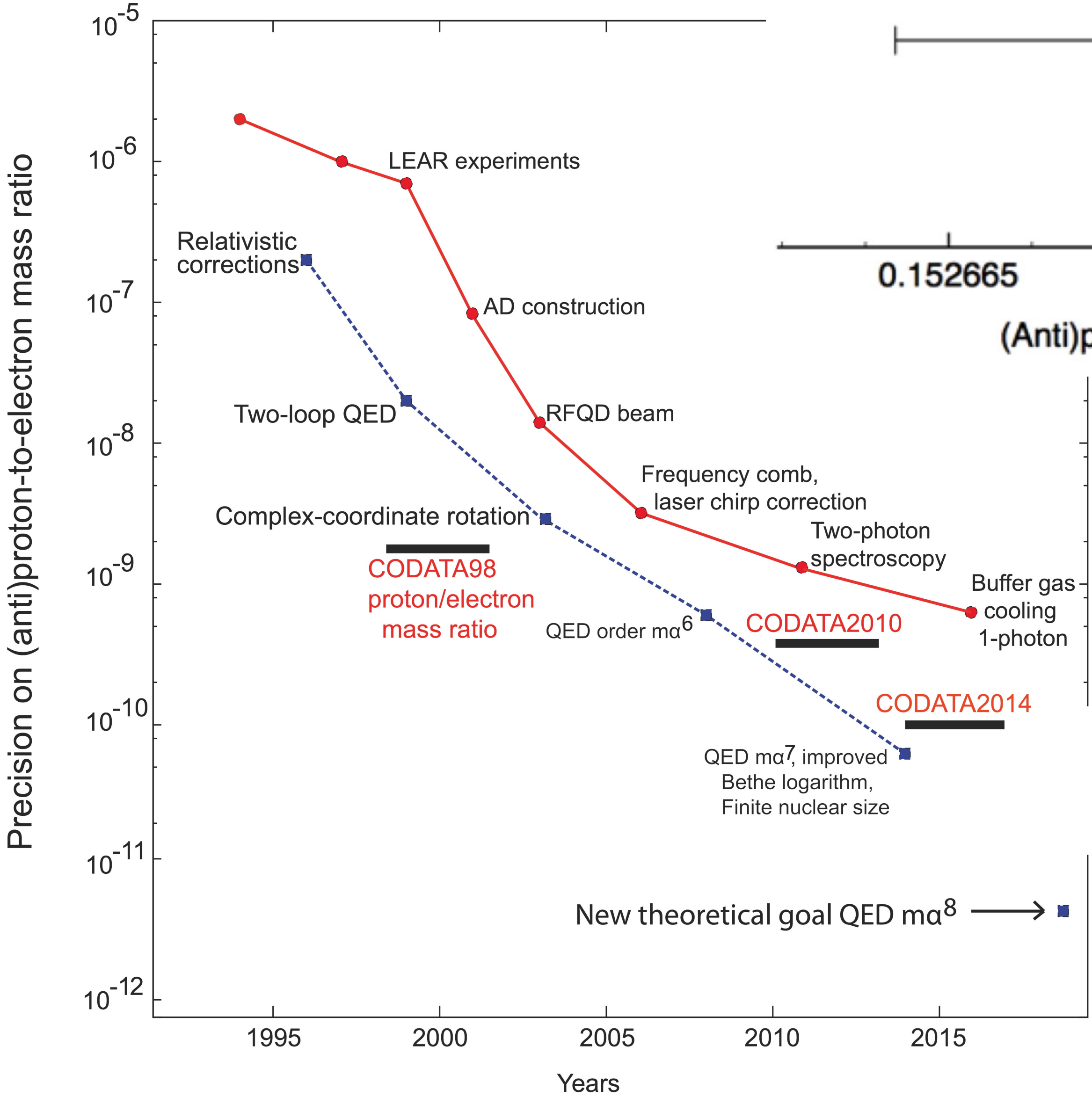
  Salumbides et al., J. Mol. Spect. 300, 65 (2014)

  Murata, Tanaka, Classical Quantum Gravity 32, 033001 (2015)
- Upper limits on exotic velocity and spin-dependent, semi-leptonic forces

  F. Ficek et al., PRL 120, 183002 (2018)
- Comparisons with precision spectroscopy experiments on metastable pionic helium atoms
- Studies of chemical physics reactions

