Polarized Target
for
COMPASS Drell-Yan program

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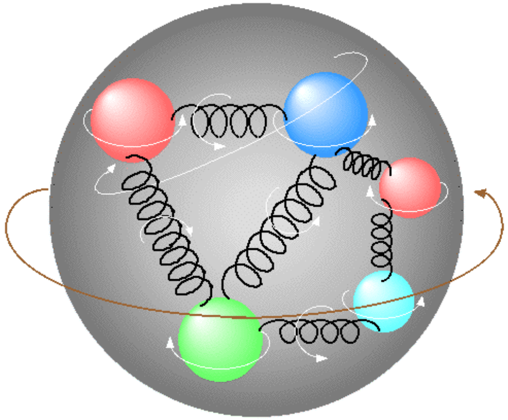
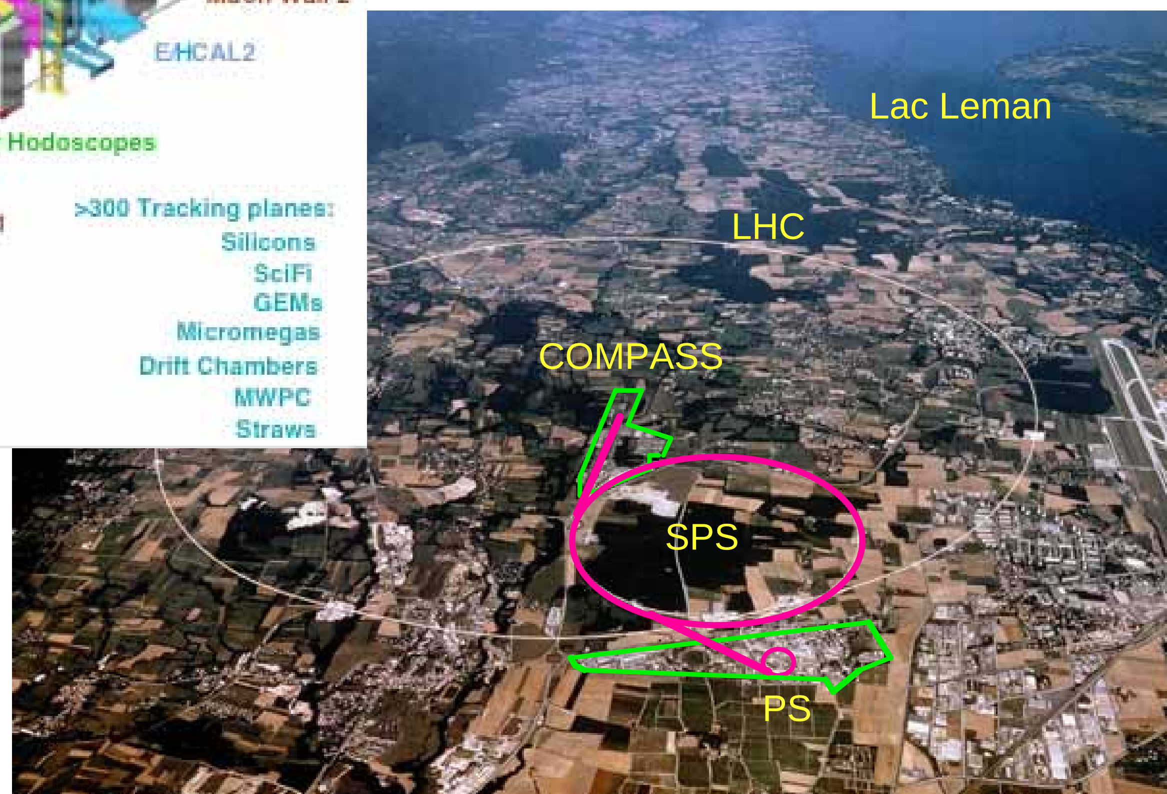
Outline

- Introduction of the Drell-Yan program at COMPASS
- COMPASS Polarized Target
  - experimental condition
- Multiplicity of incoming pion beam
  - estimation
  - test beam in 2007
- The beam spot size
- New target cells idea
- Summary

CERN and COMPASS



Study of the nucleon spin structure



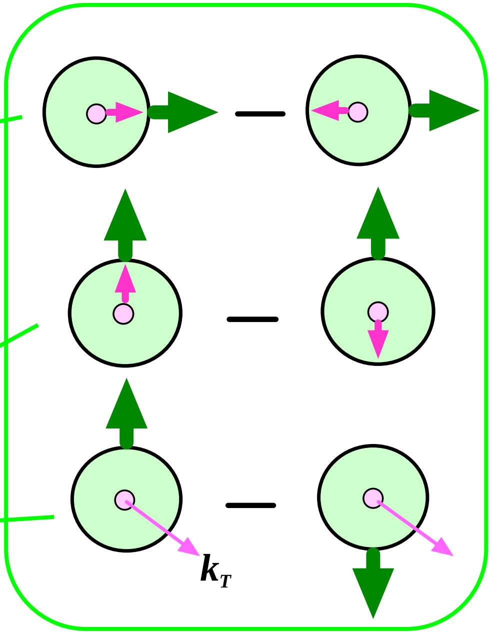
The COMPASS experiment

muon program (2002 ~ 2007) with polarized muon beam

Longitudinal polarized target

- gluon spin distribution: ΔG
- quark helicity distribution : $\Delta q(x)$

Since SMC experiment



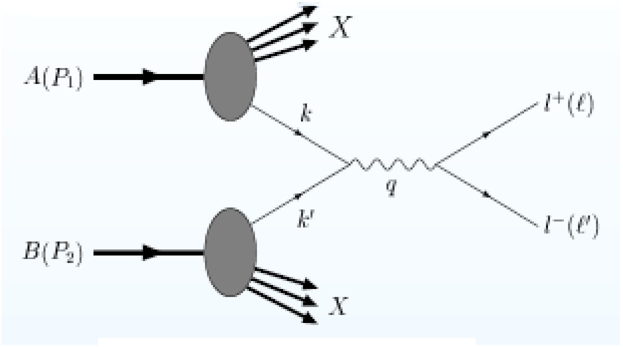
Transversal polarized target

- quark transversity distribution : $\Delta_T q(x)$
- Sivers function : $f_{1T}^{\perp}$

