--Hyper K--
Calibration Source Deployment System

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On behalf of
The Calibration WG

Key Points

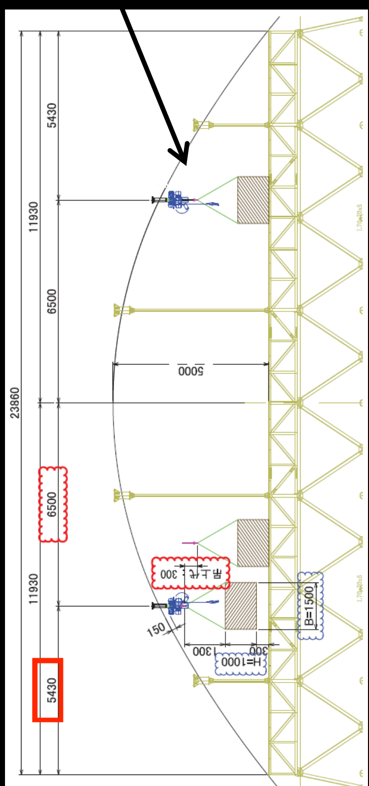
- Hyper-Kamiokande layout constraints
- Existing deployment systems
- System requirements
    - Geometric Coverage
    - Positional Accuracy
    - Interchangeability of sources
    - Robustness and automation
    - Geometric, weight and cost constraints
- Source positioning system

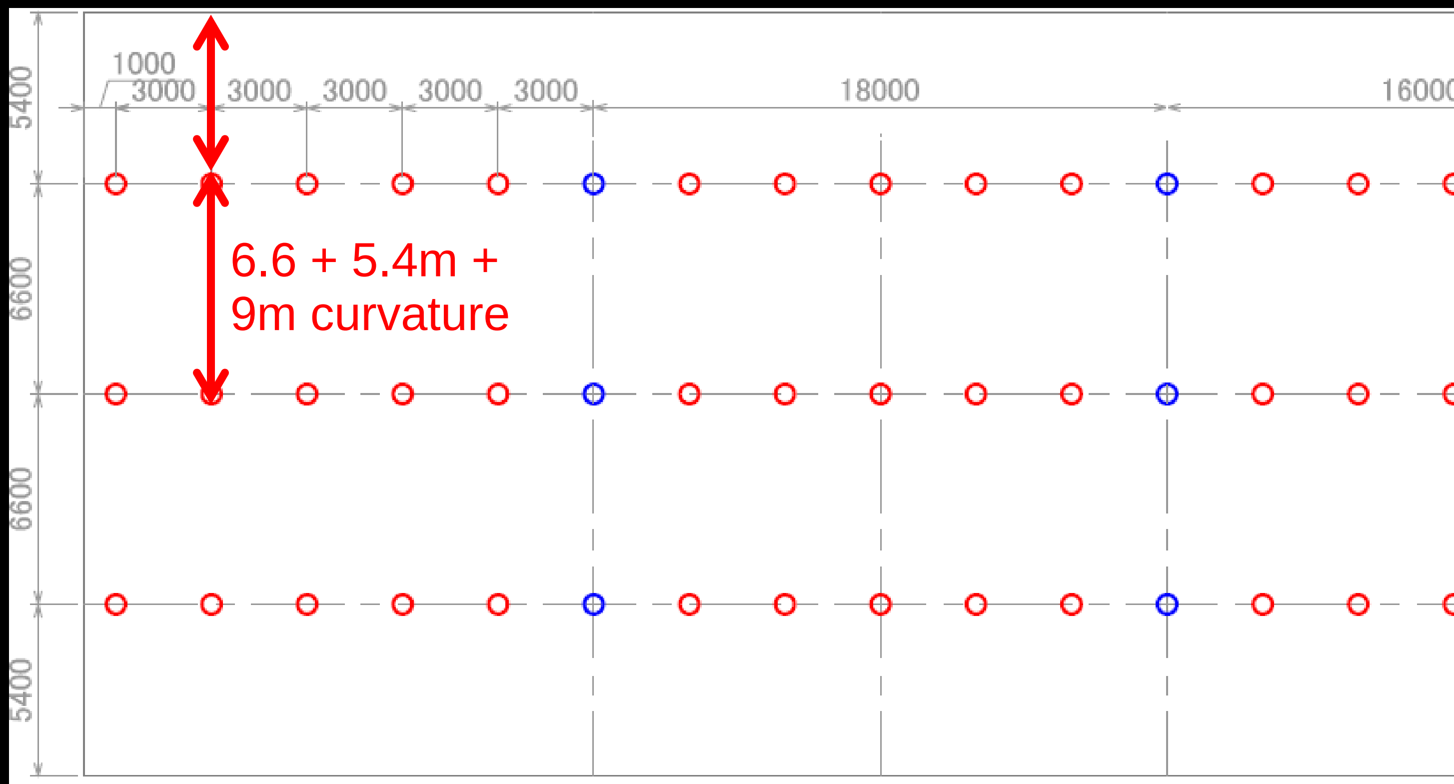
HK Design Review

Crane: only
6.6m off-center
5.4m+9m more

Rod max. length:
Only about 5 m
Above the deck

“Deuterium-Tritium
neutron Generator”
Expensive (one ?)