Antiproton-to-electron mass ratio

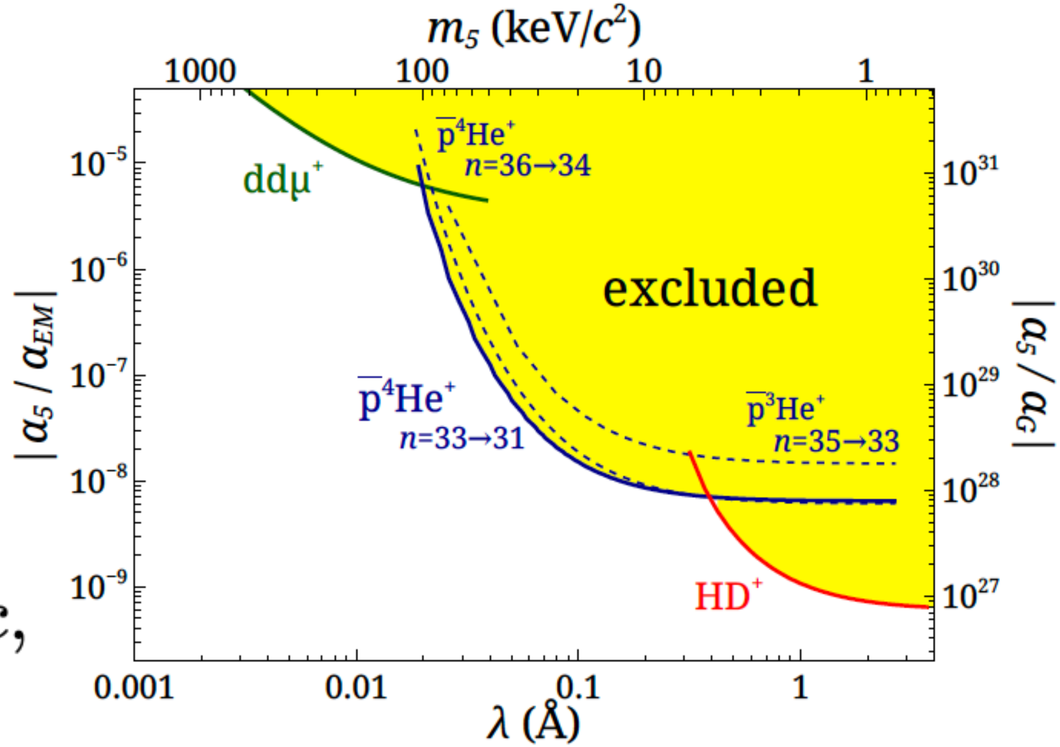


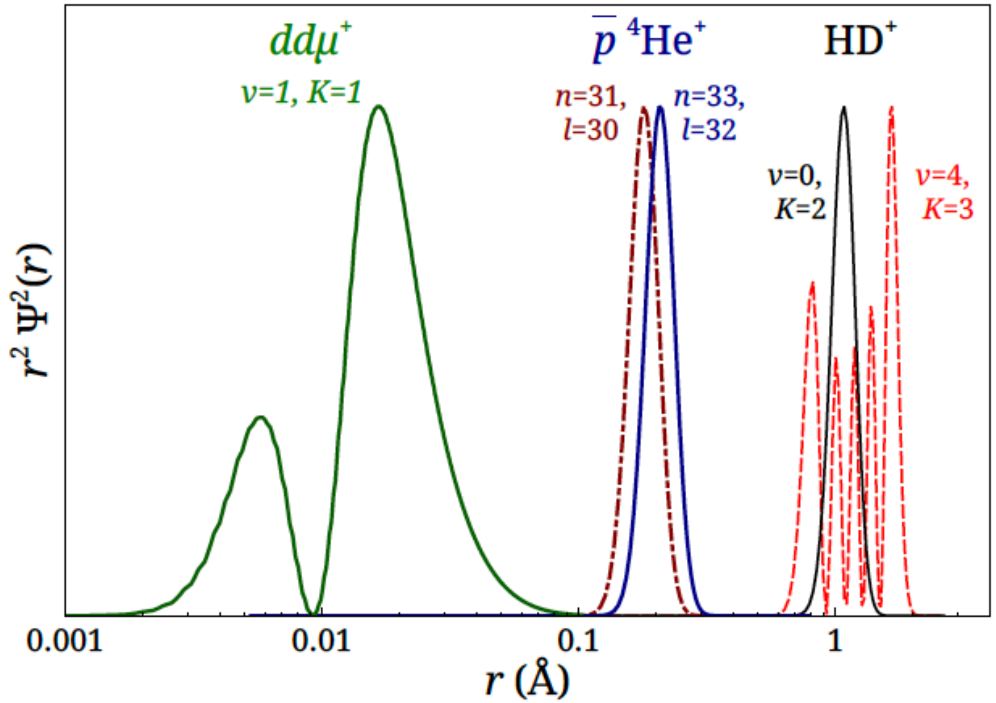


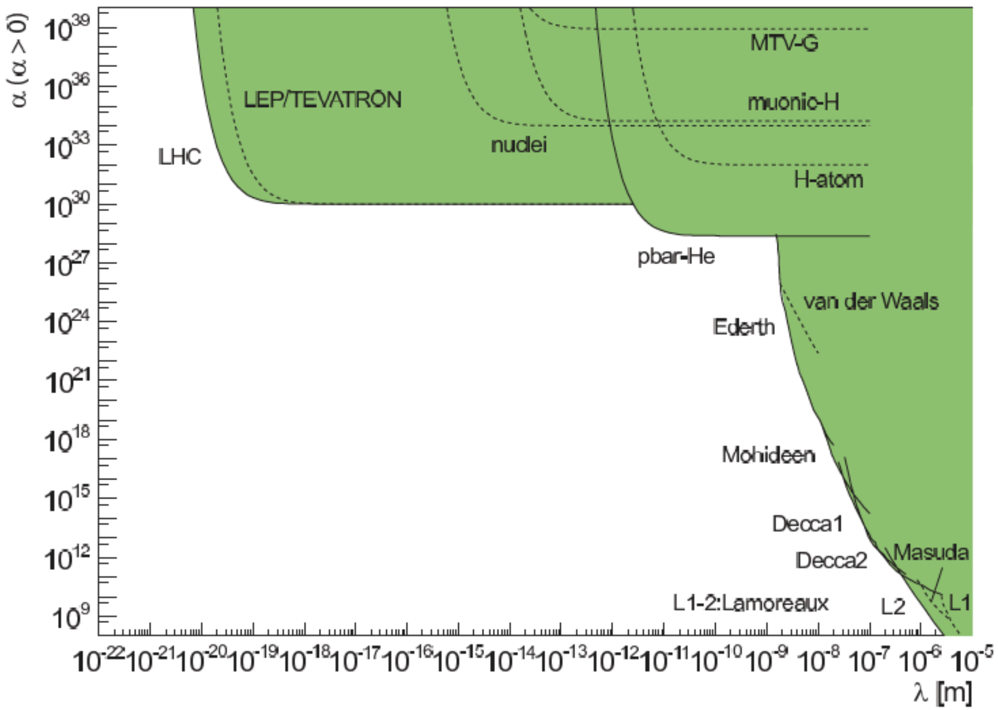
