The Magnetic Monopole Trapper (MMT)

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Large Hadron Collider

$+$

SQUID magnetometer

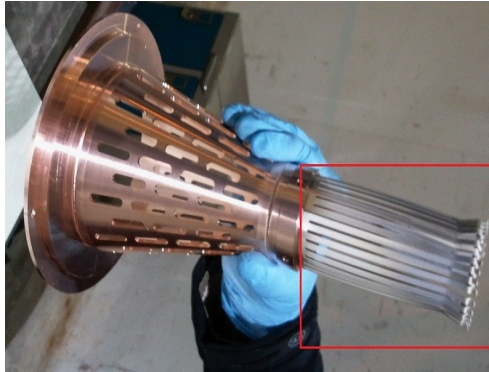$\Rightarrow$ new MoEDAL subdetector

Induction technique
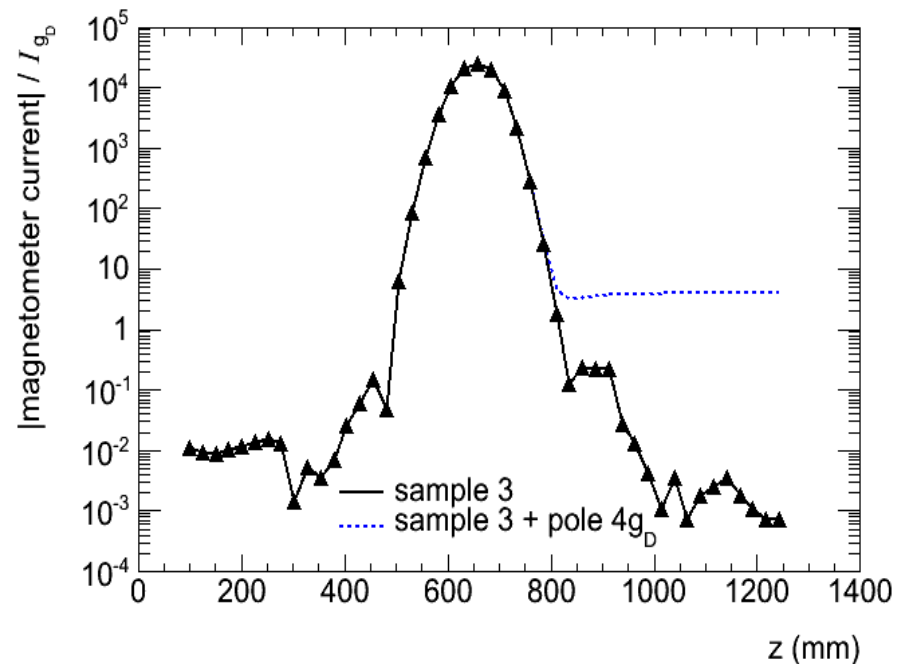## (see talk by Dave Milstead yesterday)

Context: searches for monopoles trapped in matter

SQUID magnetometer measurements at ETH Zürich

- Using accelerator material near LHC collisions
- **Proof of principle – article under publication**

"CMS debris"

Description of the idea

- Complement the MoEDAL detector with an array of trapping modules to be analysed with a SQUID
    - **Magnetic Monopole Trapper (MMT)**
    - To be installed shortly before first 14 TeV run and removed after 1 year of collisions
- Disadvantage: pretty low acceptance
- Advantages:
    - Speed! Magnetometer measurements + analysis take ~2 weeks → first monopole search at 14 TeV collision energies
    - Complementarity: a signal should be seen in both MoEDAL main detector and MMT
   - MMT can measure magnetic charges with < 5% accuracy

MMT – preliminary design

- **Material**: Aluminium
  - Large nuclear dipole moment (spin 5/2)
    → likely to bind to monopoles with binding energy several 100's of keV
  - Cheap

MMT module

- **Module**: parallelepiped 1.75 x 1.75 x 5 cm
  - Nicely fits magnetometer sample holder