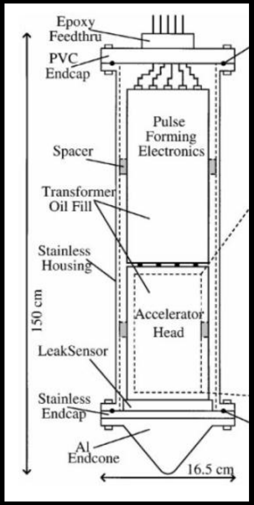


Multiple ports
Significantly away
From each other

Maximum weight
100 kg/m^2 and
1000 kg/m^2

Calibration Sources

- DTnG:
  - Absolute gain calibr.



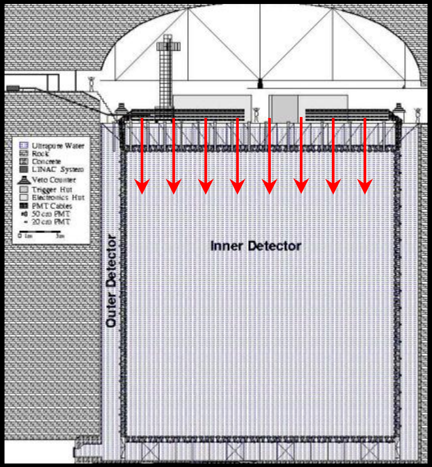
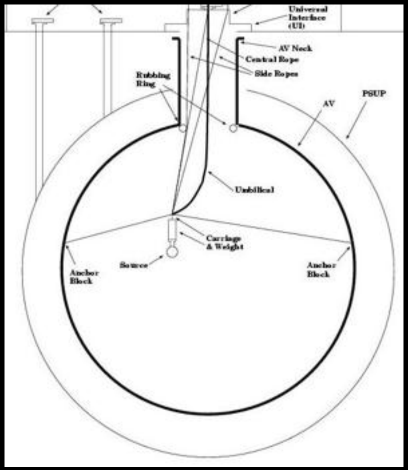
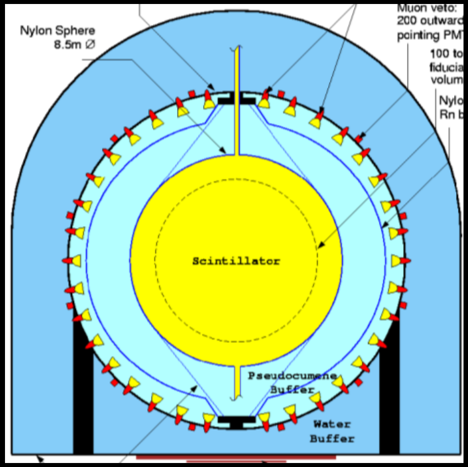
Thermo Scientific:
- A-211 no longer available
- Possibly we can use the following:
  - MP-320 or
  - API-120

- SK Nickel source

- Optical Sources:
  - Diffuser Ball
    - relative gain calibration
    - charge linearity calibration
    - timing calibration
  - Scintillation Ball
    - HV determination
    - CCD positioning LED

- No plans for LINAC

Current Deployment Systems

Super-K	SNO	Borexino
		

Super-K

Cylindrical and Symmentric

1D calibration System (manual)

Volume Calibrated: ~ 50k m^3

SNO

Spherically Symmentric

2D calibration System (manual)

Volume Calibrated: ~ 1k m^3

Borexino

Spherically Symmentric

3D calibration System (manual)

Volume Calibrated: ~ 0.3k m^3

Towards HK

Super-Kamiokande

Great
Good
Poor

- Geometric Coverage
- Positional Accuracy
- Interchangeability of sources
- Robustness and automation
- Geometric, weight and cost constraints

Towards HK

SNO

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Towards HK

Borexino

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Towards HK

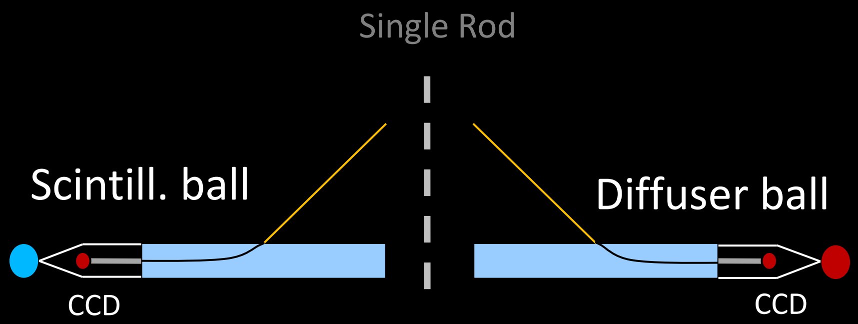
What do we need to achieve
and
HOW ?