High-order QED

Bounds on fifth force of Yukawa form

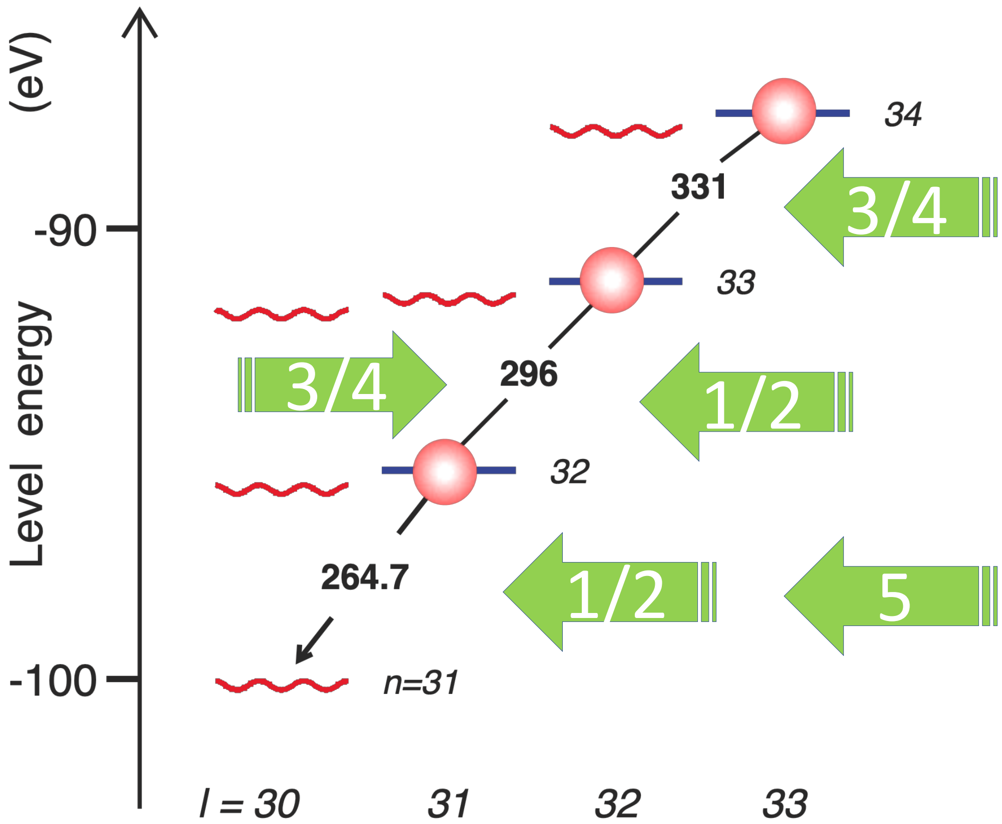
$$V_5 = N_1 N_2 \alpha_5 \frac{\exp(-r/\lambda)}{r} \hbar c,$$



