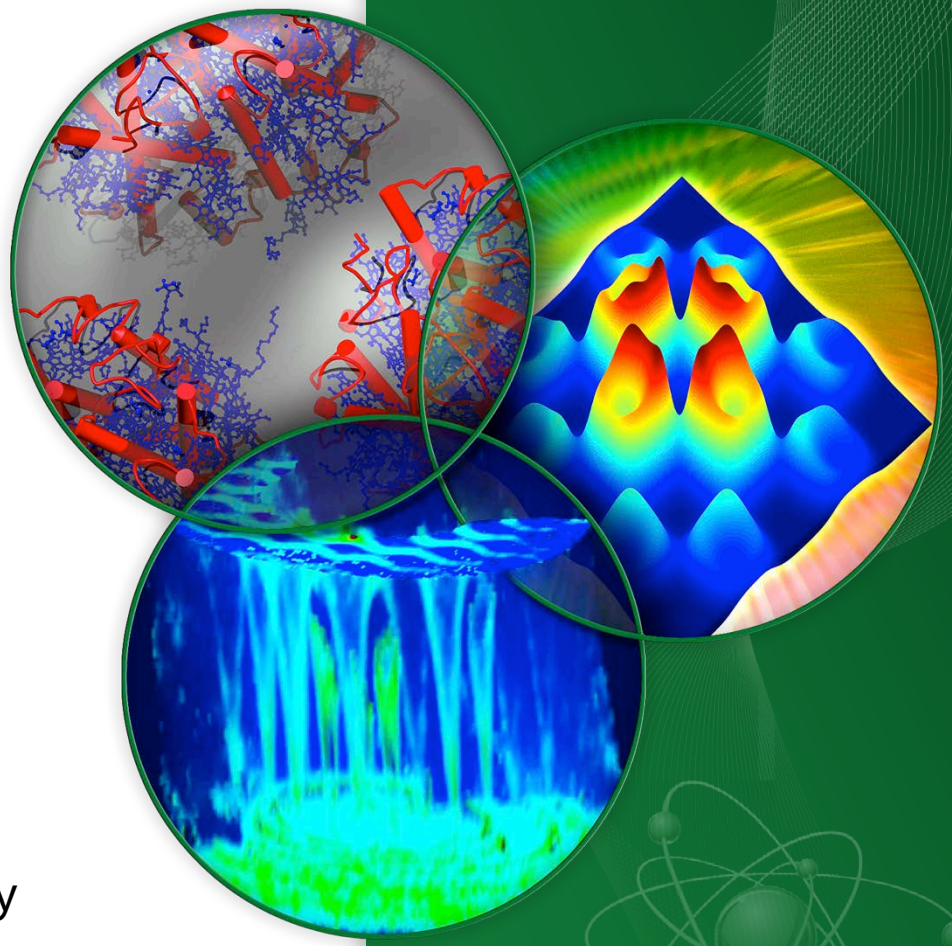
Spectroscopy of Quantum Matter under Extreme Pressures



Mark Lumsden

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Participating Staff

QCMD:

Mark Lumsden
Andrew Christianson
Travis Williams
Antonio dos Santos
Andrey Podlesnyak
Liusuo Wu

CEMD:

Timmy Ramirez-Cuesta
Luke Daemen
Chris Tulk
Sasha Kolesnikov
Shanmin Wang

Reinhard Boehler

Goals of Project

Establish a world leading program at SNS for inelastic neutron scattering measurements under pressure:

Quantum Criticality (CNCS)