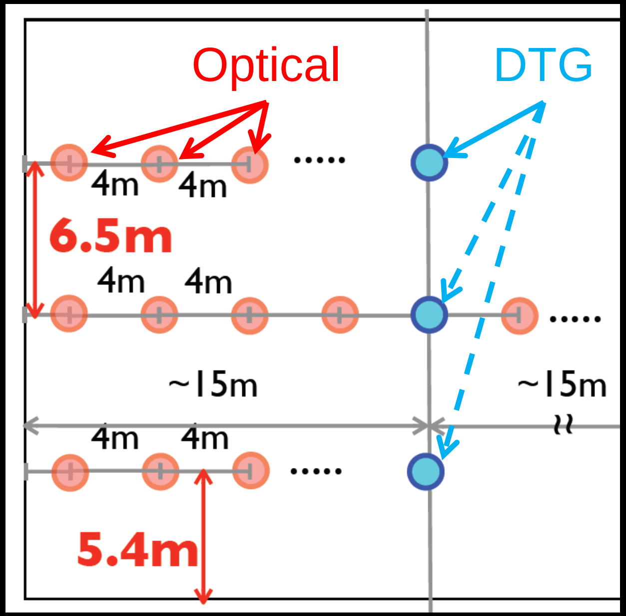
- Robustness and automation
  - The system must be personnel-independent due to its size and geometry
  - Use of the CCDs will give real time position information
- Interchangeability of sources
  - Correlated with the above statement
- Weight and cost constraints
  - Top deck can handle only certain kg/m^2

Towards HK

An Idea

- Construct multiple light-weight systems with all the optical sources already mounted
- The heavier neutron source (DTnG) could be made portable on a crane (# of detectors and its dimensions)





Towards HK

- The Daya-Bay automatic deployment system

Neutron source (Am-C)
+ Gamma source (Co-60)

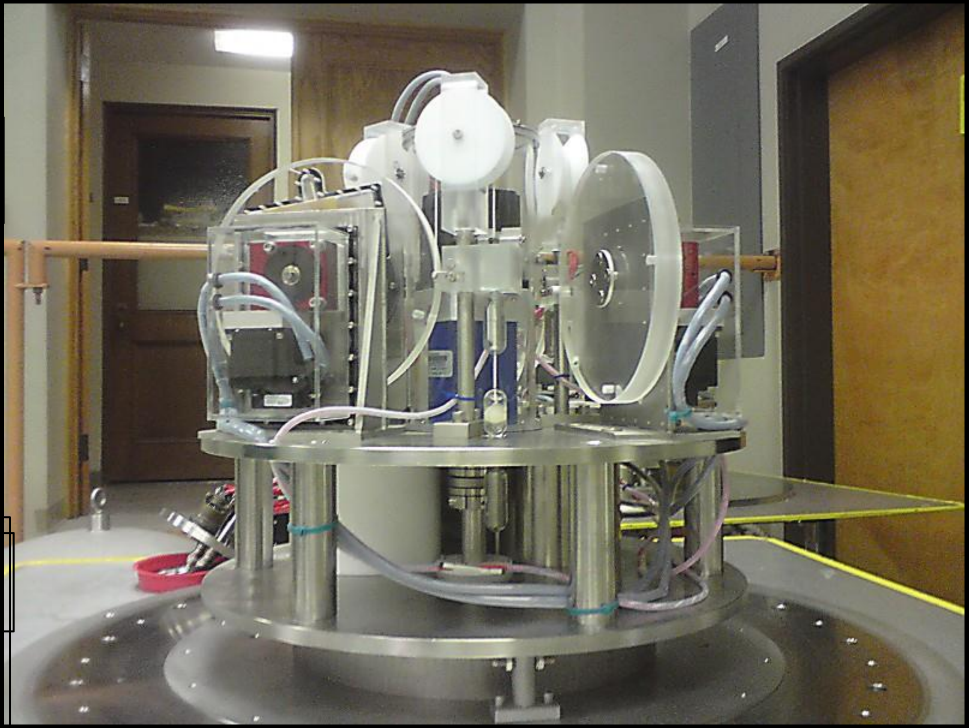
Limit switch:
Limits the range of
source motion

Gamma source (Ge-68)

Load cell: Monitors
tension in the cable

Stepper motor with
worm gear box

LED (~430 nm)
with diffuser ball



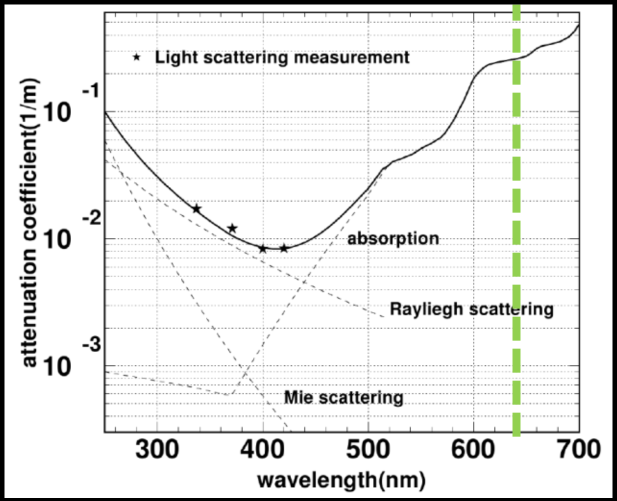
Camera with
IR LEDs:
mounted on
the inside of
the bell jar