- **Array**: 49 x 49 cm

MMT array

  - 1 layer: 784 modules, 32.4 kg, depth 5 cm
  - 2 layers: 1568 modules, 64.8 kg, 10 cm

- **Two arrays**
  - one in front (opposite to LHCb) and one on the side of VELO detector
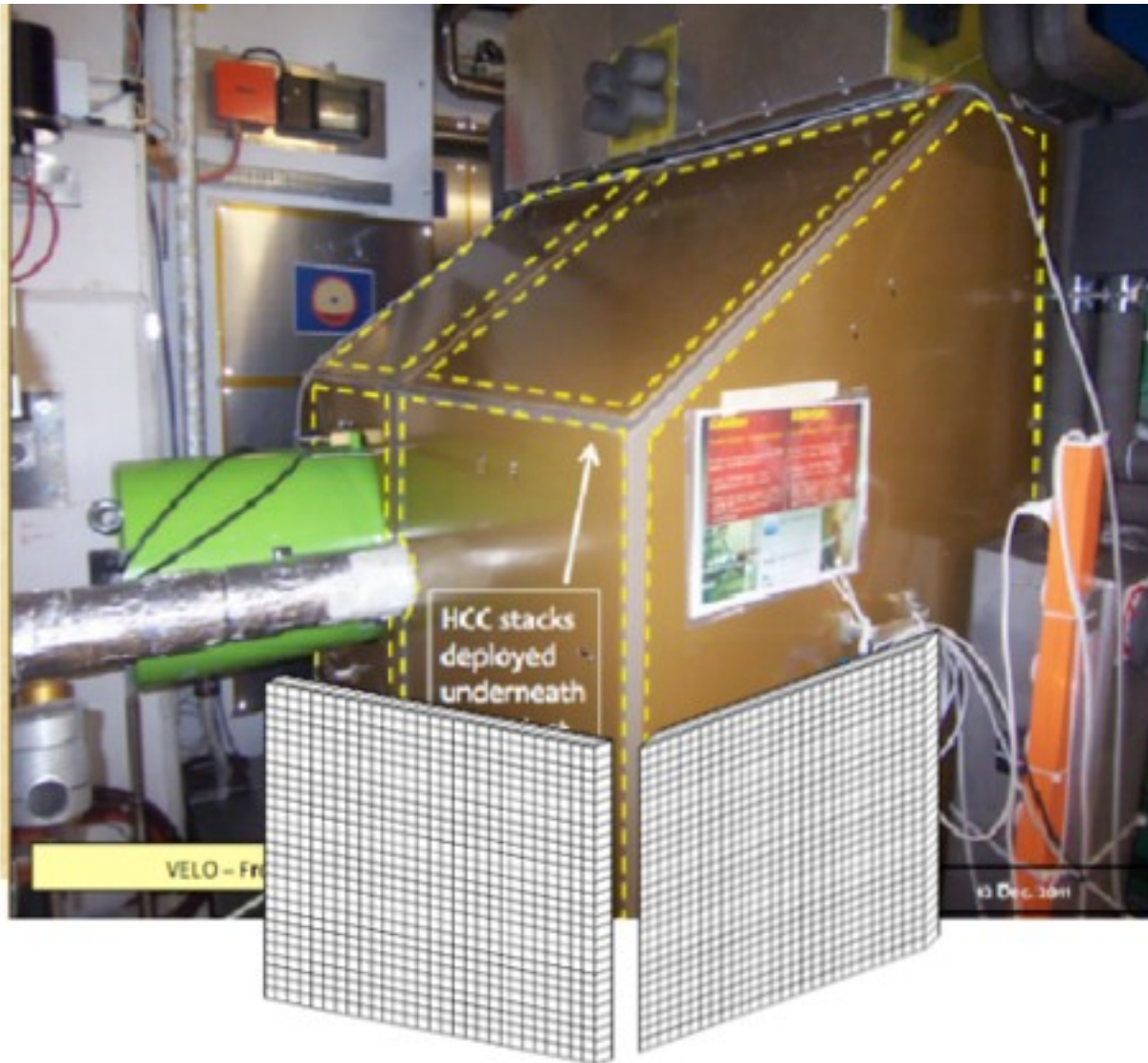
- MoEDAL TDR detector in front of each array
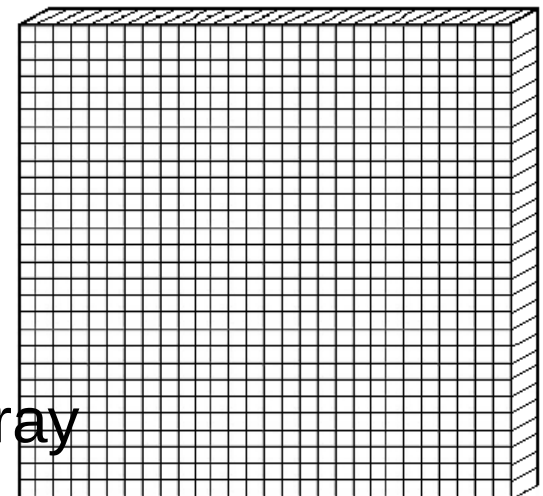
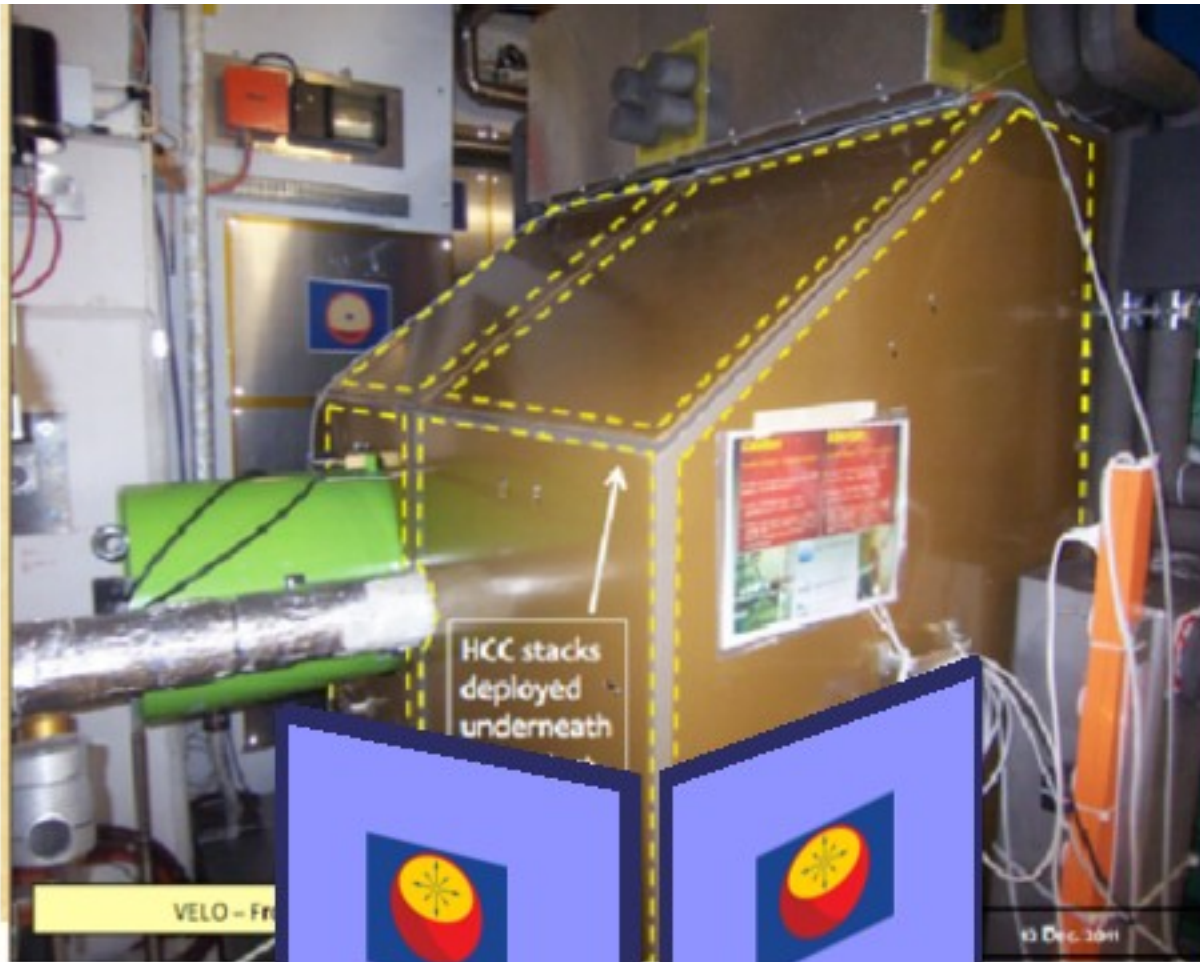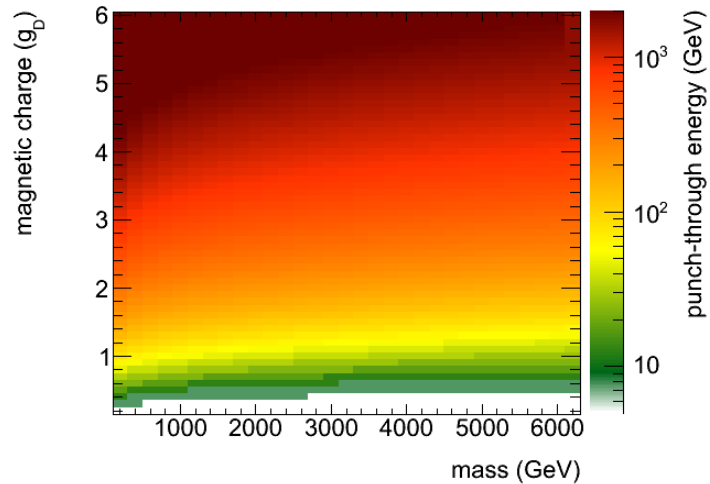# A view of the MMT in the VELO cavern