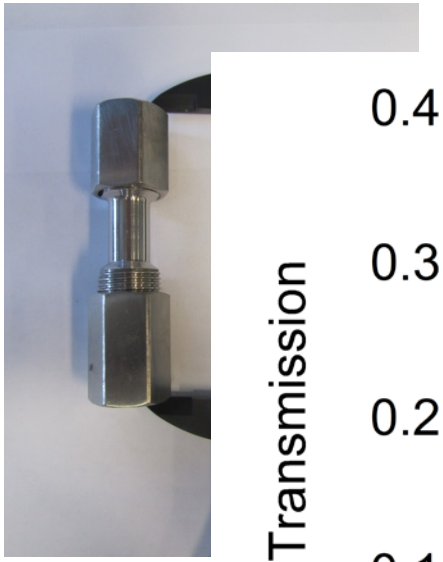
To provide a clearer understanding of quantum critical phenomena through the development of state of the art capabilities for INS at ultra-low temperatures (down to 150 mK) up to pressures of 3 GPa with sufficient sample volume for inelastic neutron scattering investigations. **Opportunity – CHESS at STS should have gain factors of ~200 when compared to CNCS**

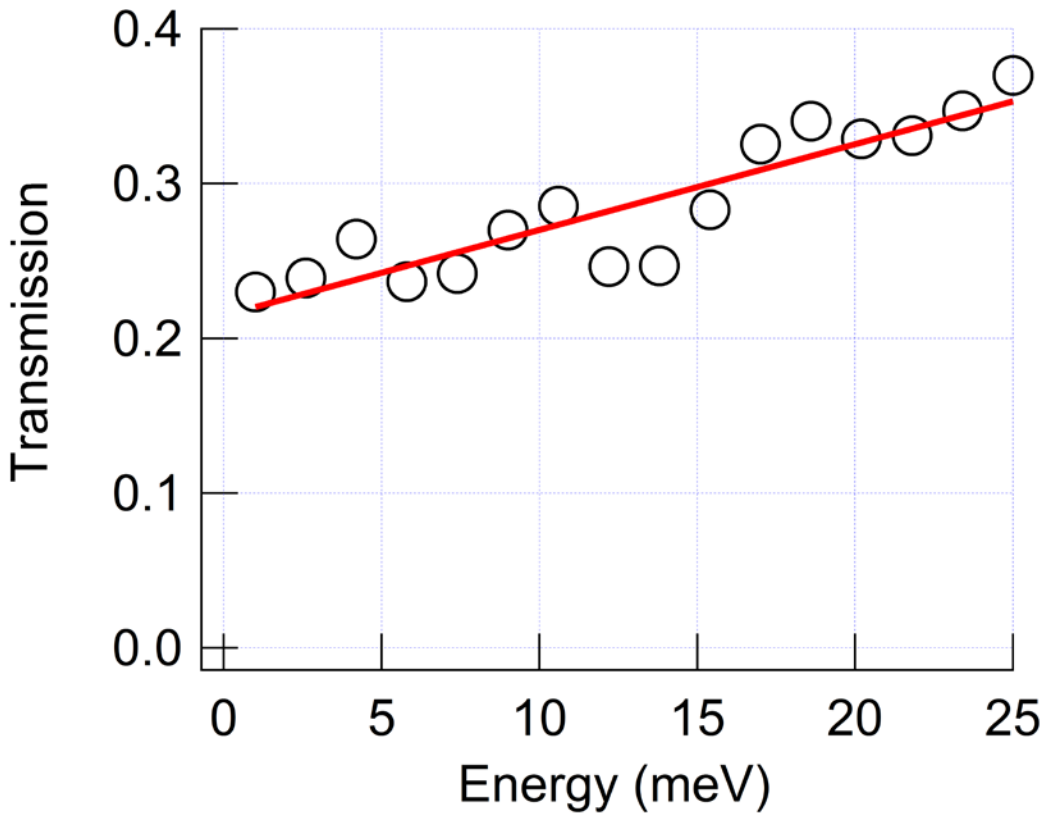
Hydrogen containing materials (VISION)

Develop a program to study the dynamics of hydrogen containing materials under pressure. This will include development of new ultra-high pressure devices to compress 1-3 mm^3 samples to several tens of GPa. **Opportunity – VISION outperforms similar instruments worldwide by large factor.**