Quark orbital angular momentum

move to Drell-Yan program

with pion beam and
transversally polarized target



Drell-Yan process

Motivation ~ Transversity and Sivers function ~

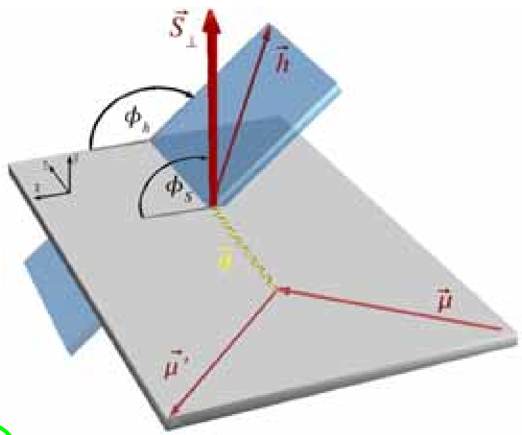
SIDIS

many components of transverse target spin dependent azimuthal modulations

$$A^{\sin(\phi_h+\phi_s)}_{\text{Collins}} \propto \Delta_T q(x)\, H_1(z)$$

$$A^{\sin(\phi_h-\phi_s)}_{\text{Sivers}} \propto f_{1T}^{\perp}(x)\, D_1(z)$$

Uncertainty of Fragmentation Function

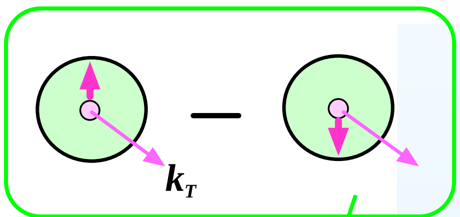


Drell-Yan

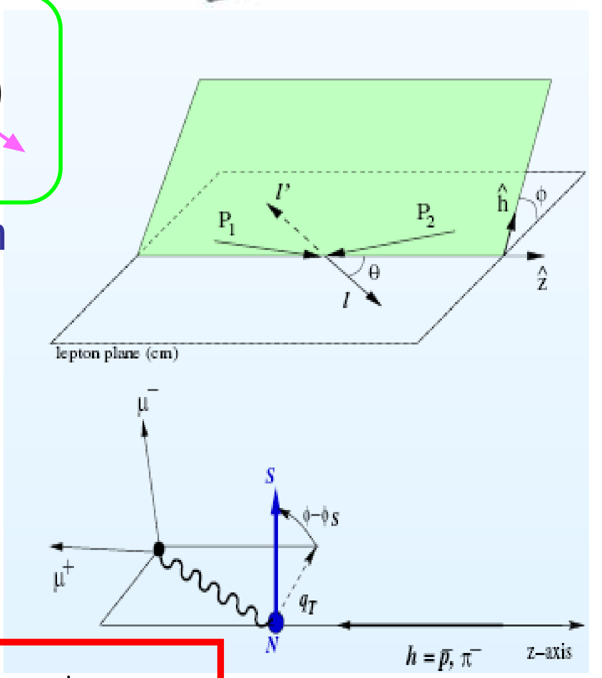
unpol. DY

$$\hat{k} \propto h_1^{\perp(1)}(x_1)\, h_1^{\perp(1)}(x_2)$$

Coefficient at cos2ϕ dependent part of the properly integrated over q_T ratio of the cross-section