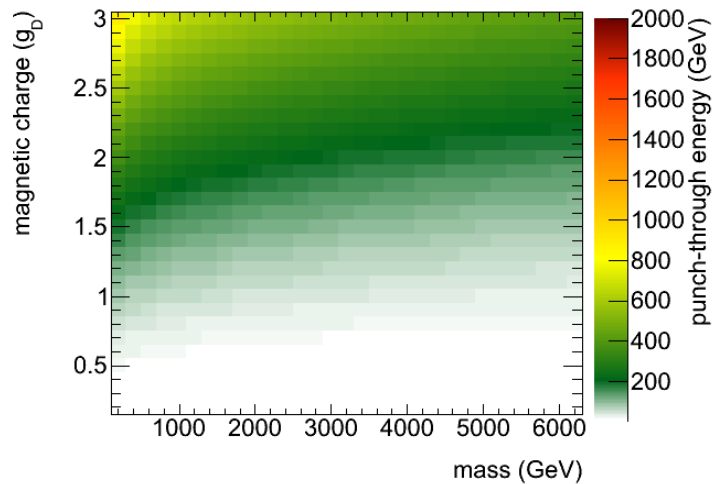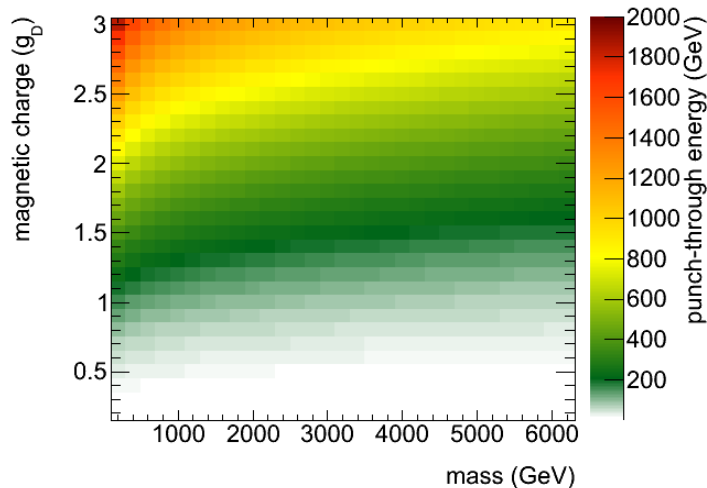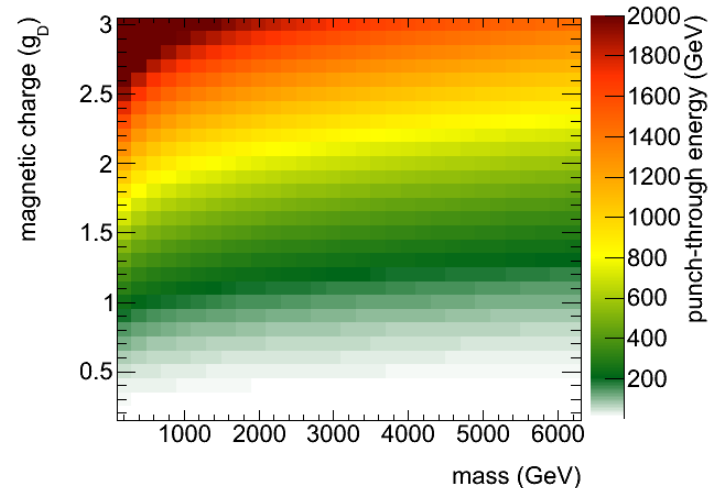# A view of the MMT in the VELO cavern

