# Neutron Electric Dipole Moment Experiment using UCN

The TUCAN Collaboration

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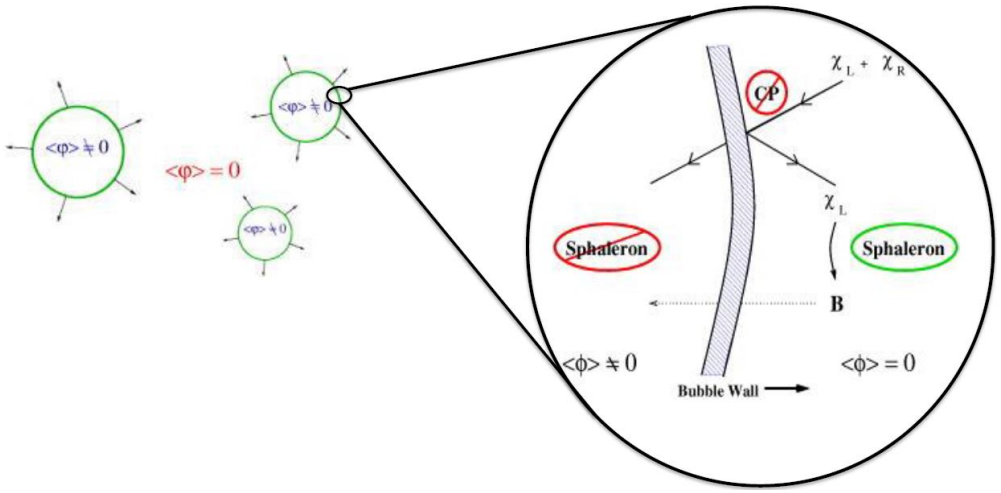
Spokespeople: J. Martin (Canada), K. Hatanaka (Japan)

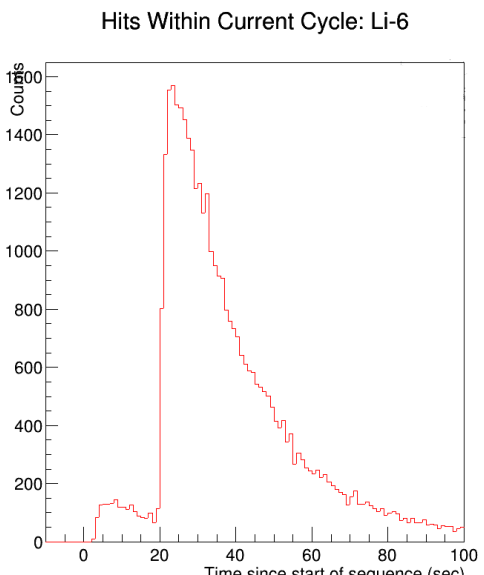
# Neutron Electric Dipole Moment

- High Science Priority
- If our UCN source can be completed in next 2-3 years, highly relevant to the world scene.




# Progress

- First UCN production and detailed experiments Nov-Dec 2017.
- Good progress made on UCN source design.  Weekly meetings and continual design discussions.
- Continuing to increase Japan-Canada collaboration, develop roles for new collaborators.




TRIUMFで超冷却中性子(UCN)の生成に初めて成功　KEK、RCNP、TRIUMF、ウィニペグ大学の共同研究で

NOVEMBER 21, 2017

MAKIO

所要時間：約3分

TRIUMF's (ultra)cool experiment fires up

20 November 2017

# Project Management and Planning

- New Project Manager (Chris Gibson) hired at TRIUMF. Starting date Jan. 2, 2018. Experienced project manager with strong mechanical engineering background, experience working with Japan groups (companies).
- Collaboration agrees: Need to improve project management and planning.
  - Collaboration commits to complete list of R&D tasks for CDR with project management and task tracking.
- Collaboration agrees: TOP PRIORITY must be on new UCN source design.
  - Collaboration commits to limit operations at TRIUMF until > Sept. 2018 to force us to focus on completion of CDR and TDR. Will be included in project plan.