$h_1^{\perp(1)}(x)$ 1st moment of Boer-Mulders function $h_1^{\perp}(x)$



single spin DY asymmetries

FF free

$$A^{\sin(\phi+\phi_{s2})} \propto h_1^{\perp(1)}(x_1)\, \Delta_T q(x_2)$$

$$A^{\sin(\phi-\phi_{s2})} \propto f_1(x_1)\, f_{1T}^{\perp(1)}(x_2)$$

Unpol. PDF

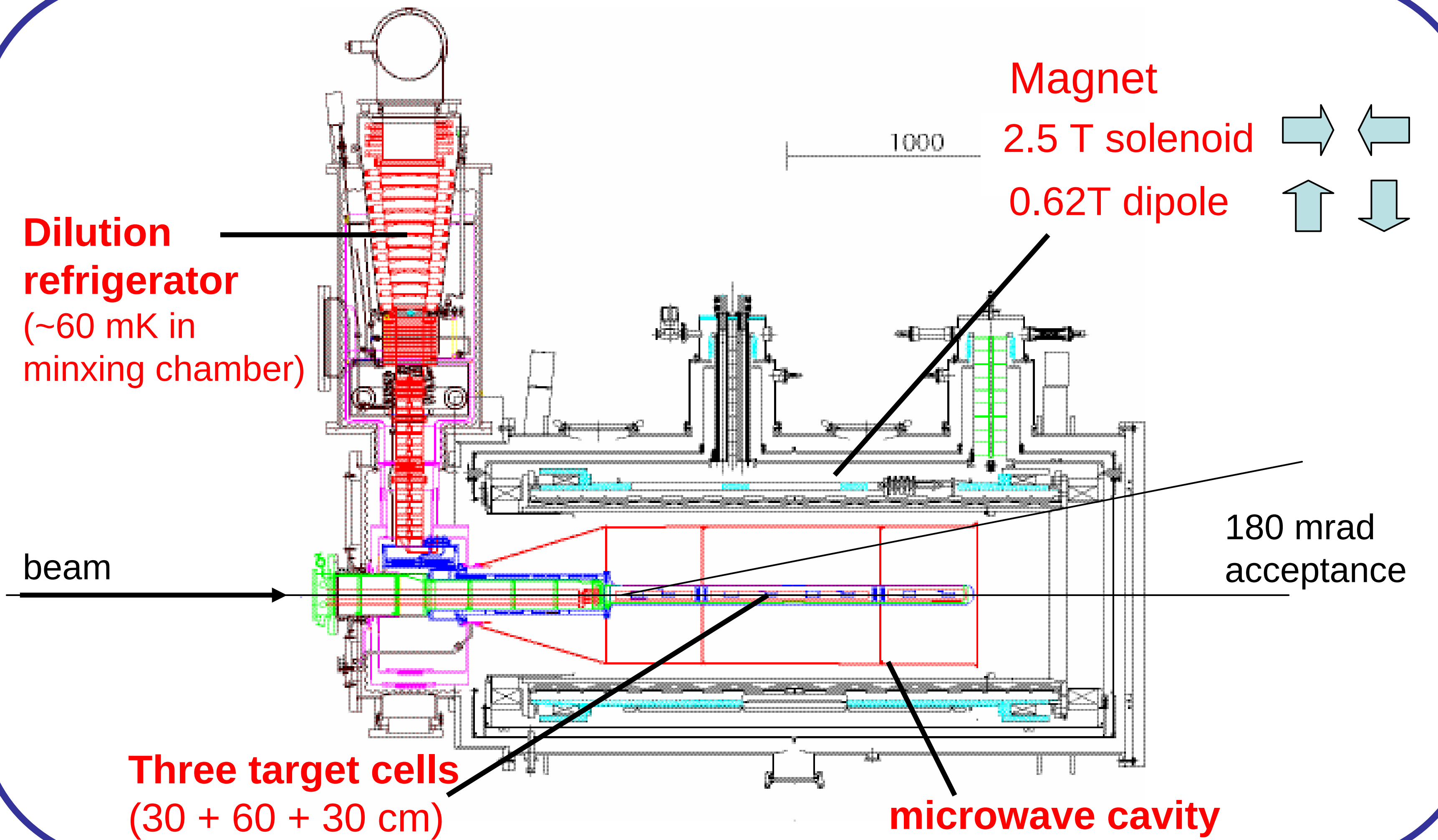
prediction

$$f_{1T}^{\perp}\Big|_{DY} = -f_{1T}^{\perp}\Big|_{SIDIS}$$

Present COMPASS polarized target

6LiD : 2002 ~ 2006
NH3 : 2007

Bochum, Saclay, Yamagata



Experimental condition in terms of target for DY

Transverse mode with hadron beam

- The present system can be used

- Proton target

  High polarization, high dilution factor and long relaxation time → NH3

- Frozen spin mode with 0.62 T for transverse polarization

  Cannot be polarized (only at 2.5T can be)

- High intensity hadron beam (~2 x 10^7 hadrons/s) → heat input ↓ Material temp. warms up ↓ Fast spin relaxation time

  Nuclear interaction produces secondly hadrons

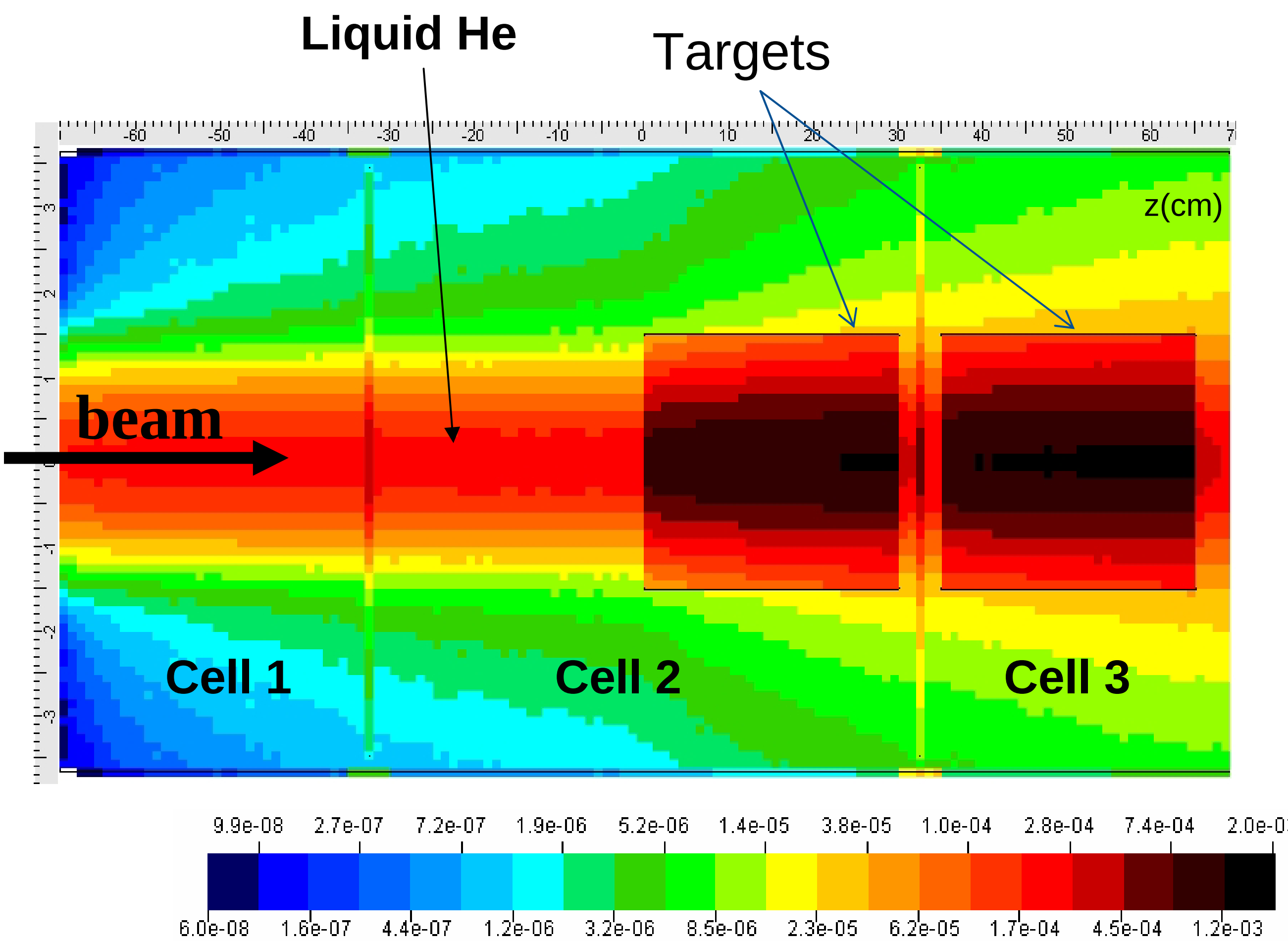
multiplicity = Total probability factor of secondly particle productions