MMT – punch-through energies

VELO only

VELO only (zoomed lower charges)

VELO + MMT 1 layer (5 cm)

VELO + MMT 2 layers (10 cm)

MMT – acceptance
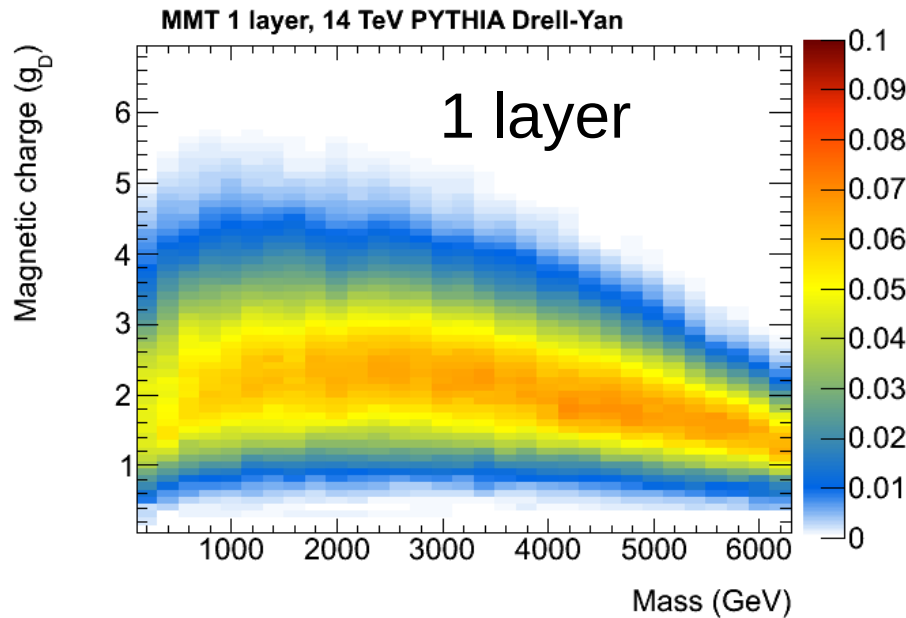## (assuming Drell-Yan pair production mechanism)