Quantum criticality – CNCS capabilities

Clamp Pressure Cells:





NiCrAl alloy

Sample spa
~ 4.5mm di
15 mm he
Volume ~ 24 .....
Pressures up to 2.0 GPa;

CNCS:

413 (2015)

Editor's Suggestion

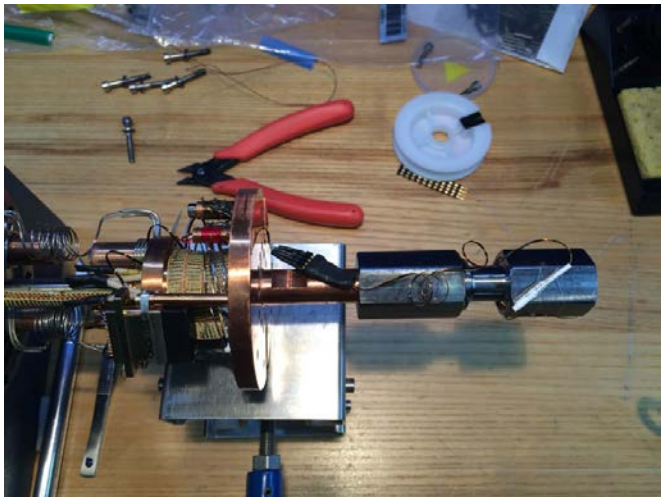
Measurements on a 150 mg single crystal

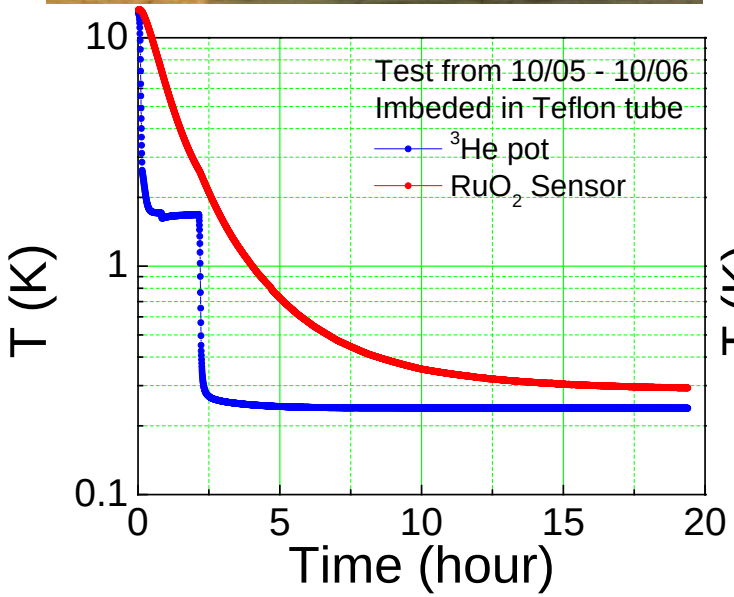
Quantum Criticality

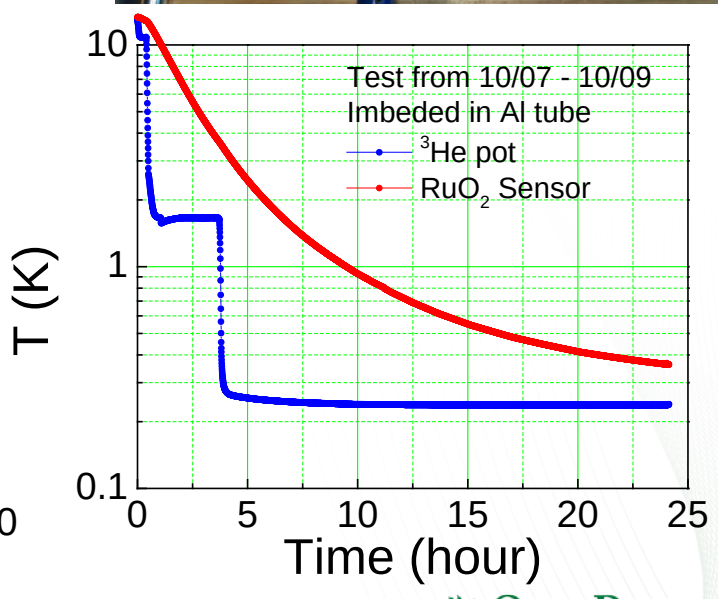
- For many quantum critical systems, pressure is the ideal tuning parameter. Alternatives (typically doping) introduce complications
- **Technical challenge**: requires measurements at ~2 GPa for temperatures in the mK range
- Challenge is one of extreme P/T!
- Purchased a new, high capacity dilution fridge to enable measurements at << 1K
- Community interest is high – highest rated proposal for CNCS this round called for 2 GPa, <300 mK + 5-8T magnetic field!!