- Smaller beam focus size → Effective beam flux gets higher

  Smaller diameter target is preferred

- Target length of 20-30 cm x 2 cells

Energy deposition in target 30-30cm



GeV/cm^3 per primary

Gaussian beam

$\sigma_x = \sigma_y = 0.5$ cm

ϕ3cm beam spot

done by H. Vincke and E. Feldbaumer

Average multiplicity per a incoming hadron

$$\text{Multiplicity} = \frac{\text{Energy deposition [GeV]}}{2\ [\text{MeV/g/cm2}] \times 0.85\ [\text{g/cm3}] \times L\ [\text{cm}] \times 0.5}$$

packing factor

Energy deposition[GeV]
(Multiplicity)

Heinz and Eduard's result

	cell 1	cell 2	cell 3
30-30	7.03×10^{-2} (2.8)	9.04×10^{-2} (3.5)	
20-20	3.99×10^{-2} (2.3)	4.89×10^{-2} (2.9)	
30-60-30	5.94×10^{-2} (2.3)	1.97×10^{-1} (3.9)	1.20×10^{-1} **(4.7)**

DY beam test, 11-12 November 2007

Feasibility study of the Drell-Yan program with COMPASS spectrometer

- 160 GeV negative pion beam

- COMPASS PT performance during the operation with the high intensity hadron beam

- Radiation conditions in the experimental hall with COMPASS PT (full length ~ 100% int.leng.);

  operation with high intensity hadron beam: 2×10^7 hadrons/spill

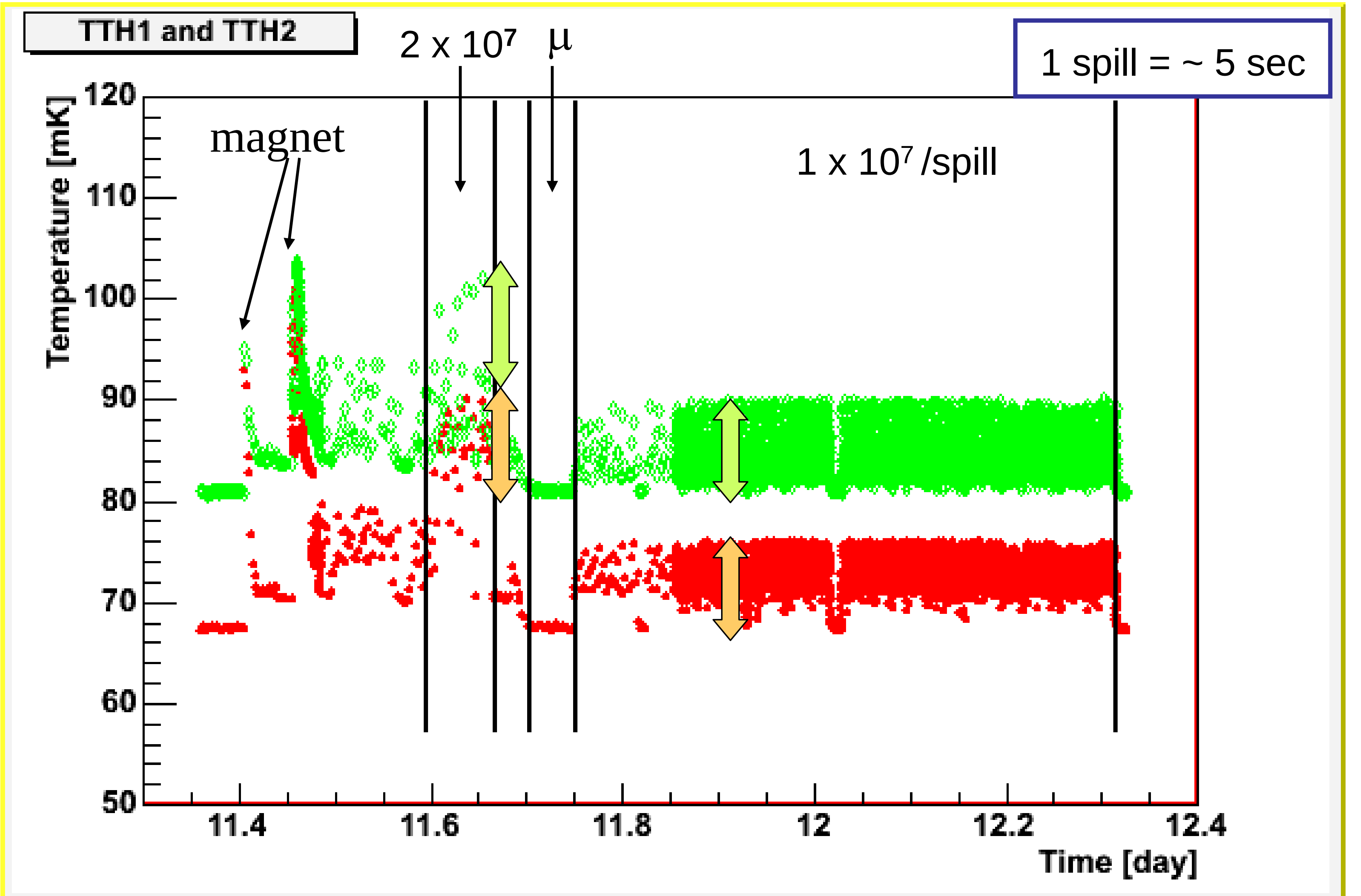
  L ~10^{31} cm^{-2} s^{-1} (~ equivalent to 10^8 hadrons/spill on 25% int.leng. PT)

- J/Ψ event rates (good normalization for DY and background)

