Cryogenic Safety – Fundamentals

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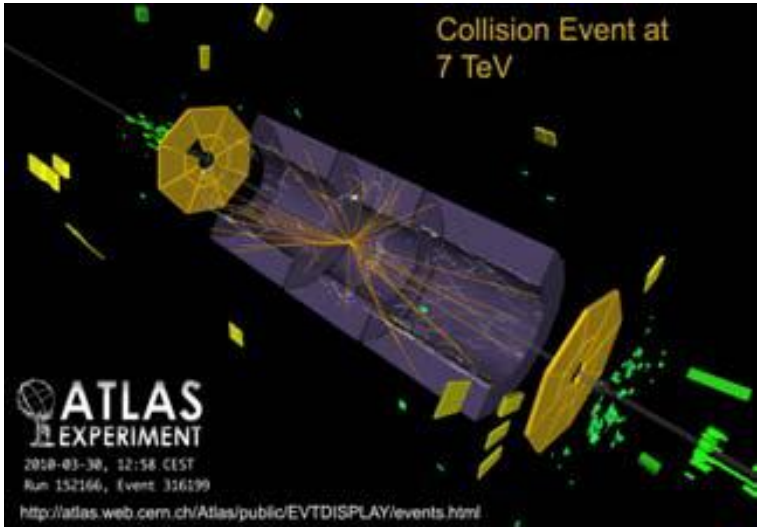
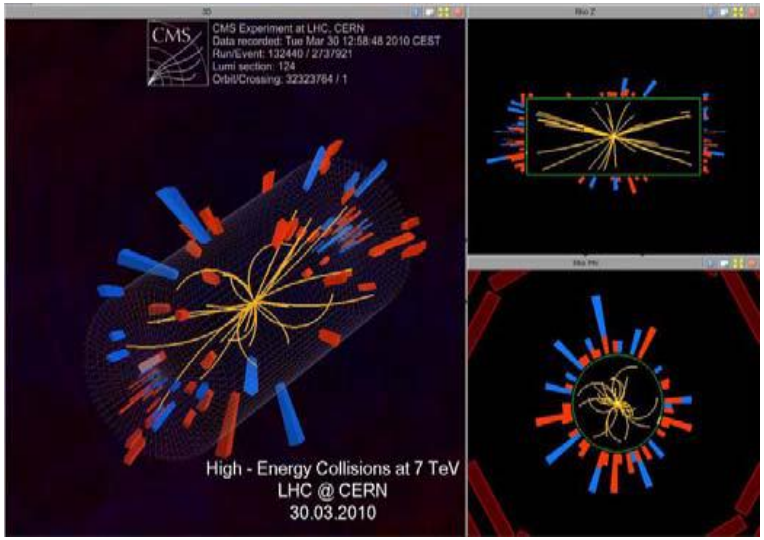
Training objectives

Be able to identify existing risks in their work area, applying safety measures to minimize risks, and react efficiently in case of malfunctioning.

Cryogenics at CERN
Main users – Physics detectors



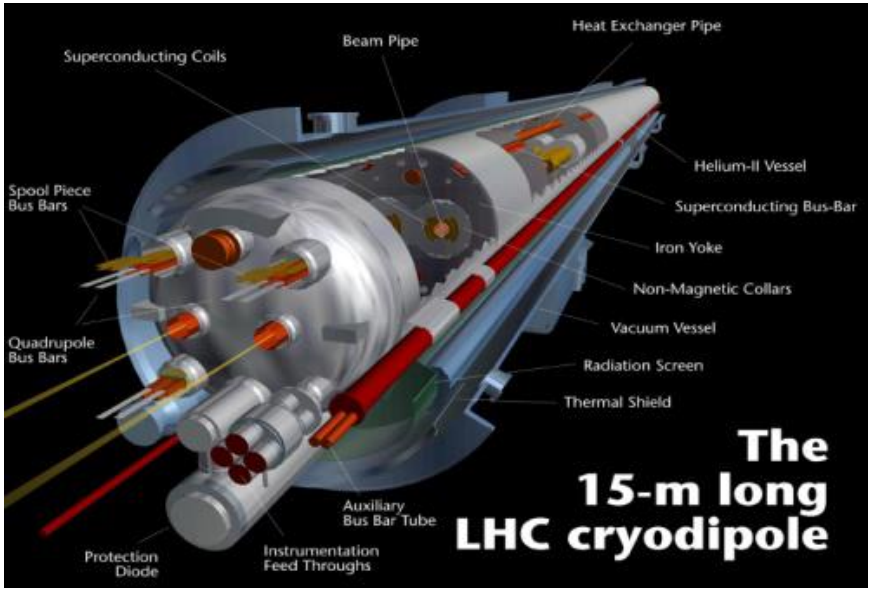
Superconducting coils of LHC detectors (ATLAS, CMS)