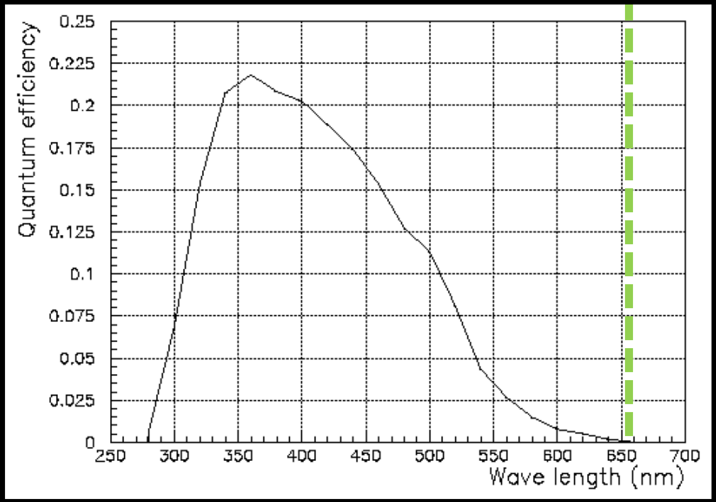
Borated-Polyethylene
neutron shield

Stainless gamma
shield

Source Positioning

- Adopted from Borexino, CCD cameras will be implemented, the remaining problem is the long distances in HK:
  up to 25 meters (curvature 9m + 5.4m)
  This eliminates the possibility to go IR in H_2O:





Source Positioning

- Adopted from Borexino, CCD cameras will be implemented, the remaining problem is the long distances in HK:
  up to 25 meters (curvature 9m + 5.4m)
  This eliminates the possibility to go IR in H_2O:

660nm used in BX
Should give enoug
Light for the CCD

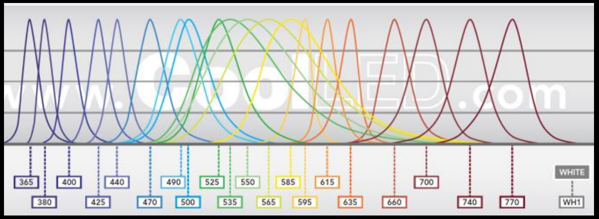
Anything > 700nm
Would require
High Watt LEDs

	Wv[nm]	CCD	PMT
		25m	25m
BX	600	15.619%	0.558%
BX	800	2.873%	0.001%
HK	600	0.472%	0.017%
HK	800	0%	0%

Light Sources

- As for the source of light, we can choose between regular LEDs or an automatic leds driver (PicoQuant), both computer controlled:

1) LEDs:



- No fiber required
- Needs custom control

- Cost ~ mainly manpower

2) PicoQuant:

- Flexibility with WaveL
- Drives up to 8 heads

- Cost ~ $35k

Key Issues

- How to reach 14.4m into the edge of the FV
  - Perhaps: -2m(FV) - 2m(at z=10m) = 14.4-4 = 10.4m
- What to do with the heavy-weight sources
  - Nickel: on an independent deployment system
  - DTnG: perhaps the SNO solution with CO_2 carrier (arXiv:nucl-ex/0109011)
- How to achieve full automation
  - Either a deployment system with all the sources on, or
  - The Daya-Bay –like autonomous system.

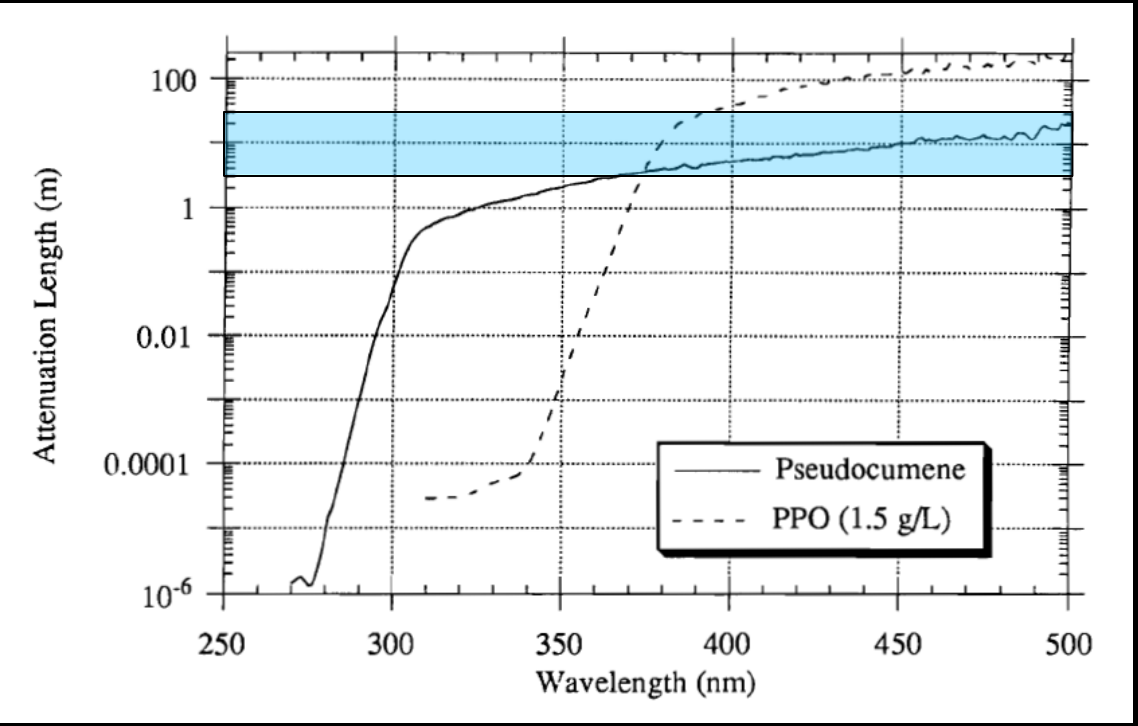
Summary

- Identified pros and cons of the existing calibration systems (SK, SNO, Bx, Daya-Bay)
- Identified minimal requirements for the HK calibration system
- Work in progress on a conceptual design
- Closely collaborate with the physics WG:
  - determine new requirements for HK
  - adapt conceptual design to that