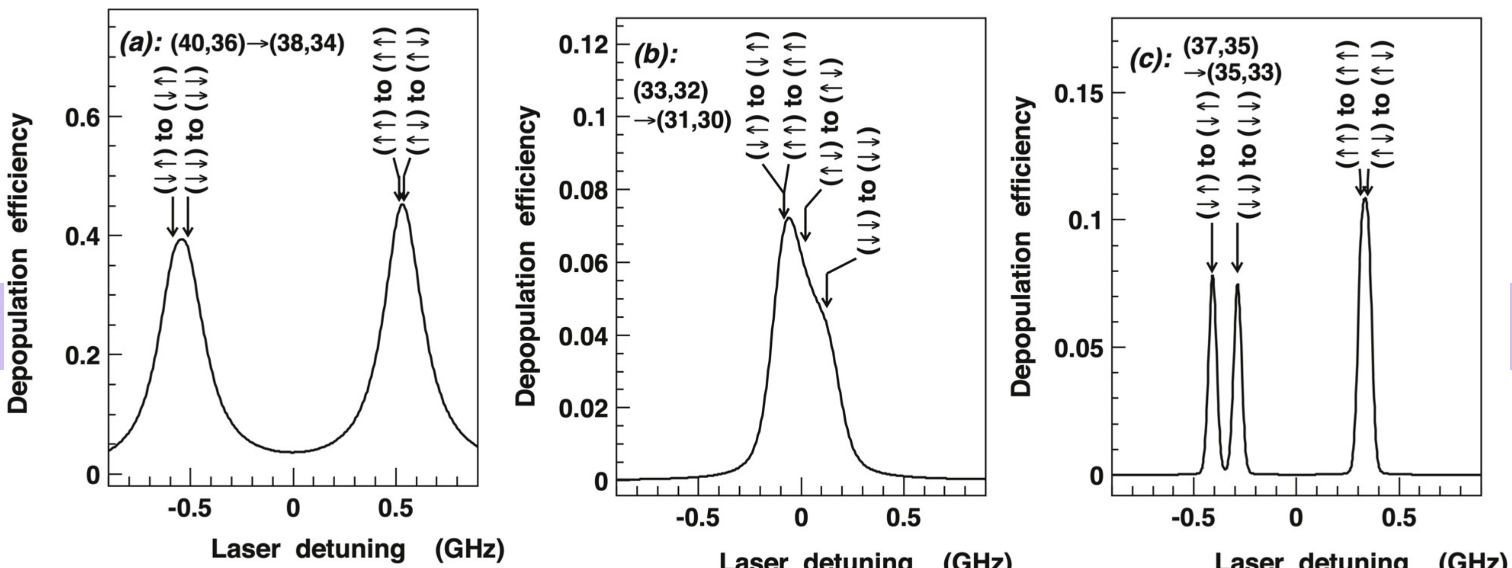




Experiment at ELENA

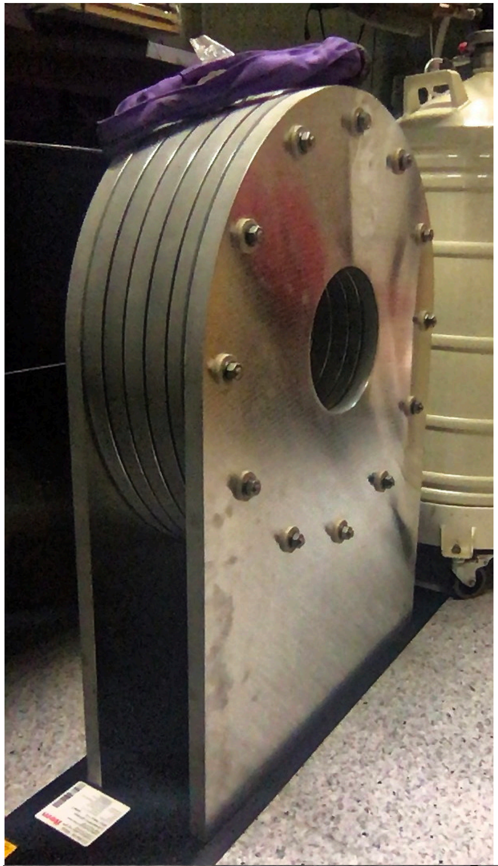


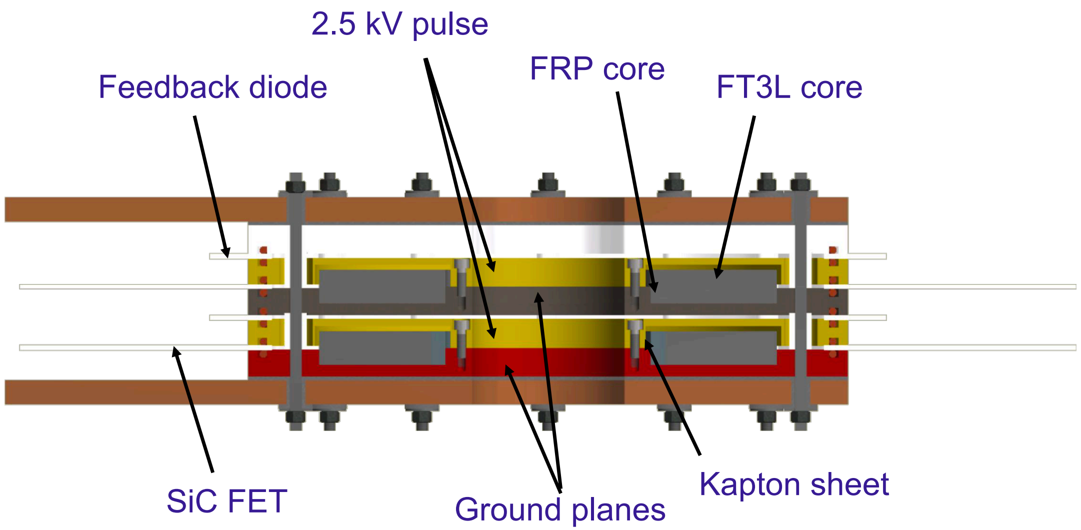
1. Empty antiprotons in two states and create asymmetry.
2. Excite narrow two photon transition.
3. Detect population asymmetry.