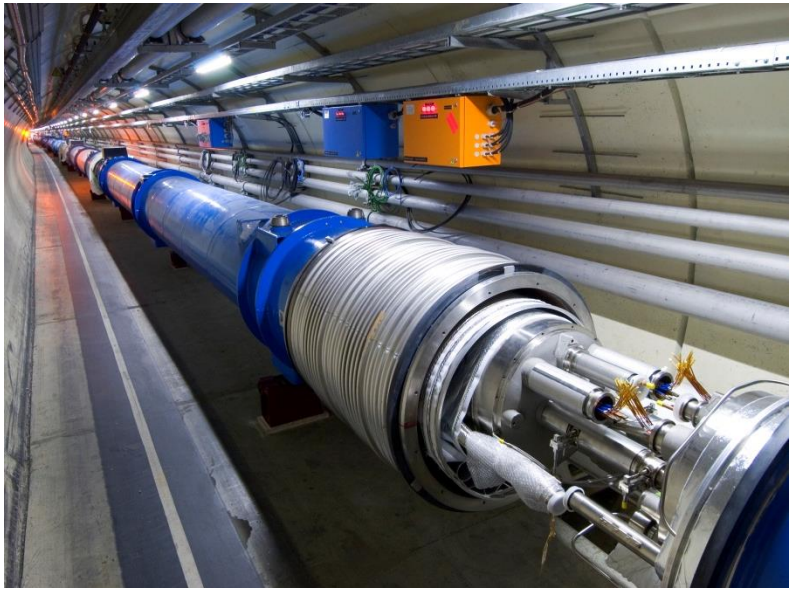
Different types of cryogens (Helium, Nitrogen and Argon)

Cryogenics at CERN

Main users – Accelerator complex



Superconducting magnets of LHC accelerator



Helium at different operating temperatures (thermal shields, beam screens, distribution and magnets,…)

Cryogenics at CERN
Refrigeration plants, liquefiers, storage

- Refrigeration plants (e.g., LHC, ATLAS, CMS)
- Refrigeration units (e.g., LHC cold compressor units)
- Liquefiers (Central Liqu., SM18, ISOLDE, CAST...)
- Storage vessels: warm compressed gas or cryogenic
- Networks of distribution lines (warm and cryogenic)

Cryogenic Hazardous Events

Thermo-physical properties

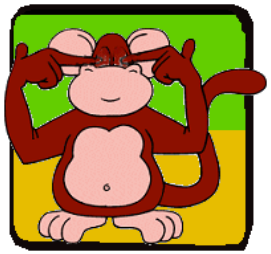
Fluid	^4He	N_2	Ar	H_2	O_2	Kr	Ne	Air	*Water*
Boiling temperature (Tb) in (K) at 1.013 bar	4.2	77.3	87.3	20.3	90.2	119.8	27.1	78.8	***373***
Latent heat of evaporation at (Tb) in kJ/kg	21	199.1	163.2	448	213.1	107.7	87.2	205.2	***2260***
Ratio volume gas (273 K) /liquid	709	652	795	798	808	653	1356	685	***…..***
Specific mass of liquid (at Tb) in kg/m3	125	804	1400	71	1140	2413	1204	874	***960***

1 l of cryogenic fluid expands to about 700 l (0.7 m^3) of gas when warmed to ambient temperature (at constant pressure)

Demonstration: LN_2 properties: clear liquid, mist of moisture

Cryogenic Hazardous Events

Cryogens – Warning signs



Eyes

Ears

Nose

Liquid or gaseous cryogens are odourless and colourless.

Surface temperatures are not obvious

The human senses do not warn!

OFTEN ONLY secondary signs:

Ice, water, air condensation (!) → indicates cold surfaces

Fog → may indicate a leak of liquid or gazeous cryogens

Cryogenic Hazardous Events

Physiological – Contact burns/frost bite

Contact burns

Similar to hot burns

Frost bite → freezing of skin and body party:

Permanent damage and discoloration
Exposure time on the order of **seconds**, not minutes!