Quantum Criticality

Initial test of clamp cell in ^{3}He insert (tests with new dilution fridge are pending)





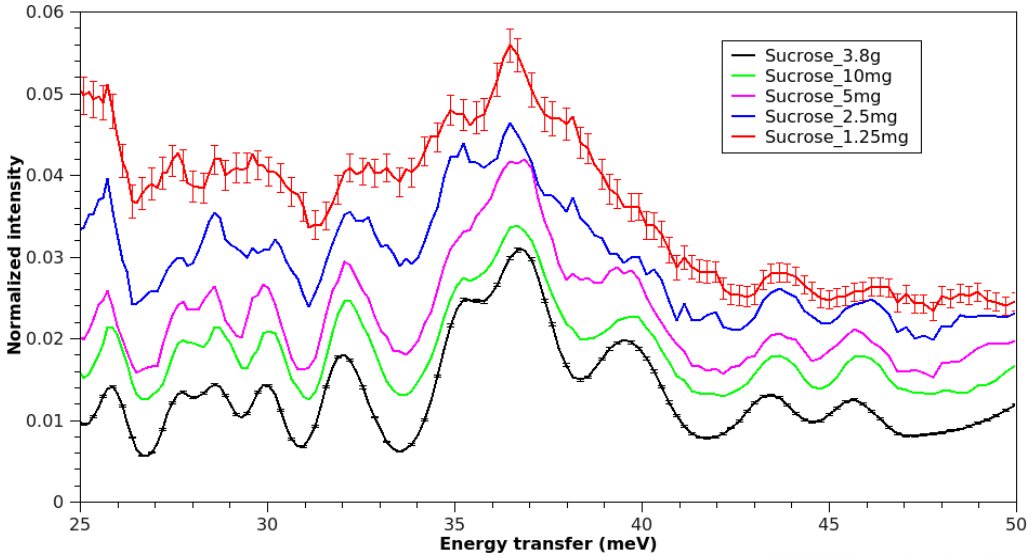


Hydrogen Containing Materials

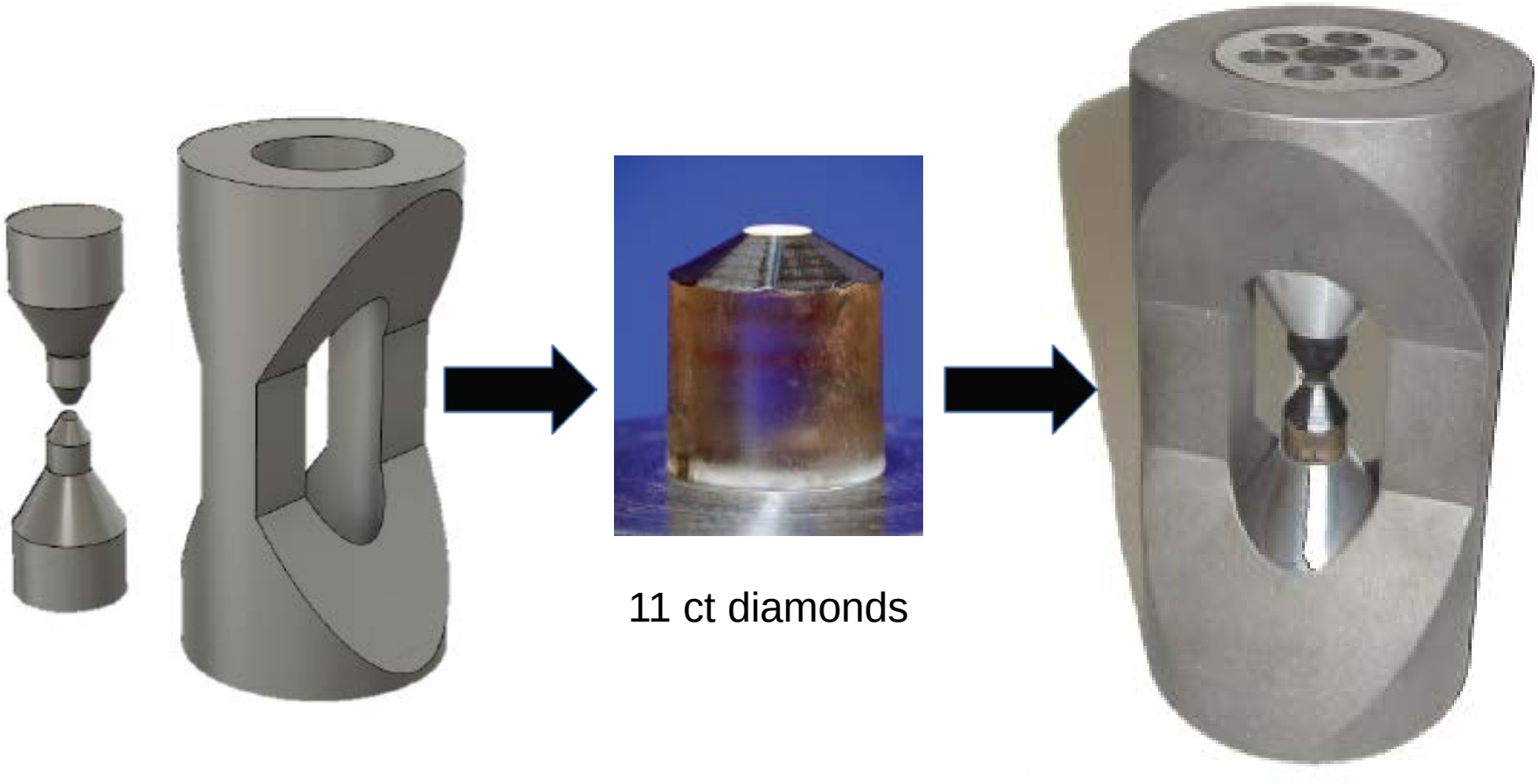
VISION enables inelastic neutron scattering measurements on milligrams of sample

- **1.25 mg of sucrose (table sugar)**

Sugar grains on Al foil (magnified, the total volume of the grains is about 0.8 mm^3)