MMT 1 layer, 14 TeV PYTHIA Drell-Yan

1 layer

Magnetic charge (g_D)

Mass (GeV)

MMT 2 layers, 14 TeV PYTHIA Drell-Yan

2 layers

Magnetic charge (g_D)

Mass (GeV)
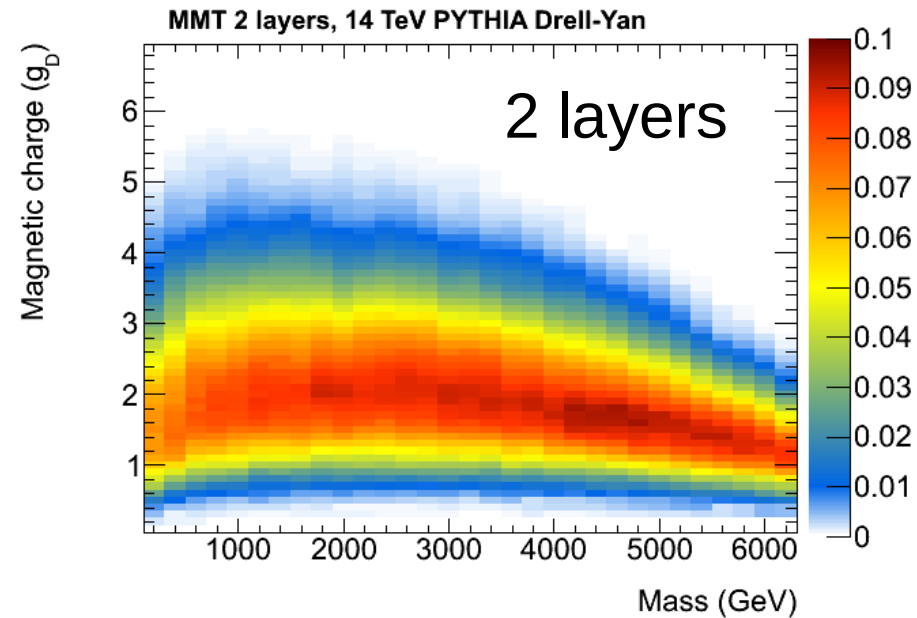
2–10% acceptance for monopoles in the range 1–4 g_D

– Higher charge → monopole stops in VELO chamber

– Lower charge → punches through the MMT
  (2 layers preferred for studying 1 g_D)

Monopoles at the LHC

Cross section needed for a discovery (1 event required in MoEDAL and 10 events in active detectors)