# Project Scope – Draft version in progress

**Detailed Project Scope for UCN** (a scope summary will be presented for reviewers)

Triumf Document number - **xxxxx**

C. Marshall Dec/12/2017 – Rev 2

Not included in this scope

- Further work on existing beamline,water pack,D2O handling, or Target
- Experimental components such as shielded room, or magnetometer
- UCN Guide tube & valve system

| The main components of the scope are… | Responsibilities |
|---|---|
| - Project Management | Prm/Tri/Jpn |
| - Concepts development | Jpn/Tri |
| - Physics Simulations | Jpn |
| - Source Cryostat | Jpn |
| - Source Cryostat support frame | Tri? |
| - Source Cryostat testing/Shipping frame | jpn? |
| - Source 3He & 4He Pumping system | Tri |
| - Source Gas handling System | Jpn |
| - Source control System | Tri? |
| - Isopure Storage tank | Tri? |
| - Source Interconnecting piping | Tri |
| - Helium Transfer line | Tri |
| - LD2 Cryostat | CM |
| - LD2 Cryostat suport frame | CM |
| - LD2 Report for BCSA | CM |
| - LD2 Gas handling System | CM |
| - LD2 Control System | Tri |
| - LD2 Interconnecting piping | CM |
| - LD2 Reservoir System | CM |
| - Biological Shielding | Tri |

| He-II Source Cryostat | Primary |
|---|---|
| **Cryogenic Engineering** | |
| - Design Concepts | Jpn/Tri |
| - Heat transport from Bottle | TO |
| - Required cryogen flow rates | |
| > Source cooling | SK |
| > 4He & 3He pot fill rates | SK |
| > Shield cooling flows | SK |
| > 4K bath fill rate | SK |
| > Loss of Vacuum relief sizing | SK |
| - Schematic-internal vessels, shields, piping, valves & sensors | |
| - Heat exchanger sizing (7? Exchangers) | TO |
| - Sizing of internal vessels | SK |
| - Sizing of Needle valve impedances. | SK |
| - Superinsulation spec | SK |
| - Static heat loads | SK |
| - Sizing of Vacuum pumps & Connected piping | SK |
| - Specification of sensors | SK |
| - Specification of gas storage volume & Pressure | SK |
| **Mechanical Engineering** | Primary |
| - Interface design to Cold Moderator | |

...

- Draft detailed scope at conceptual level.
- Input to WBS and project plan.

# Jan.-May 2018

1) Come to agreement on concept (Source with moderator)

2) Prepare for Concept Design
- Requirements Document
- Calculations & drawings in support of one or two concepts
- Scope Document (Feeds Work breakdown structure)
- Organizational Structure & Initial work breakdown Structure
- Initial Budget
- Roles and Responsibilities
- Management plan for control of Scope, Configuration, and cost.
- Initial Hazard Analysis
- Risk Registry

3) Secure a panel for the review

4) Concept Design Review (Gate 1)

# May-Dec. 2018

5) Technical Design
- Detailed Physics calculations & simulations
- Delated Engineering calculation & specifications
- Drawings

6) Secure a panel for Technical design review(s) (various preliminary design reviews are often held in advance of Gate 2