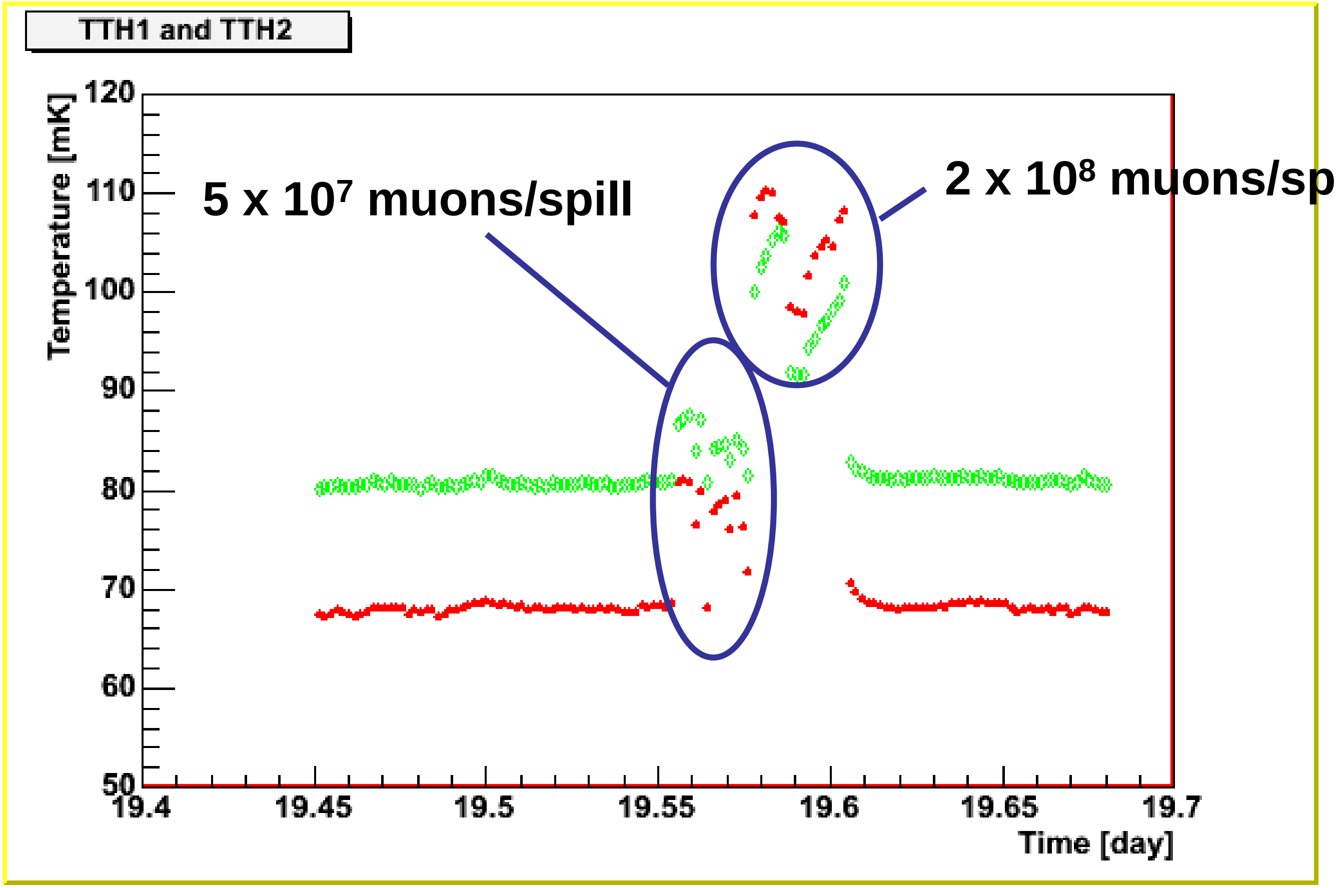
- **COMPASS spectrometer performance during the operation with high intensity hadron beam**

- Background/Signal level and trigger rates

Temperature sensors behavior during the beam test



Multiplicity measurement by temperature sensors



5 x 10^7 muons/spill ⟺ 1 x 10^7 pions/spill

Multiplicity ~ 5 with 30-60-30cm long

Average multiplicity per a incoming hadron

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Beam test

$4.7 \times 1{\cdot}10^{7}$ [/s] = 4.7×10^{7} [/s]

Physics run

$2.9 \times 2{\cdot}10^{7}$ [/s] = 5.8×10^{7} [/s] ~ muon intensity for muon program

Limitation of target cell size

heat input by high intensity of hadron beam

- **Diameter** ⇒ beam intensity in terms of a bead ⇒ **Temperature of material bead**