Inhalation

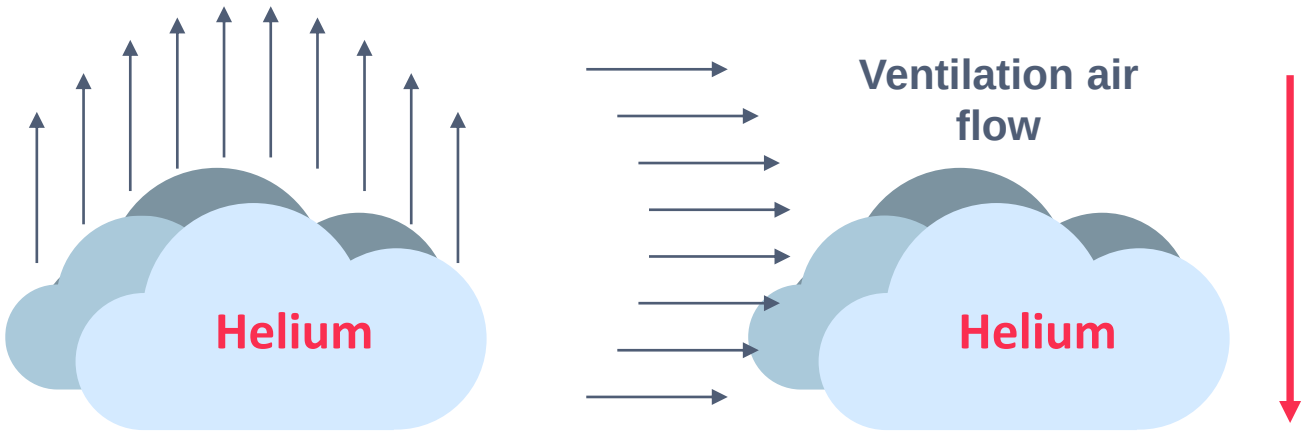
Inhalation of cold vapour can cause damage to the lungs and may trigger an asthma attack

Due to the low viscosity and surface tension of cryogens, it will flow through clothing much faster than water.

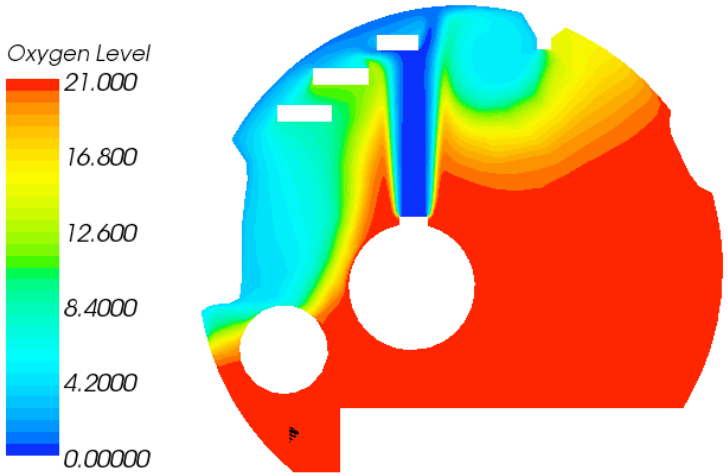
Demonstration: Leidenfrost effect fingers, cold surfaces, gummy bears

Cryogenic Hazardous Events

Cryogens - Discharge



Safer location at the floor

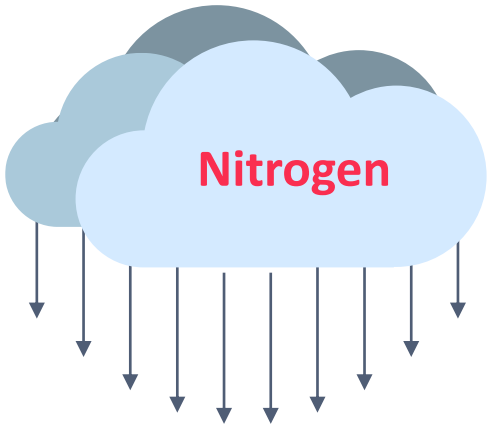


Simulated blow out in the LHC tunnel cross section

- Helium forms clouds while evaporating that move up, mixing rapidly with air
- Helium gas accumulates on the top T>40 K
- **Displacement of Oxygen!**

Cryogenic Hazardous Events

Cryogens - discharge



Safer location is at the top

- Argon and nitrogen fall downwards when discharged, forming clouds
- Avoid confined spaces in pits underground channels etc.