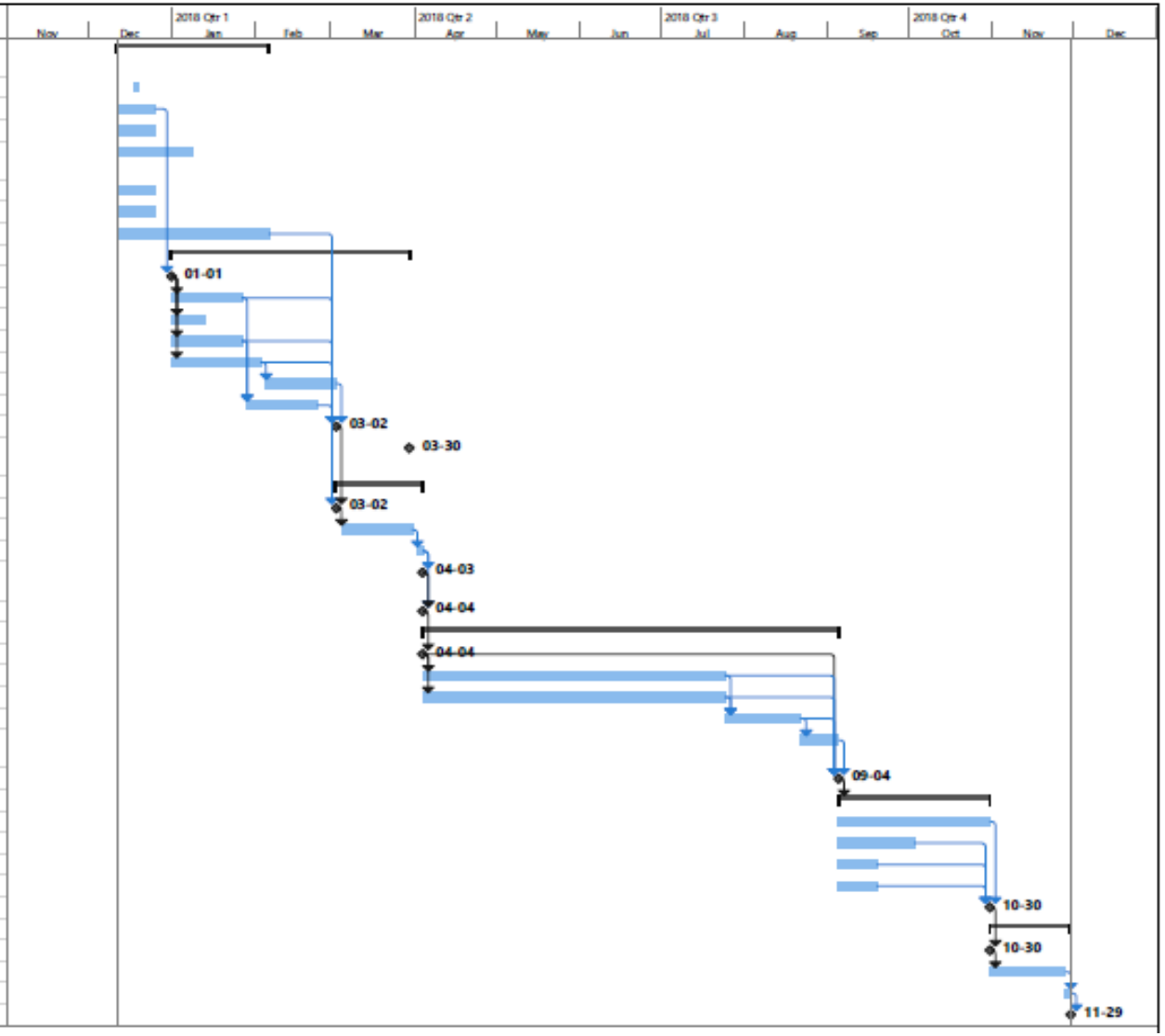
7) Technical Design review (Gate 2)

8) Revisions & proceed to manufacturing

After Dec. 2018:

Procurement, assembly & testing, installation, safety/operational review, commissioning.