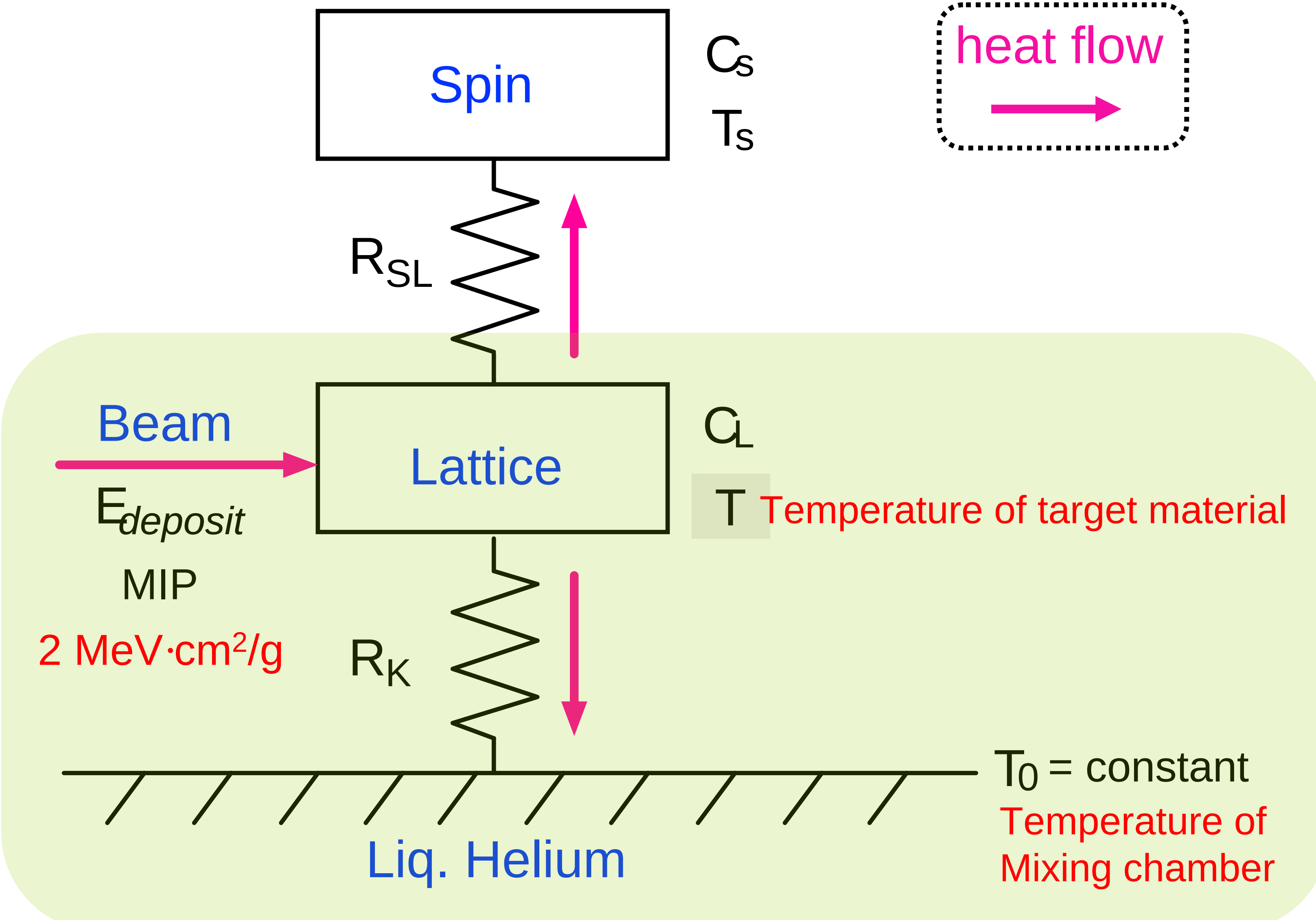
- **Length** (20 cm x 2) ⇒ total heat input into cells ⇒ **Temperature of Mixing chamber** ⇔ Cooling power of DR

Investigate the possibility of
- smaller beam focus size and target cell
- higher beam intensity

via
- temperature variation of the material
- total heat input into Mixing chamber

with
- NH_3

Heat flow diagram



Specific Heat

$$C_L = C_{phonon} + C_{cryocrystal} + C_{non\text{-}crystal}$$

$$C_{phonon}(T) = \frac{12}{5}\pi^4 N_A k_B \left(\frac{T}{\theta_D}\right)^3$$

θ_D : Debye temperature

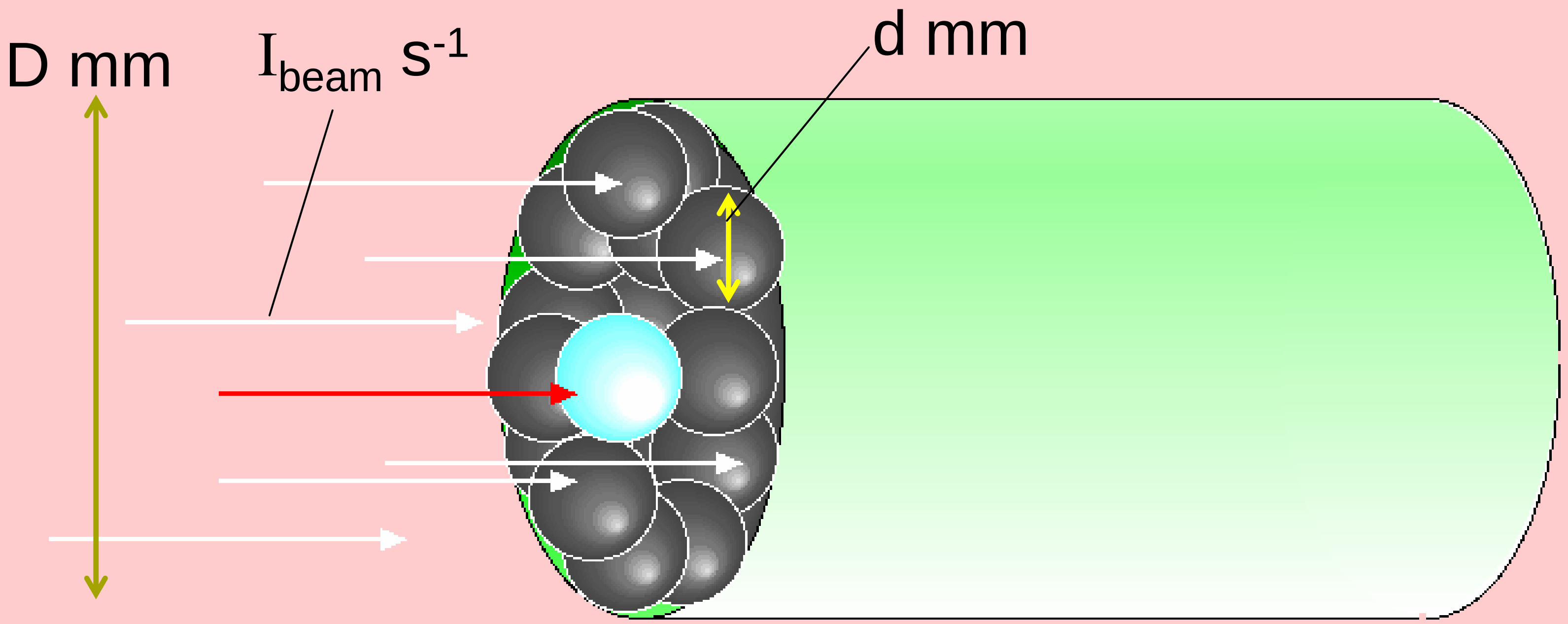
^7LiD ~1030K

$^{14}NH_3$ ~235K

$C_{cryocrystal}(T)$ = ?? For NH_3, ND_3

$C_{non\text{-}crystal}(T)$ = ?? For butanol?, CH_2, CD_2

Model for calculation of temp. variation



- Target material : spherical shape, LiD: d=4 mm, NH_3: d=3 mm

- Beam focus = target size: circular cross section (D=30mm for muon program)