Backup

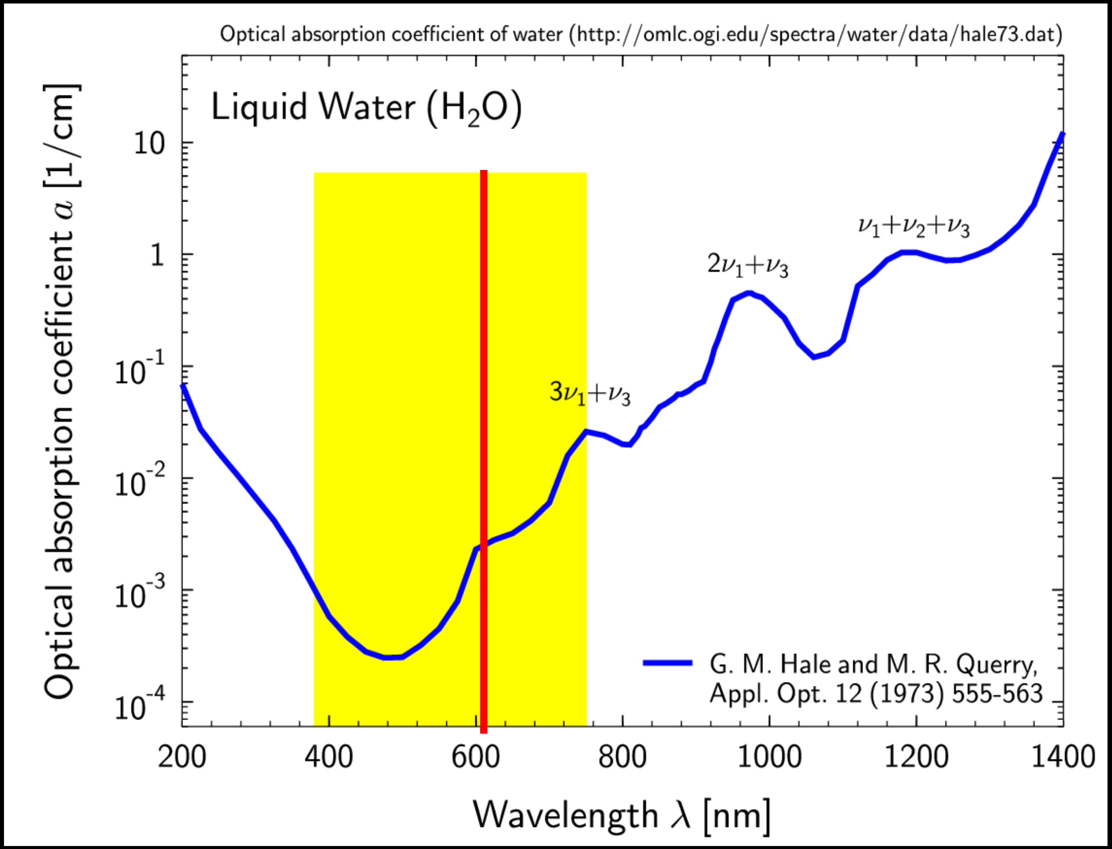
Borexino CCD

- Laser wavelength: 635nm (visible red)
- Intensity: 500mW (about 1.6×10^{18} photons/sec)
- Pulse: 150ms
- 30% of light visible at distances of ~10m
- No need to turn PMTs OFF