14 TeV PYTHIA Drell-Yan, m=1000 GeV
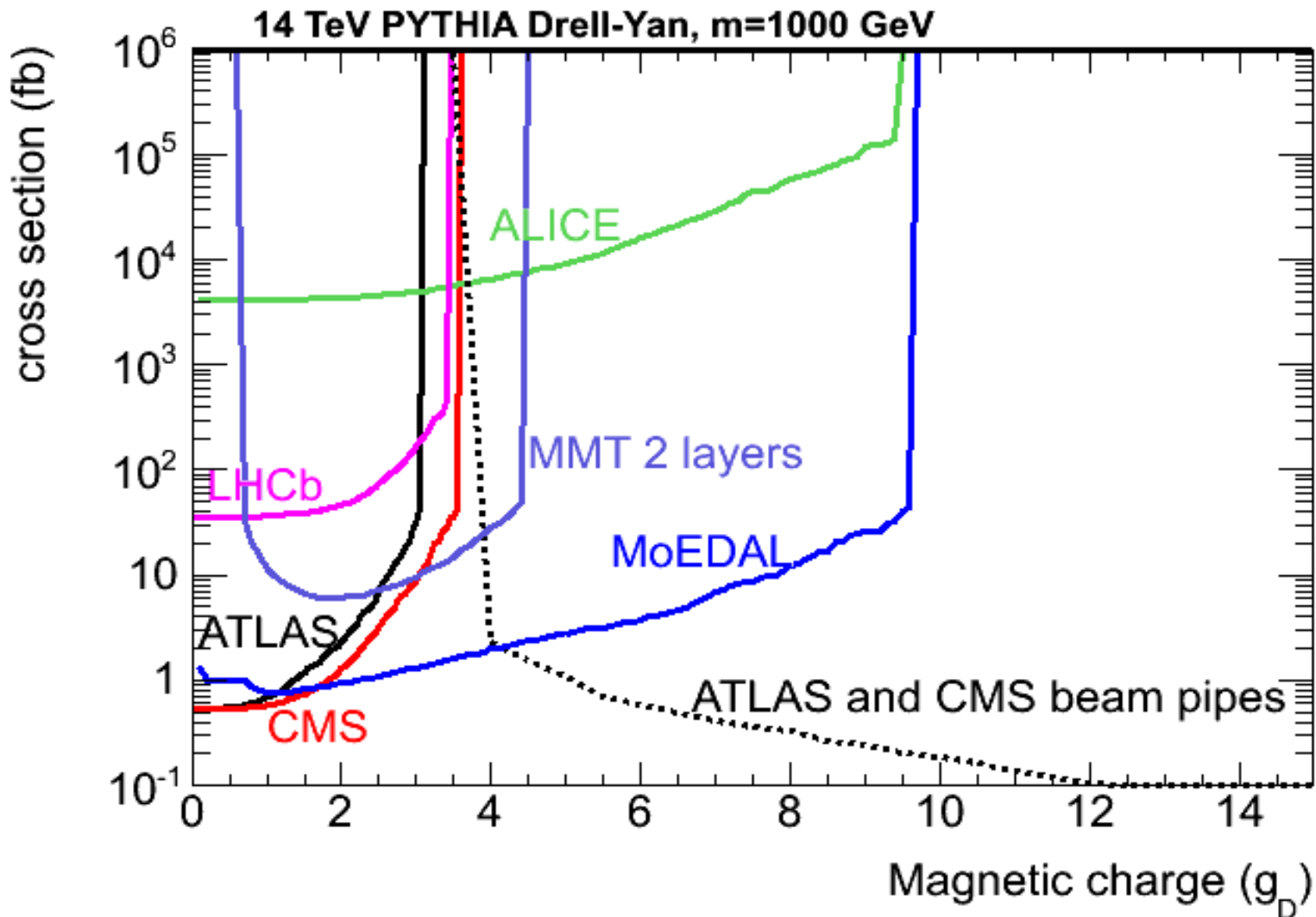
MMT – Conclusions

- The University of Geneva group proposes to coordinate the construction, installation and analysis of the MoEDAL Magnetic Monopole Trapper (MMT)

  - First LHC monopole search in 14 TeV collisions

- Cost estimate: CHF 20'000.- (includes manufacturing, SQUID running, and transport)

  - Possible in-kind financial contribution of University of Geneva to the MoEDAL Collaboration (to be discussed)

- Still need green light from LHCb

Another project – search for monopoles in ATLAS and CMS beam pipes

- ATLAS and CMS beam pipes
    - Beryllium 29 mm inner diameter 0.8 mm thick
    - To be replaced next year to allow for new pixel layers to be inserted
    - Challenge: cutting into strips suitable for SQUID analysis; safety issues (radiation and poisoning)
- Idea (discussions started yesterday): making this project a part of the MoEDAL experiment would seem to make perfect sense
- Key people: A. De Roeck, P. Mermod, D. Mistead
    - Two of us are already in MoEDAL
    - D. Milstead and Stockholm University would be happy to join as well