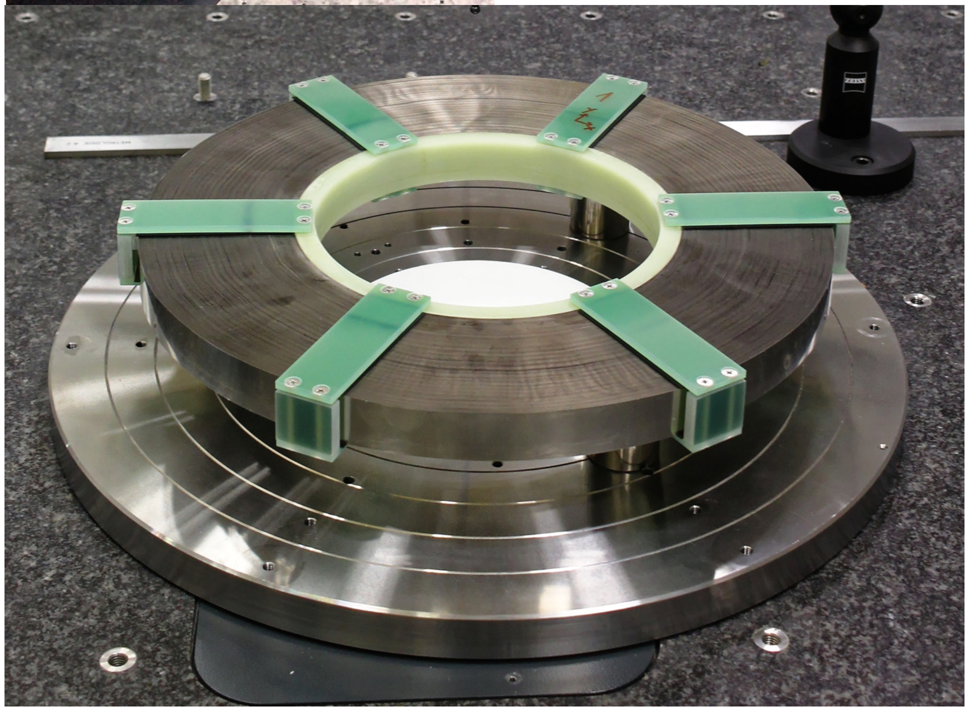


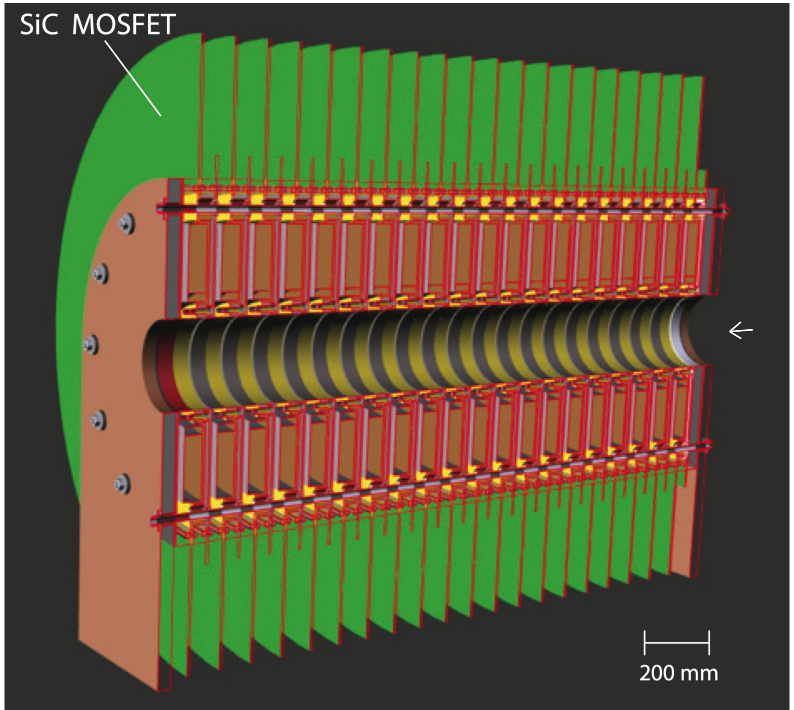
Induction decelerator

Deceleration from 100 keV to <50 keV.
First two stages now under construction.