Demonstration: Balloons air and helium

Cryogenic Hazardous Events
Technical risks

Build-up of pressure

- Pressure can be released when thermal loads are beyond normal operation due to:
  - Fire
  - Loss of insulation vacuum
  - SC magnet resistive transition (quench)
  - Return line blocked

- Release of cryo-pumped gases during warm-up (air leaks)

Use pressure-relief devices to protect both the fluid volume **and** vacuum vessel against overpressure **is mandatory.**

Cryogenic Hazardous Events

Pressure rise

Explosion of a Dewar with 50 L - 2005

Example of a Dewar LN2 50L

Demonstration: Table tennis ball, film box

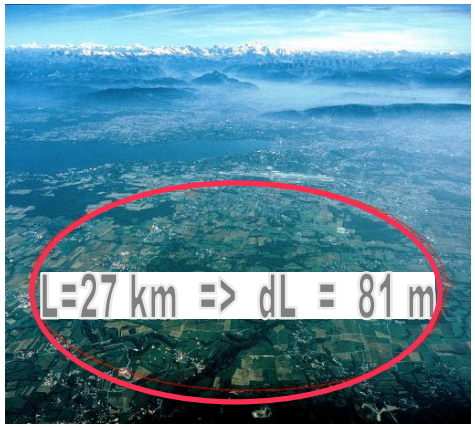
Cryogenic Hazardous Events
Technical risks

Embrittlement

- Some materials become brittle at low temperature and rupture when subjected to loads
- Protect surrounding equipment/structures from crogens discharge.

Thermal contraction (293 K to 80 K)

- Stainless steel: 3 mm/m
- Aluminium: 4 mm/m
- Polymers: 10 mm/m



Demonstration: Rubber tube, Al plate hole

Cryogenic Hazardous Events
Technical risks

Combustion / Fire

- Use of flammable cryogens (e.g. Hydrogen).
- Liquid oxygen can cause spontaneous combustion. Adheres to clothing and presents an acute fire hazard.

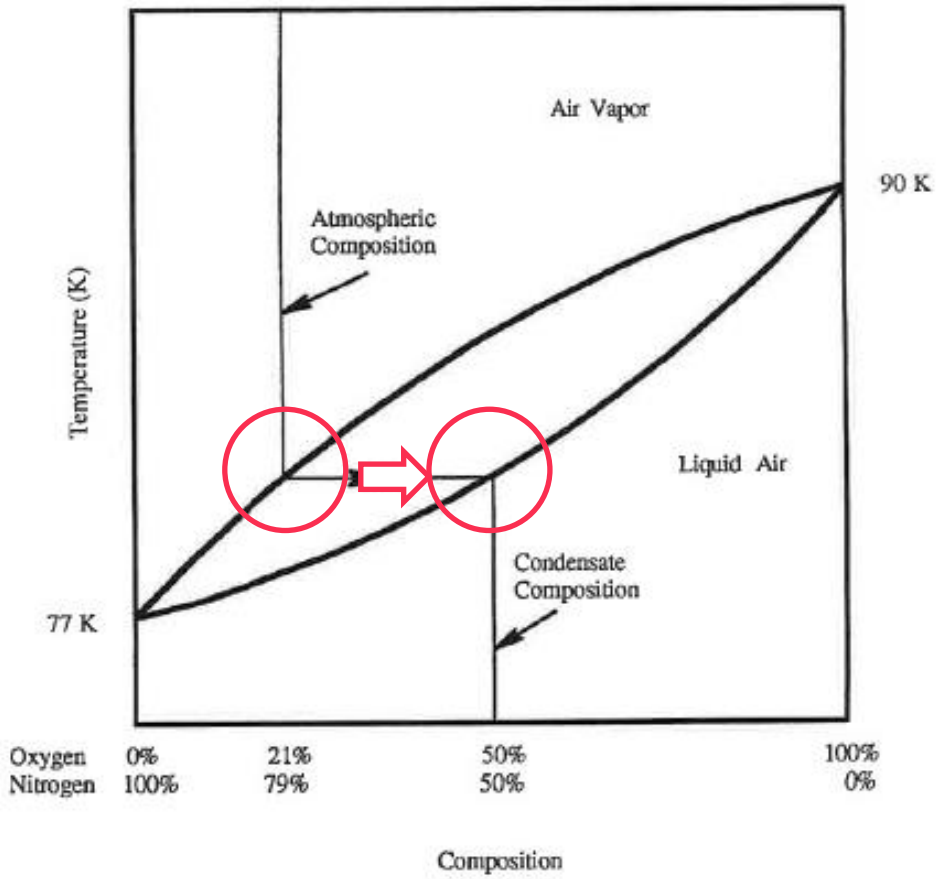
Condensation of atmospheric gases

- Innappropriate insulation or discharge of cryogens can lead to oxygen enrichment
- Mainly observed at tranfer lines and during filling operations