- Beam intensity
  in terms of one bead : $I_{\mathbf{bead}} = \frac{d^2}{D^2} \cdot I_{\mathbf{beam}} \cdot N_{\mathbf{m}}$

multiplicity

Algorithm for the calculation

Beam interval: $t_i - t_{i-1} = \nu$ sec $= 1/I_{bead}$

$$E_{deposit} = n\, C_L(T(t_{i-1}))\,(T(t_i) - T'(t_{i-1})) \Rightarrow T(t_i)$$

$$\int_0^{\nu} \dot{Q}\, dt = \int_0^{\nu} \frac{A}{R_K} (T(t_{i-1})^4 - T_0^4)\, dt$$

$T_0 = 65$ mK

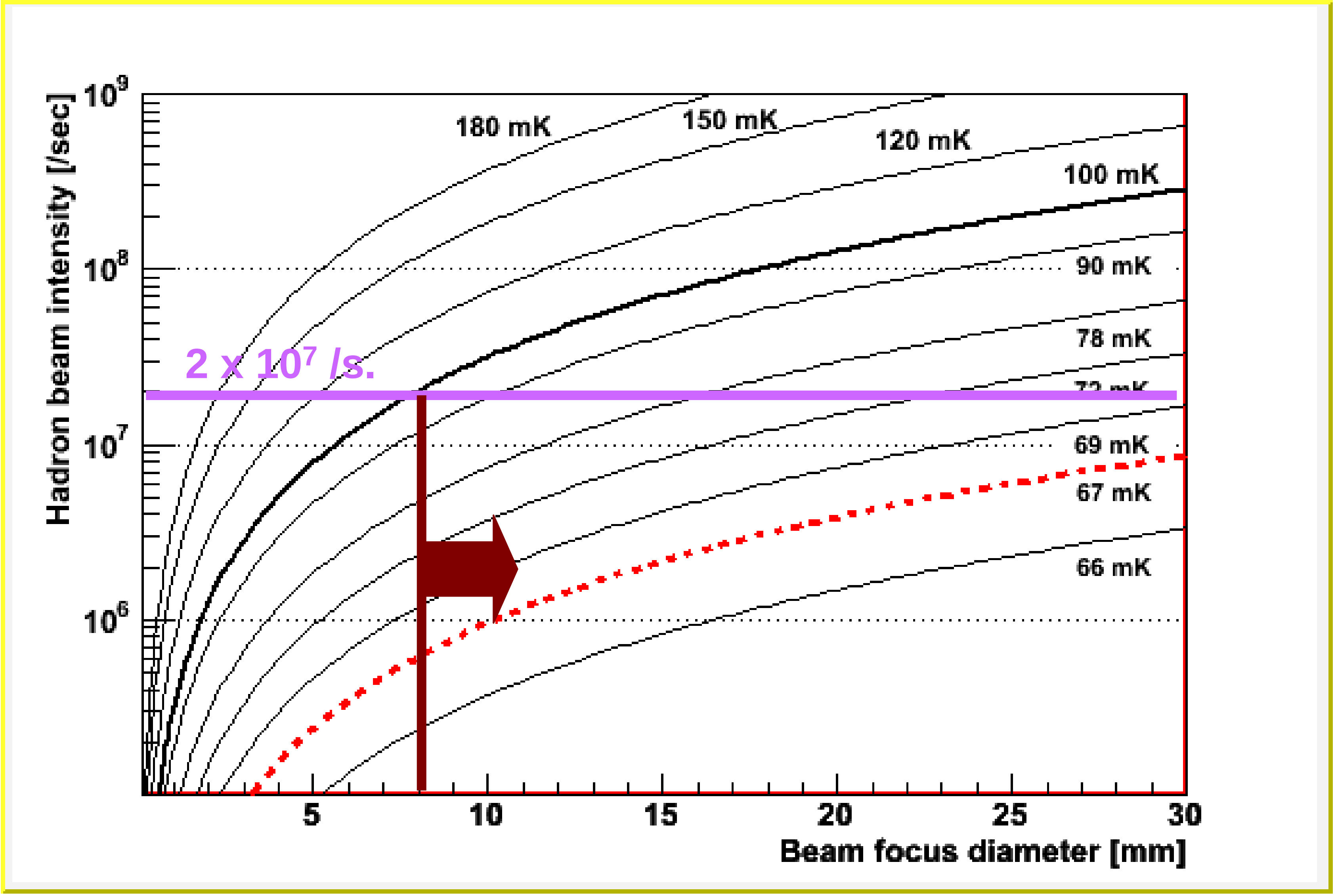
$R_K = 50$ cm^2K^4/W

(CrK crystal - ^4He)

$$T'(t_i) = \frac{E_{deposit} - Q}{n\, C_L(T(t_{i-1}))} + T(t_{i-1})$$

NH_3 material temperature

It should be kept below 100 mK.



Total heat input in the target cells

$$\dot{Q}_{total} = N_m \cdot (\rho_m \cdot \kappa + \rho_{He} \cdot (1 - \kappa)) \cdot 2L \cdot E_{MIP} \cdot I_{beam}$$