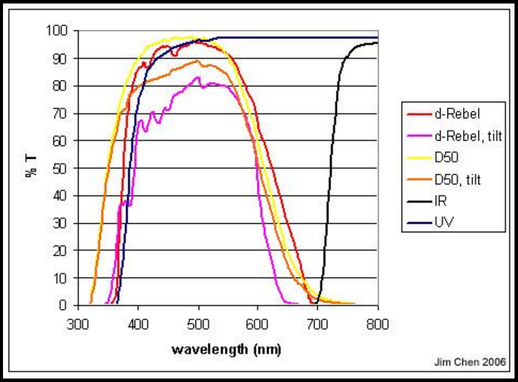
Hyper-K Cameras

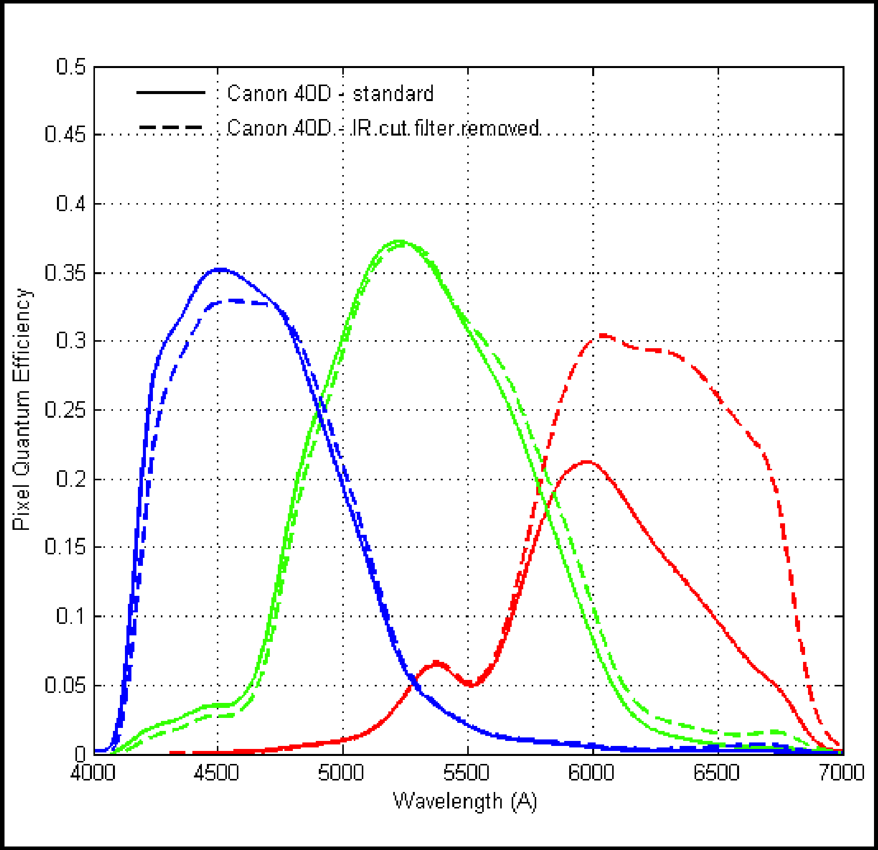
- Absorption coefficient increases rapidly with wv. in water
  - At 500nm ~ 3x10-4 [1/cm]
  - At 600nm ~ 2x10-3 [1/cm]
  - At 700nm ~ 4x10-3 [1/cm]
  - At 800nm ~ 2x10-2 [1/cm]



Hyper-K Cameras

- CCD Quantum Efficiency (commercial CCD)
  - Non-modified Trans.



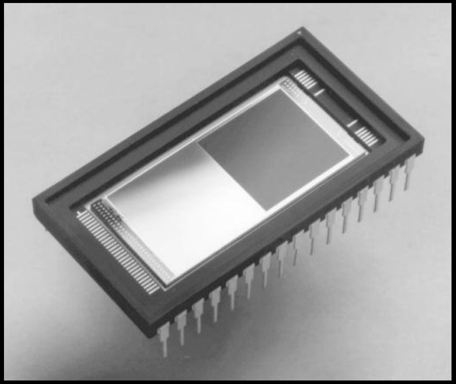


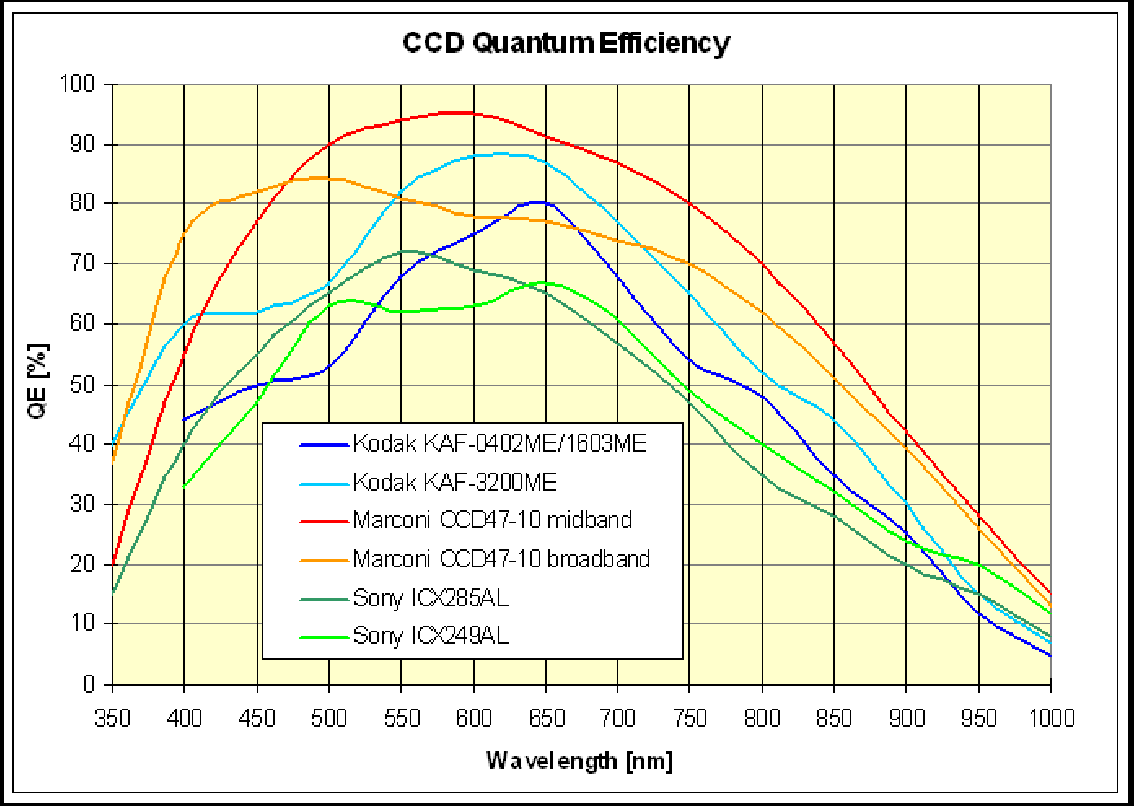
  - Modified Filter:

    QE on the order of 20-30%

Hyper-K Cameras

- CCD Quantum Efficiency (professional CCD)





- QE even at 60-90%

Hyper-K Cameras

- Light intensity loss assuming certain intensity of the laser
  - Comparison for PC and Water at distance 0 and 25m

	Wv[nm]	CCD	PMT	CCD	PMT
		0m	0m	25m	25m
BX	600	70%	2.5%	15.619%	0.558%
BX	800	35%	0.01%	2.873%	0.001%
HK	600	70%	2.5%	0.472%	0.017%
HK	800	35%	0.01%	0%	0%

  - At 600nm the remaining amount of light should be still sufficient for the CCD Camera

Laser Diode

Light source

- PicoQuant *ns* or *ps* diode laser drivers

Modular system, drives up to 6 laser heads

Various operation modes: Synchronous, delayed, sequential

Repetition rate from single shot to 40 MHz (optional 64 or 80 MHz)

Laser power adjustable via individual driver units

Laser heads for wavelengths between 375 nm and 1990 nm

$18k head drive and basic rack

+

x $3k each drive

+

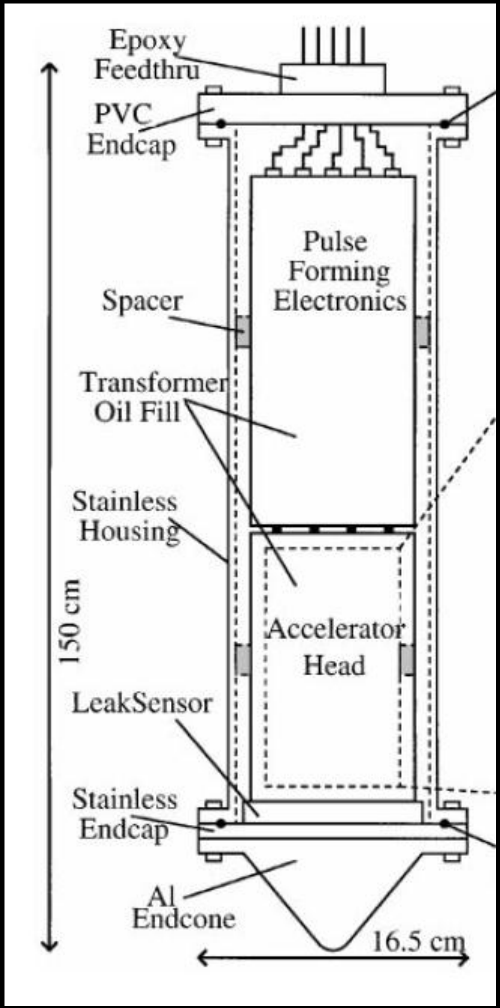
x $5k each head

Calibration Sources

Requirements

- Gain calibration
  - HV determination (scintillation ball)
  - Absolute gain calibration (20 - 150cm neutron source)
  - Relative gain calibration (diffuser ball- N_2 laser)
- Charge linearity calibration (diffuser ball -off-center)
- Timing calibration (diffuser ball)
- OD calibration
- Water transparency measurement
  - Light scattering using a laser (light injection from the top)
  - Using cosmic ray muons (no hardware needed)
- Energy scale (LINAC or DT for ~10MeV range)

DTG neutron Generator



Currently used in SK

Thermo Scientific

- Custom MF Physics M A-211
- Original Cost: ~ $80k (From B. Svoboda: "Part of the cost was to repackage the electronics to be operated remotely (the pulser had to located at the source rather than with the control panel)")

A-211 no longer available from Thermo-Sc

14MeV neutrons

An ultrasonic water sensor prevents operation of the generator when not in detector.