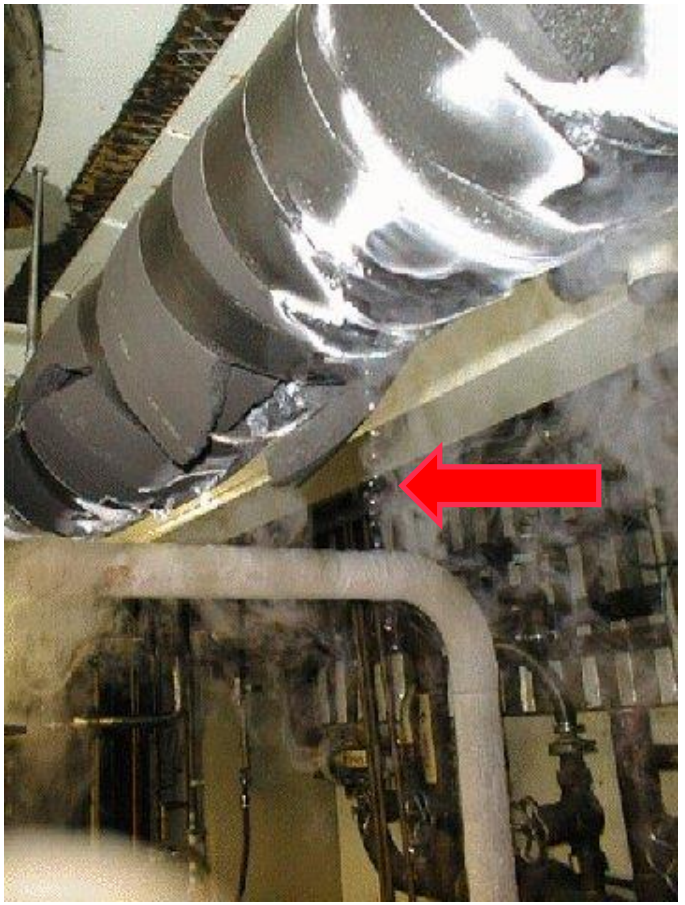
  (liquid air → **50% O_2** instead of 21% in atmospheric air)

Cryogenic Hazardous Events

Condensation of atmospheric gases – Oxygen enrichment



From: F. Edeskuty, Safety in the Handling of Cryogenic Fluids



Demonstration: Oxygen enrichment at cone

General Safety Practices
General practice

- Use only containers and systems specifically designed for these products!
- Transfer of cryo-liquids only in well ventilated areas => ODH!
- Materials must be compatible with the cryogen and the low temperatures.
- All cryogenic systems, including piping and vacuum space must be equipped with pressure-relief devices to prevent excessive overpressures.

Demonstration: Stainless steel Dewar example

General Safety Practices
General practice

Wear Personal Protective Equipment (PPE)

- Safety glasses (or face shield)
- Cryogenic gloves → loosely fitting
- Cryogenic apron
- Full length pants that extend over shoe tops
- Closed-toed shoes that are impermeable to liquids, such as leather, or covered with liquid proof shoe covers

PPE must be clean, free of oil and grease

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Demonstration: LN_2 through fabric

Cryogenic Hazardous Events
Oxygen Deficiency Hazard (ODH)

Actions

- Vent discharged cryogenic fluids to safe locations outdoors (use of relief lines)
- Equipment/system leak tightness
- Ventilation/extraction systems
- Oxygen deficiency hazard monitoring (ODH detectors)
- Emergency procedures & evacuation plan
- Use self-rescuing mask (PPE for long exposure to lack of oxygen – LHC tunnel) :
  Special HSE training required!

Keep evacuation paths free

Follow evacuation / exit panels

Keeping in mind the movement of cold gas clouds

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Thank you for your attention!

Questions ?


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