This heat should be removed by Dilution refrigerator

N_m : Multiplicity

ρ : Material or helium density

κ : Packing factor

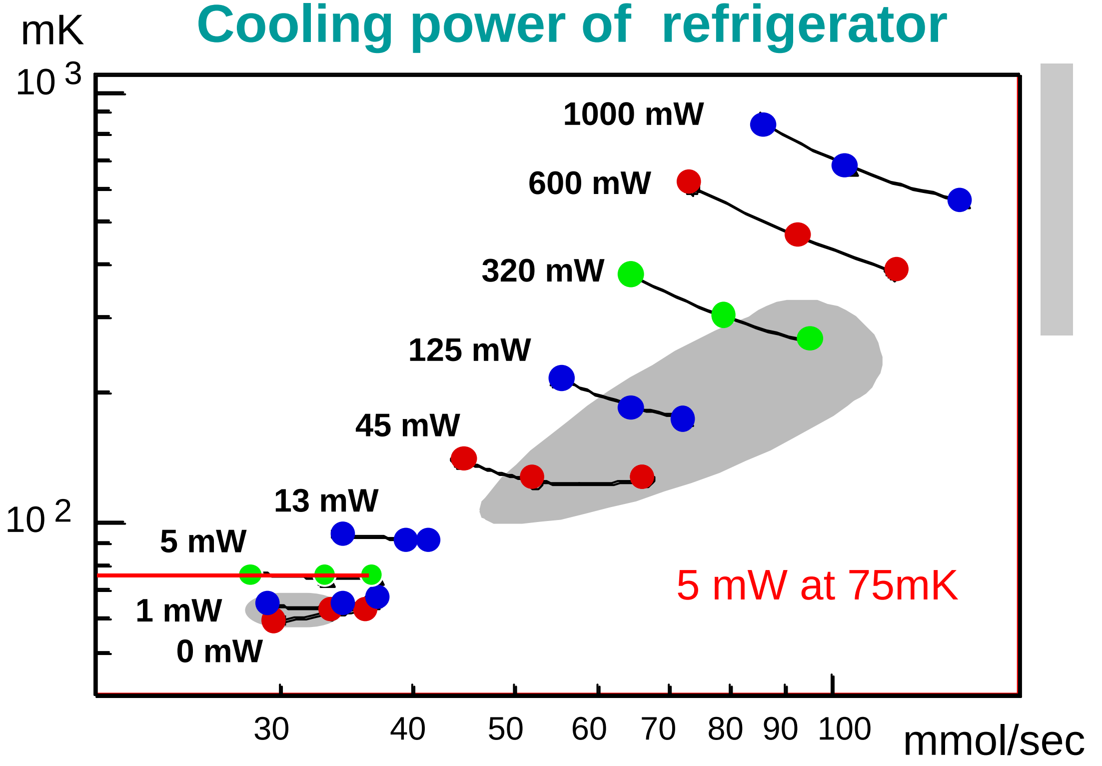
L : Target cell length =20cm

E_{MIP} : 2 MeV· cm^2/g

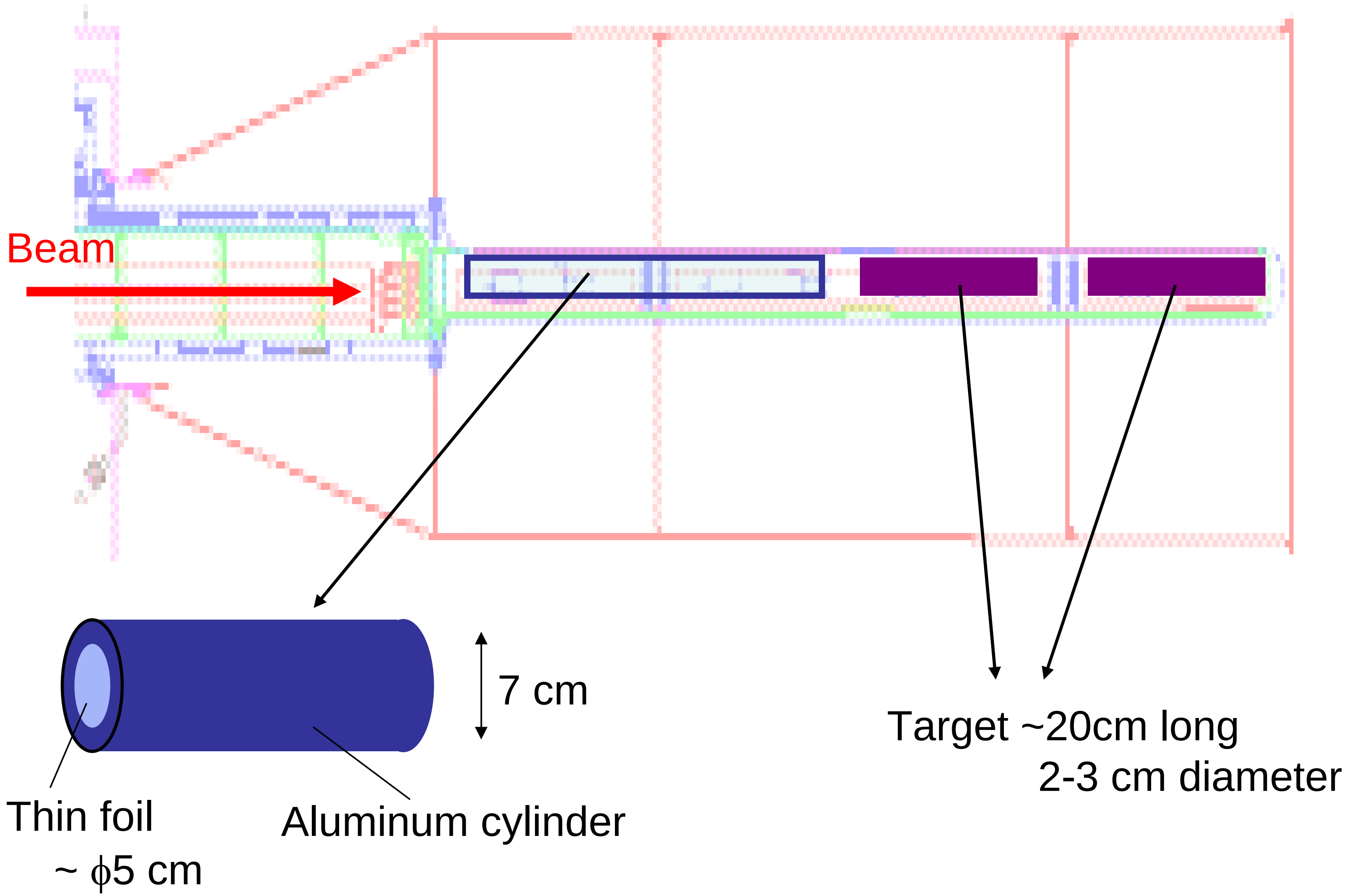
I_{beam} : Beam intensity

Q_{total} = 0.6 mW

Cooling power of refrigerator



New target cells idea



Summary

- Compass plans for the Drell-Yan program.
- Multiplicity of 3 in the 20-20cm long target is estimated.
- Any problems of the material temperature cannot be expected at the beam spot size more than 10 mm diameter.
- The modification of the target place is needed.