| ID | Task Mode | Task Name | Duration | Start | Finish | Predecessors |
|---|---|---|---|---|---|---|
| 1 | | **Officially create new project according to TSOP-15** | **40 days** | **Tue 17-12-12** | **Mon 18-02-05** | |
| 2 | | submit project initiation sheet (=Gate 0) | 2 days | Mon 17-12-18 | Tue 17-12-19 | |
| 3 | | compile requirements document | 10 days | Tue 17-12-12 | Mon 17-12-25 | |
| 4 | | compile scope document | 10 days | Tue 17-12-12 | Mon 17-12-25 | |
| 5 | | define organizational structure, roles, responsibilites | 20 days | Tue 17-12-12 | Mon 18-01-08 | |
| 6 | | create management plan | 10 days | Tue 17-12-12 | Mon 17-12-25 | |
| 7 | | create first budget estimate | 10 days | Tue 17-12-12 | Mon 17-12-25 | |
| 8 | | define gate review committee | 40 days | Tue 17-12-12 | Mon 18-02-05 | |
| 9 | | **Compile CDR** | **64 days** | **Mon 18-01-01** | **Fri 18-03-30** | |
| 10 | | ready to start work on CDR | 0 days | Mon 18-01-01 | Mon 18-01-01 | 3 |
| 11 | | evaluate 3He pumping | 20 days | Mon 18-01-01 | Fri 18-01-26 | 10 |
| 12 | | heat exchanger design | 10 days | Mon 18-01-01 | Fri 18-01-12 | 10 |
| 13 | | evaluate direct pumping | 20 days | Mon 18-01-01 | Fri 18-01-26 | 10 |
| 14 | | check feasibility of ~100L liquid D2 | 25 days | Mon 18-01-01 | Fri 18-02-02 | 10 |
| 15 | | assess hazards (in particular LD2) | 20 days | Mon 18-02-05 | Fri 18-03-02 | 14 |
| 16 | | assess risks and necessary safety margins | 20 days | Mon 18-01-29 | Fri 18-02-23 | 11,13 |
| 17 | | all components merged into CDR | 0 days | Fri 18-03-02 | Fri 18-03-02 | 11,13,14,15,16 |
| 18 | | Results from Kapitza resistance measurement available | 0 days | Fri 18-03-30 | Fri 18-03-30 | |
| 19 | | **Review of CDR (=Gate 1 review)** | **22 days** | **Fri 18-03-02** | **Wed 18-04-04** | |
| 20 | | pass CDR to reviewers | 0 days | Fri 18-03-02 | Fri 18-03-02 | 17,8 |
| 21 | | reviewers prepare for review | 20 days | Mon 18-03-05 | Fri 18-03-30 | 20 |
| 22 | | perform CDR review | 2 days | Mon 18-04-02 | Tue 18-04-03 | 21 |
| 23 | | decide on cooling scheme: 3He vs direct pumping | 0 days | Tue 18-04-03 | Tue 18-04-03 | 22 |
| 24 | | passed Gate 1 review | 0 days | Wed 18-04-04 | Wed 18-04-04 | 22,23 |
| 25 | | **Mechanical design process** | **110 days** | **Wed 18-04-04** | **Tue 18-09-04** | |
| 26 | | start mechanical design | 0 days | Wed 18-04-04 | Wed 18-04-04 | 24 |
| 27 | | design cryostat superfluid helium | 80 days | Wed 18-04-04 | Tue 18-07-24 | 26 |
| 28 | | design cryostat LD2 moderator | 80 days | Wed 18-04-04 | Tue 18-07-24 | 26 |
| 29 | | formulate integration plan | 20 days | Wed 18-07-25 | Tue 18-08-21 | 27,28 |
| 30 | | design instrumentation concept (list of all sensors etc) | 10 days | Wed 18-08-22 | Tue 18-09-04 | 29 |
| 31 | | mechanical design completed | 0 days | Tue 18-09-04 | Tue 18-09-04 | 26,27,28,29,30 |
| 32 | | **Compile TDR** | **40 days** | **Wed 18-09-05** | **Tue 18-10-30** | **31** |
| 33 | | perform cryogenic safety analysis | 40 days | Wed 18-09-05 | Tue 18-10-30 | |
| 34 | | perform radiation/remote handling analysis | 20 days | Wed 18-09-05 | Tue 18-10-02 | |
| 35 | | specify controls requirements | 10 days | Wed 18-09-05 | Tue 18-09-18 | |
| 36 | | specify interlock requirements | 10 days | Wed 18-09-05 | Tue 18-09-18 | |
| 37 | | all components merged into TDR | 0 days | Tue 18-10-30 | Tue 18-10-30 | 33,34,35,36 |
| 38 | | **Review of TDR (=Gate 2 review)** | **22 days** | **Tue 18-10-30** | **Thu 18-11-29** | |
| 39 | | pass TDR to reviewers | 0 days | Tue 18-10-30 | Tue 18-10-30 | 37 |
| 40 | | reviewers prepare for review | 20 days | Wed 18-10-31 | Tue 18-11-27 | 39 |
| 41 | | perform TDR review | 2 days | Wed 18-11-28 | Thu 18-11-29 | 40 |
| 42 | | passed Gate 2 review | 0 days | Thu 18-11-29 | Thu 18-11-29 | 41 |




- Plan to complete technical design by late 2018 needs resource loading and input of new Project Manager.