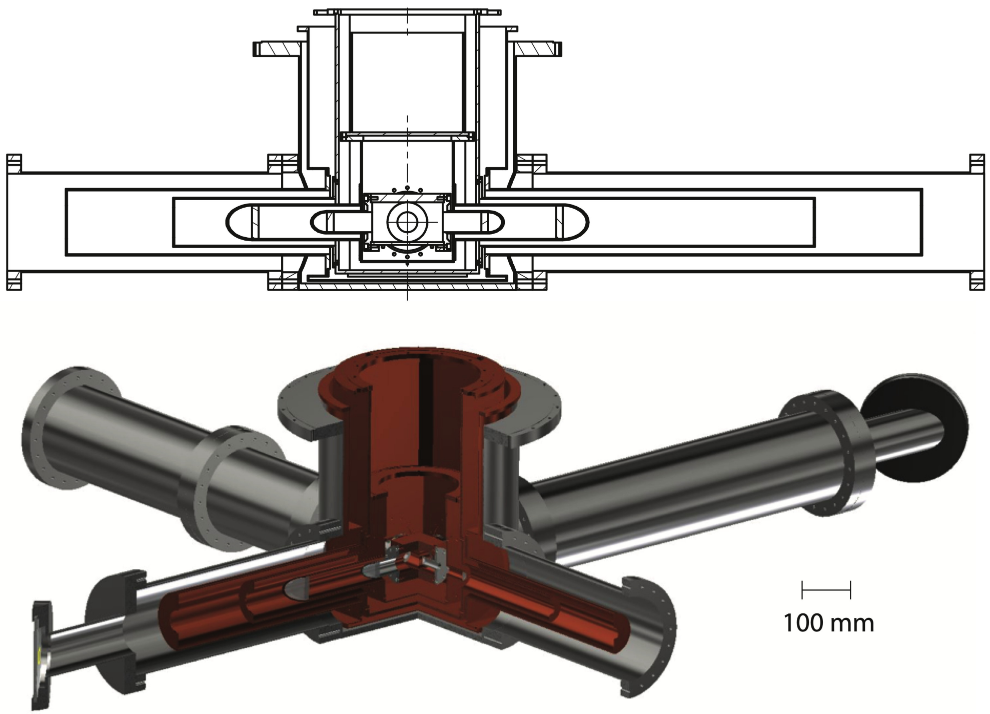


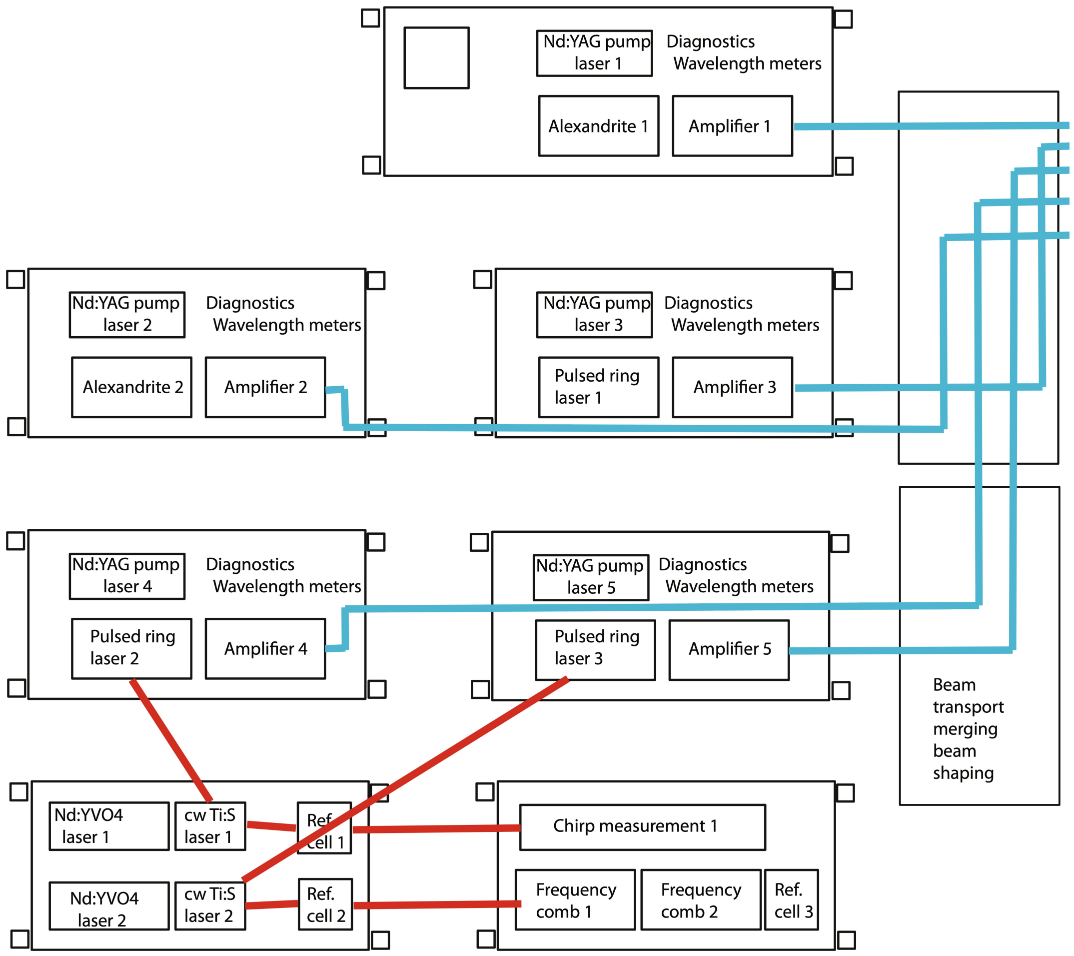


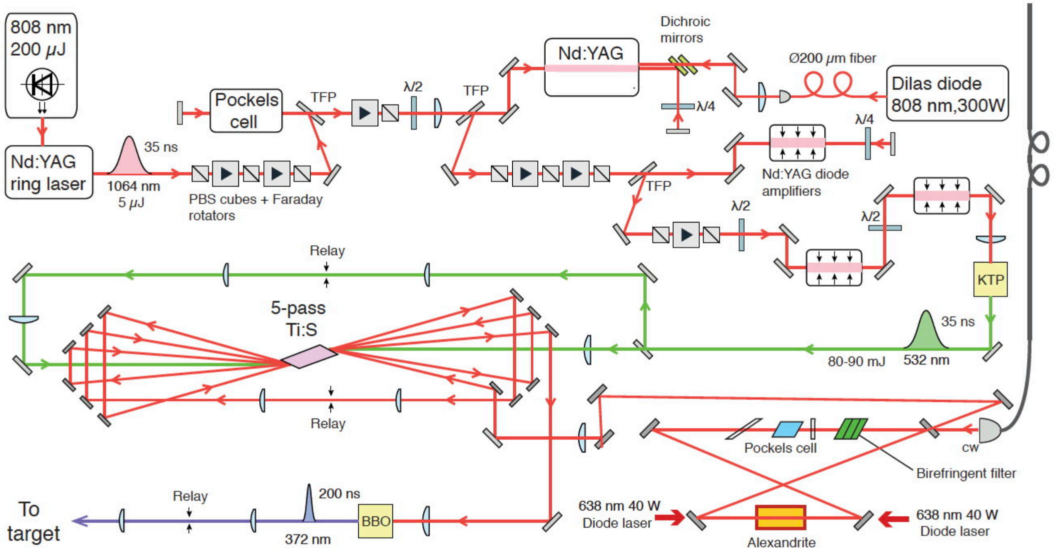




New laser systems + experimental target







Possible long-haul distribution of optical frequency standards via optical fibre

Potential users: ALPHA, BASE, ASACUSA (others?)

- AD spectroscopy experiments measure ***frequencies***.

- The SI second is currently defined in terms of the 9.92631 GHz hyperfine transition of ^{133}Cs at T=0 K. GPS + low-cost Cs or Rb standards + quartz oscillators (10 MHz) or hydrogen masers (100 MHz) have been sufficient for nearly all spectroscopic applications in the AD. These RF signals are distributed inside the AD using coaxial cables. One needs an **integration time** for a frequency counter to count a given number of (jittering or noisy) RF cycles so that the required precision can be achieved.

- AD experiments (ALPHA, ATRAP, ASACUSA) that involve optical laser transitions currently use **femtosecond frequency combs** to multiply these RF signals (typically 10-100 MHz) by factor 10^6-10^7 into optical laser frequencies (typically 190-400 THz). This multiplication has to be done correctly on a 24/7 basis so as not to introduce systematic errors/mistakes/excess noise. E.g., a sub-Hz scale spurious noise appearing in the RF oscillator gets multiplied to MHz scales and must be integrated out. The AD environment is full of RF and low-frequency noise.

- In general it is more convenient to measure optical frequencies using **optical standards** (and RF frequencies using RF standards). **Optical clock standards** (optical lattice clocks, Paul trap-based standards) can achieve higher precision over shorter integration times.

- Need for such optical standard signals transmitted via optical fiber to the AD experiments.

