XFELO Comb Summary

- **Why X-Ray narrow linewidth laser and X-Ray combs ?**
  - **High spectral and temporal coherence**
  - **BOTH Frequency domain and Time domain simultaneously**
  - **Very high spectral resolution 10^{-13} and better feasible**
- **Science motivation**
- **Technology requirements, questions, development**

Enabled Science

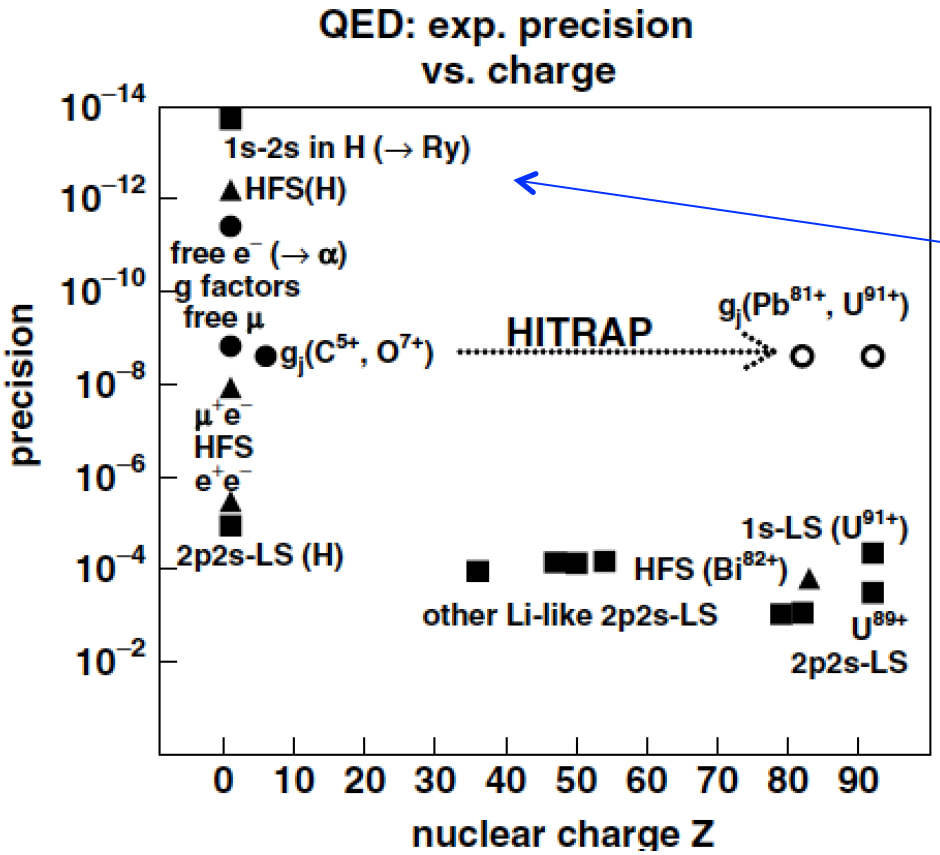
- X-Ray laser with high spectral resolution and brightness will inpact research much the way highly coherent sources have in microwave, IR, visible, UV, XUV

- High spectral resolution
  - Atomic physics
    - 1 and 2 electron atoms tests of QED
    - H-like and He-like high Z atoms
    - Most stringent tests of QED at low energies
      - now some experimental discrepancies
  - Nuclear physics
    - Structure: multi-level nuclear transistion
    - Dynamics: X-Ray driven nuclear – electronic transitions
    - X-Ray probed or driven nuclear reactions
    - ultra-narrow X-Ray resonances Mössbauer

Science Con't

- X-Ray frequency and wavelength metrology
- With f_{ceo} control and dispersion compensation, pulse shaping can imagine time resolution dynamics at $< 10^{-18}$ s
- Nonlinear phase coherent driving and probing at X-Ray wavelengths and over long times , > 10 s

Hydrogen-like Ion Spectroscopy



Enabled by:
-- frequency stable lasers
-- fs optical combs
-- laser cooled atoms

HTRAP at GSI Darmstadt , NIM B 2005

Technologies Enabling phase-coherence and X-ray combs and applications

- Enable multi-color phase-coherent spectroscopy, pump probe
- Injection seeding of FEL with XUV HHG
  - perhaps near 100 eV
- Higher repetition rates important for Combs
- X-Ray resonant cavity
  - Optical stabilization of of X-ray cavity
  - Many questions to answer: spectral, spatial, temporal modes, dispersion
- X-Ray heterodyne methods, phase sensitive drive, probe detect

Potential Actionable Directions

- Experiments relevant to X-Ray cavity, e.g.
  - 3-5 meter cavity
  - calculations of cavity materials, dispersion ...
  - more info on gain characteristics , gain, dispersion ...
- f_{rep} multiplication , harmonic mode locking, delay lines
- X-ray – optical cavity demonstration
  - measure loss, spectral-spatial mode control, dispersion compensation
- X-ray intra-cavity spectroscopy (e.g. cavity ring-down)

Optical stabilization of X-Ray Laser

Cavity analysis and designs explored :
Cavity and material expts
Multi-pulse in cavity
Intra cavity X-ray spectroscopy (weak absorption, phase shifts)