# Key milestones (goals)

- Full merged CDR sent to reviewers — March 2, 2018
- Results of KEK Kapitza resistance and thermal conduction measurements — March 30, 2018
- CDR Review (=~ TRIUMF Gate 1 review) — April 4, 2018
- TDR completed — September 4, 2018
- TDR Review (=~ TRIUMF Gate 2 review) — October 30, 2018

# Ongoing R&D – technical tasks for CDR

- Temperature gradient in 4He.  Difficult to measure; analyze measurements with vertical source (ongoing).
- Kapitza conductance and temperature gradient measurement (KEK).  Experiment being designed and planned.  Probably 2-3 months, to be done early 2018.
- Neutron captures in 3He and Cu, additional radiation heat load to 3He pot.
- General layout and impact on mechanical design.
- Clogging.  Reportedly an issue in other cryostats.  Was an issue in our cryostat in summer 2017.  Solved!  Operation reliable for 1 month.  Issue is certainly related to purifier in 3He line and minimizing leaks.
- Suggestion that He-II source lifetime degrades over time due to freezing out contaminants.  Initial data imply not a problem.  Planned measurements interrupted.  Plan to do next year with higher priority.
- Other ideas:  purifier/getter for hydrogen, dual needle valves, remove needle valve and use orifice for JT, heater around orifice, …
- Key technology question of 3He fridge or direct 4He pumping needs more focus on direct pumping.  TRIUMF+KEK to work together on this.
- Remote maintenance, radiation effects.
- Create extensive list of issues to be tackled.  Task lists, and project management/tracking of tasks.

# KEK and Japan groups

- KEK
  - S. Kawasaki – UCN source leader
  - T. Okamura (& Y. Makida) – UCN source cryogenics
  - K. Mishima – neutron moderation, UCN transport, diamond nanoparticles, VCN
- RCNP Osaka
  - K. Hatanaka – cospokesperson; I. Tanihata – EC member
  - Support to A. Konaka and E. Pierre (also TRIUMF)
  - Possibility to grow group in the future (international programs)
- Nagoya U
  - M. Kitaguchi & H. Shimizu – VCN line, CN and VCN characterization, quantitative understanding of neutronics, transport and UCN storage,
  - Possibility to grow group in the future
- Other groups
  - New faculty members in Japan
  - Very welcoming of new collaborators from Japan institutes

# Ideas for further collaboration/communication

- Short-term
  - Weekly skype meetings are not enough to complete CDR.
  - Continue technical discussions this afternoon and Monday, Dec. 18, 2017.
  - New UCN source “workshop” (working group) at TRIUMF -- Jan. 15-19, 2018.
- Longer-term
  - Continue to build relationship with Nagoya group through student projects.
  - Build groups at Japan universities and KEK.
  - Promotion of UCN science in Japan at conferences and workshops.

# Funding scenarios in Japan

- Key question is funding of He-II cryostat.
- Cost ~$500kCAD =~ 40MJPY.
- Could be supported over multiple years.
- JSPS support?  KEK support?

# Request to TRIUMF

- Maintain resource commitments at levels to move project forward
  - Cam Marshall is still an absolute requirement! (Engineer with extensive cryogenics experience.) $LD_2$ cryostat and engineering oversight (safety aspects). Additional cryogenics support would be welcomed.
  - Transfer of proton beamline and target responsibilities to Accelerator Division
    - Operations is close to completing transfer. Maintenance.
  - Completion of lingering hardware:
    - Raster magnet (if necessary) for 40 uA operation, optics studies.
    - Target cask.
- Retain $1.6M support in present 5-year-plan (2015-2020)
- Consideration of collaboration request for next 5-year-plan (2020-2025)
  - Additional TRIUMF BAE's
  - Maintain UCN technical staff once CFI NIF/IOF support would be expended
  - Second liquefier, "upgrade" including cold return to UCN source

# Request to KEK

- Approval in principle of the plan to reach “TDR/Gate 2”.
- We can reach this stage with existing resources.
  - S. Kawasaki is a key resource and leader of most important part of experiment.
  - Cryogenic expertise necessary:  T. Okamura, Y. Makida.  Please keep/increase support from IPNS Cryo group.
  - K. Mishima (Materials Science, IMMS):  Extensive CN, VCN, UCN experience. Generator of new ideas (diamond nanoparticles, VCN line, …).  Needs permanent position.
- After this time we expect to need increased resources (after ~Dec. 2018).
  - Need to complete UCN source cryostat construction & testing.
    - Estimate $500kCAD =~ 40MJPY cost of UCN source cryostat.
    - Construction at e.g. JECC-Torisha; testing at KEK.
- Please commit to finding a solution to fund new He-II cryostat upon successful completion of TDR/Gate 2, via KEK+JSPS (scenarios discussed in parallel session).