- Long-haul distribution of optical reference signals for, e.g., spectroscopic applications have been carried out over the last decade (e.g., Torino-Matera link constructed by INRIM et al., PTB-MPQ 930 km link used in the hydrogen 1s-2s spectroscopy experiment, French link). The transmission technology involves the active compensation of optical disturbances in the 100-km-scale fibre, but this is nearing maturity.

- Still no standards laboratory provides 24/7 support for this, due to manpower and funding constraints, as well as total reliability issues. The experiments are carried out on a campaign basis. The rental cost of the optical fiber is also significant.

- Efforts in Switzerland to provide optical frequency standard signals to Swiss users.

- A separate pan-European proposal lead by GEANT to interconnect all the networks into several circular ones ("A standing wave over Europe").

- Some people within CERN expressed willingness to perhaps eventually host a node of this proposed infrastructure, subject to scientific evaluation by SPSC etc.

- On December 9th, there was a discussion between researchers from
  - METAS (Swiss standards laboratory)
  - SWITCH (Swiss research+educational network manager),
  - INRIM (Italian metrological laboratory)
  - Menlo Systems (provider of frequency combs)
  - CERN (IT-CS leaders, external network manager)
  - ALPHA, ASACUSA (BASE mentioned interest)

- SWITCH/METAS is constructing a link between ETH Zurich-Basel-Bern. An innovative technology that uses the dark channels (CH07) of existing data fibers around wavelength 1572 nm will be implemented. First results expected by end of 2020. First users involve spectroscopy of Rydberg molecular hydrogen. This project is carried out with technical assistance from INRIM.