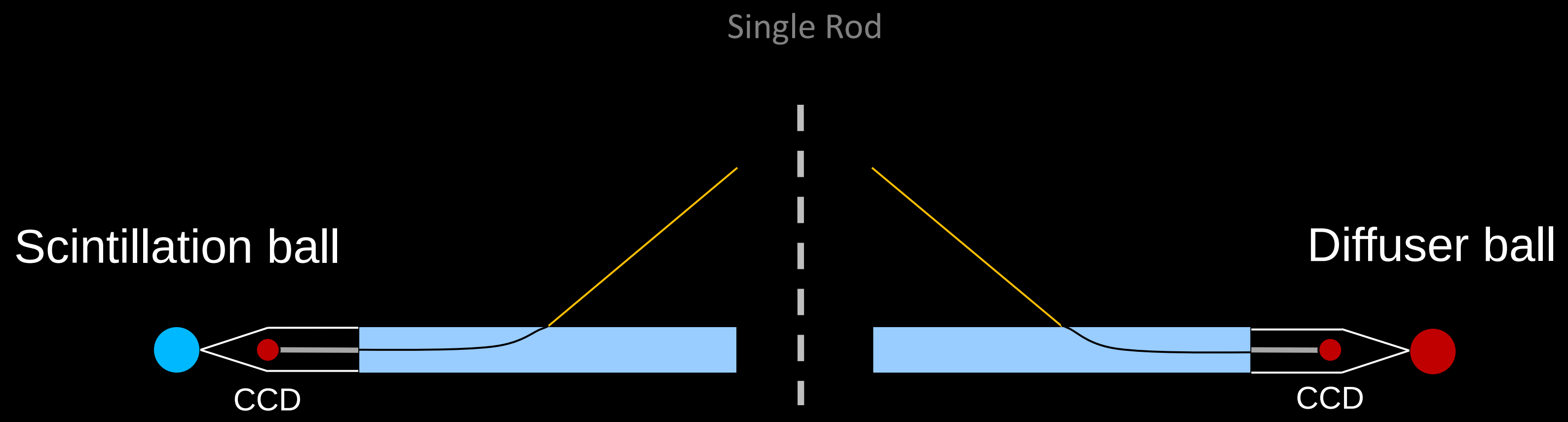
DTG- MP 320

Specifications	
Yield	1.0E+08n/s (Neutron)
Neutron Energy	14MeV
Duty Factor	5% to 100%
Voltage	90kV (Maximum Accelerator)
Current	60µamps (Beam)
Power Supply	Integral
Neutron Module	4.75 x 22.5 in. (12.07 x 57.15cm)
Module	Integral, digital (Control)
Safety Features	Keylock: on/off Emergency: on/off Normal-open and normal-closed interlocks Pressure switch
Remote Control	RS-232/RS-485
Weight [ENGLISH]	12kg
Weight [METRIC]	26.46 lb.

DTG- API 120

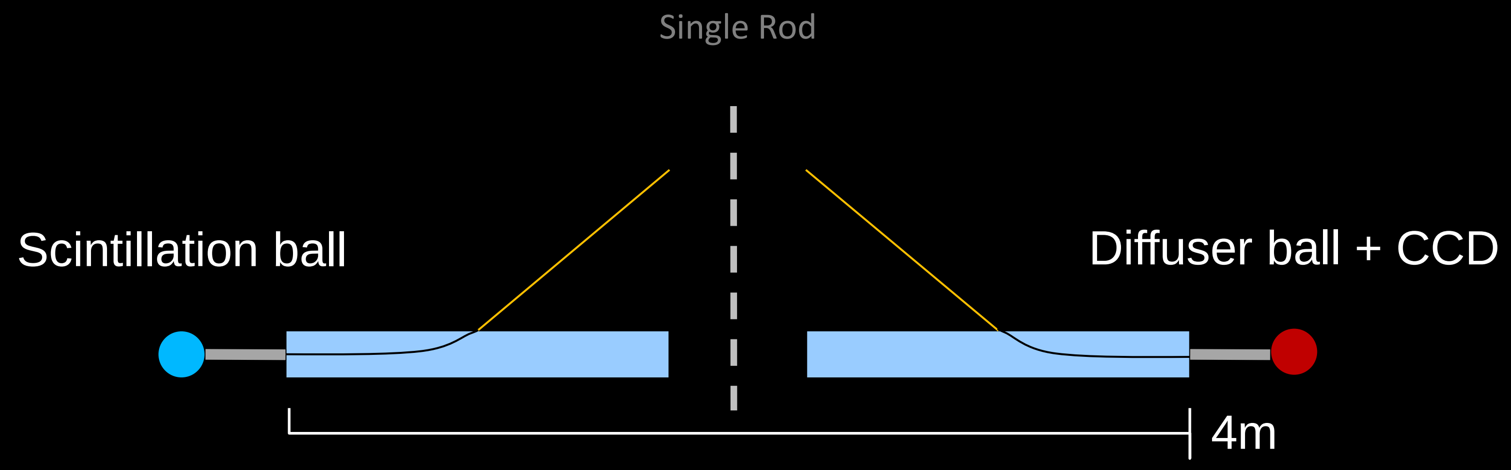
Specifications	
Neutron Yield	2.0E+07n/s
Neutron Energy	14MeV
Subtended Neutron Angle	~60 degrees, others available
Typical Lifetime	1200 hours @ 1 x 10cn/s
Operating Mode	Continuous only
Maximum Accelerator Voltage	90kV
Maximum Beam Current	50µA
Power Supply	Integral
Neutron Module Size	3 in. (7.62cm) diameter
Control Module	Integral, digital
Safety Features	Keylock: on/off Emergency: on/off Normal-open and normal-closed contacts Pressure switch
Remote Control	RS-232/RS-422 (optional)
Total Weight	33 lb. (15kg)
Software	Open source text or GUI
Electronics	Radiation tested to 80,000+ hours
Configuration	OEM-type available

Calibration Design I



- DB + CCD-LED and SB + CCD-LED
  - Individual fibers for the Scintillation and Diffuser balls
  - Separate Diffusers for two CCD positioning sources
- Advantage
  - Precise 3D position determination

Calibration Design II



- DB/SB + CCD-LED
  - Scintillation ball for the Xe lamp only
  - Diffuser ball shares the fiber for CCD and calibration lasers
- Advantage
  - Simplified hardware