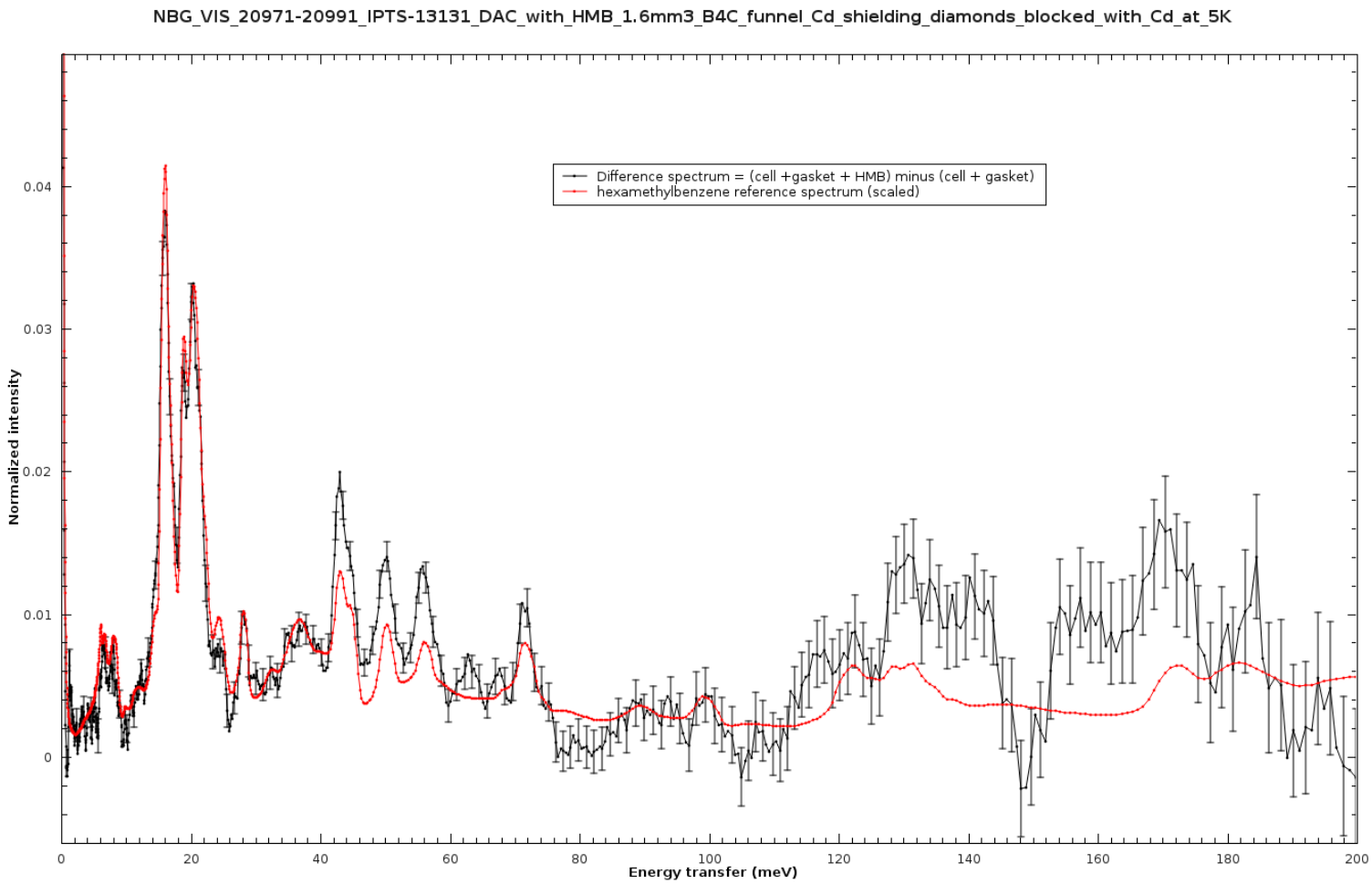
New VISION Diamond Anvil Cell



11 ct diamonds

Sample volume ~1.5 mm^3

New VISION DAC – Initial Measurements



Spectrum of hexamethylbenzene

Remaining Tasks

- Optimize shielding / collimation around cell (considering 3d printed collimators)
- Develop better cell centering / positioning for VISION
- Pressure testing of cell
- Iterate on cell design based on initial testing
- Build hydrogen gas loader (components have been purchased)

Ongoing

- High pressure sample environment steering committee (led by Antonio dos Santos) is developing a plan and strategy for various aspects of high pressure research at SNS and HFIR
- This includes gas pressure cells, clamp cells, PE cells, and DACs.
- High pressure elastic and inelastic neutron scattering will grow in importance with time and with the new capabilities at STS – this LDRD should lay the groundwork for this expanding capability