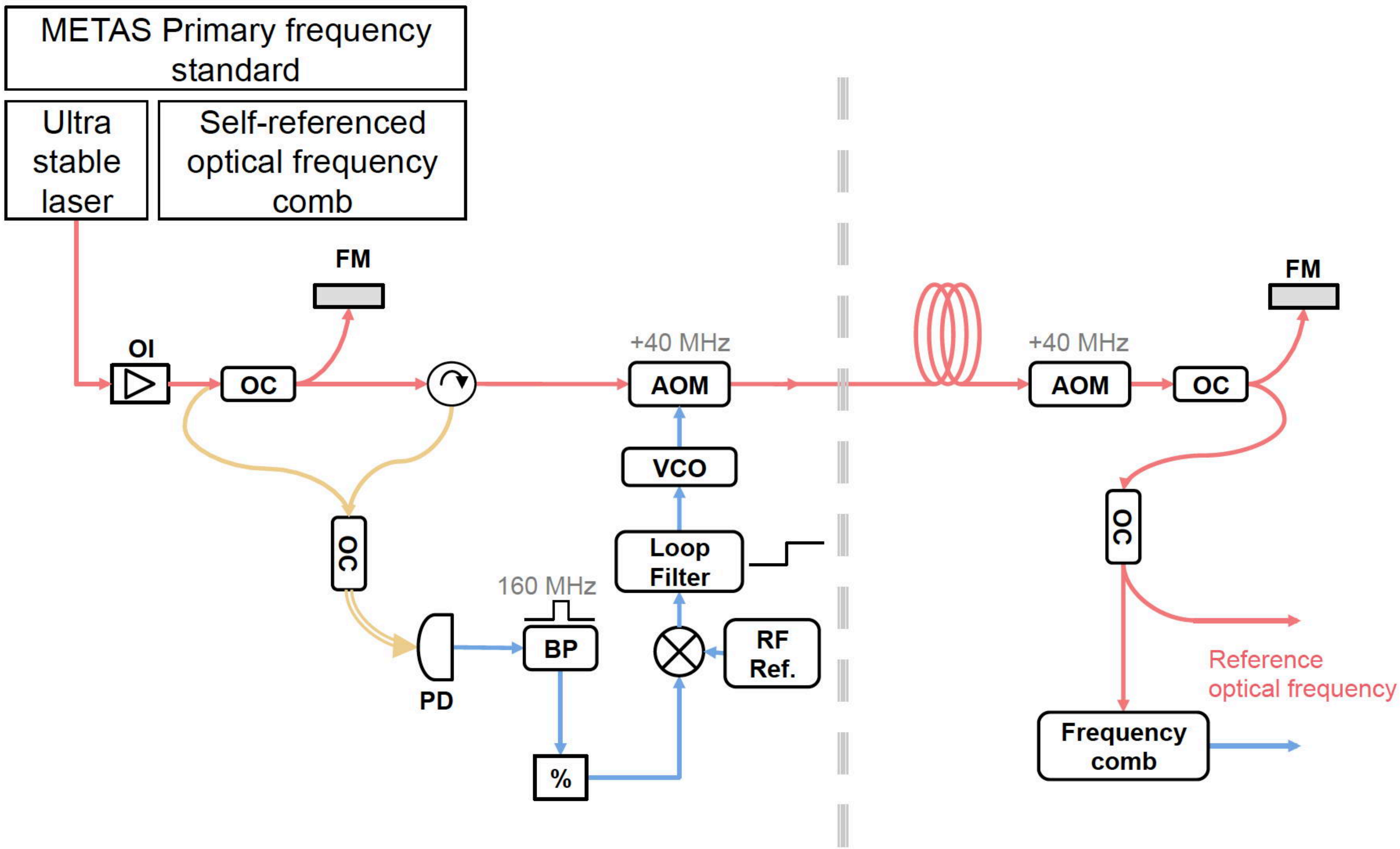
- Subject to the success of this commissioning, this link can be extended to CERN using a Bern-CERN fiber which should become available end of 2020. Too early to make a commitment or cost estimation.

- Most logical setup involves placing the receiver device provided by SWITCH/METAS inside Bat. 513 (computer center), and pulling optical fibers to each of the user experiments in AD, to be discussed.

- The total cost for the infrastructure + fiber rental would be of order 100 kCHF+ local loop fibres and sharing the spectrum, over the entire LS2-LS3 running interval.

- IT is in principle willing if recommended by SPSC and authorized by management to host the device, and the pulling of the fibers to the AD experiments. However they made it clear that 24/7 maintenance is not possible. The optical signal itself will not be 24/7 available either.

Basic implementation of a first stabilized link



- Perhaps eventually submit a proposal (to be verified with SPSC) detailing,
    - Which experiments are interested in this infrastructure (so far ALPHA/ BASE/ASACUSA)
    - Physics justification
    - Technical layout, requirements
    - Cost (tentative 100 kCHF total over LS2-LS3, fibre infrastructure involving SWITCH/METAS should hopefully be handled by CERN, if CERN agrees to do this)
    - Manpower (It was mentioned that pulling fibers from the computer center to AD on an existing pipe should be possible).
    - Too early to make a price price estimation.

- In the +5 year time scale, there are proposals lead by GEANT for a pan-European network of optical standard signals. CERN unofficially expressed interest in hosting a node of such an European infrastructure, making use of its extensive optical fibre network. The SWITCH/METAS/CERN link might be a first step towards that goal perhaps, gaining valuable experience with the

- Opinions (future discussions are opened to all)?