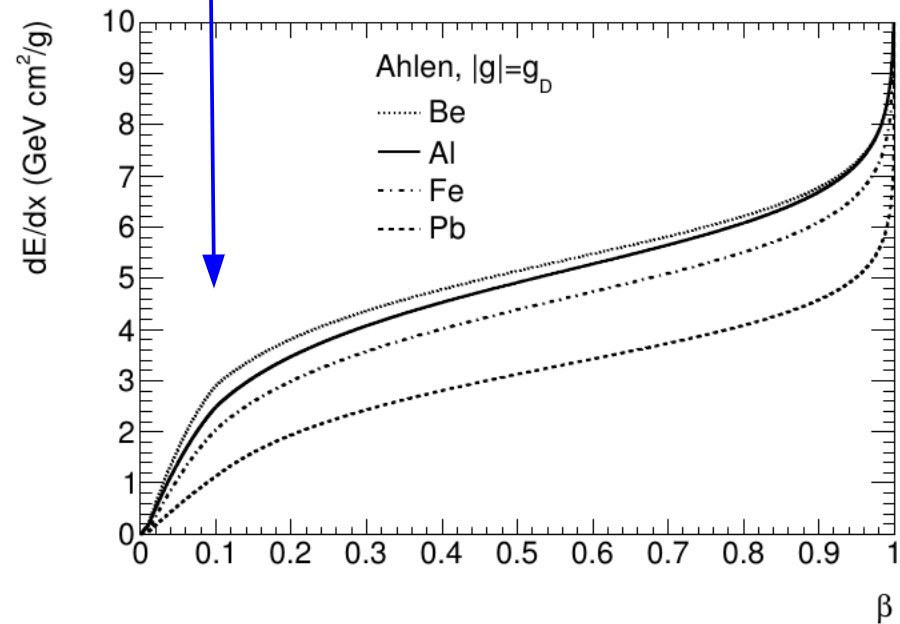# Extra slides

Monopole ionisation energy loss

Electric   **Magnetic**

$$-\frac{\mathrm{d}E}{\mathrm{d}x} = K\frac{Z}{A}\frac{z^2}{\beta^2}\left[\ln\frac{2m_ec^2\beta^2\gamma^2}{I} - \beta^2\right]$$
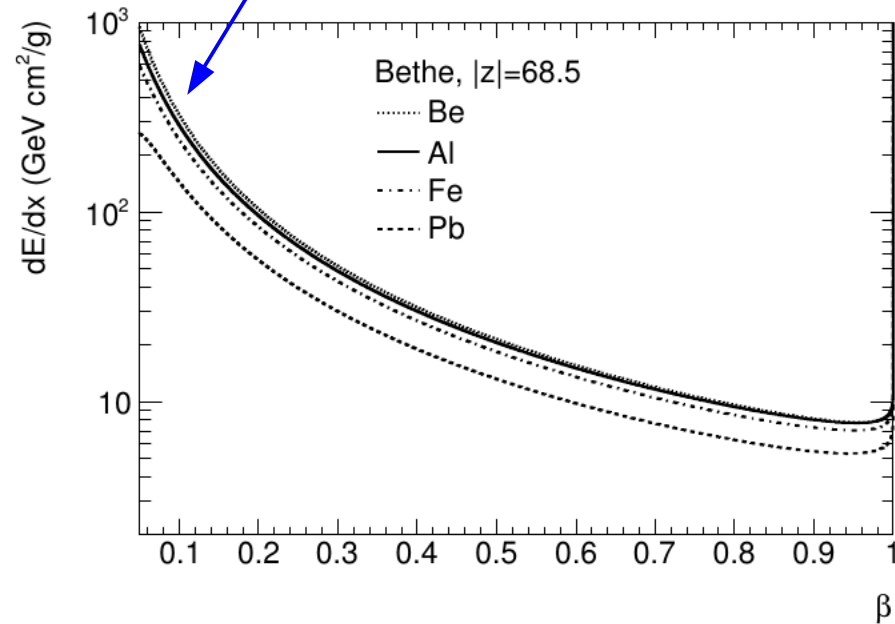
$$-\frac{\mathrm{d}E}{\mathrm{d}x} = K\frac{Z}{A}g^2\left[\ln\frac{2m_ec^2\beta^2\gamma^2}{I_m} + \frac{K(|g|)}{2} - \frac{1}{2} - B(|g|)\right]$$
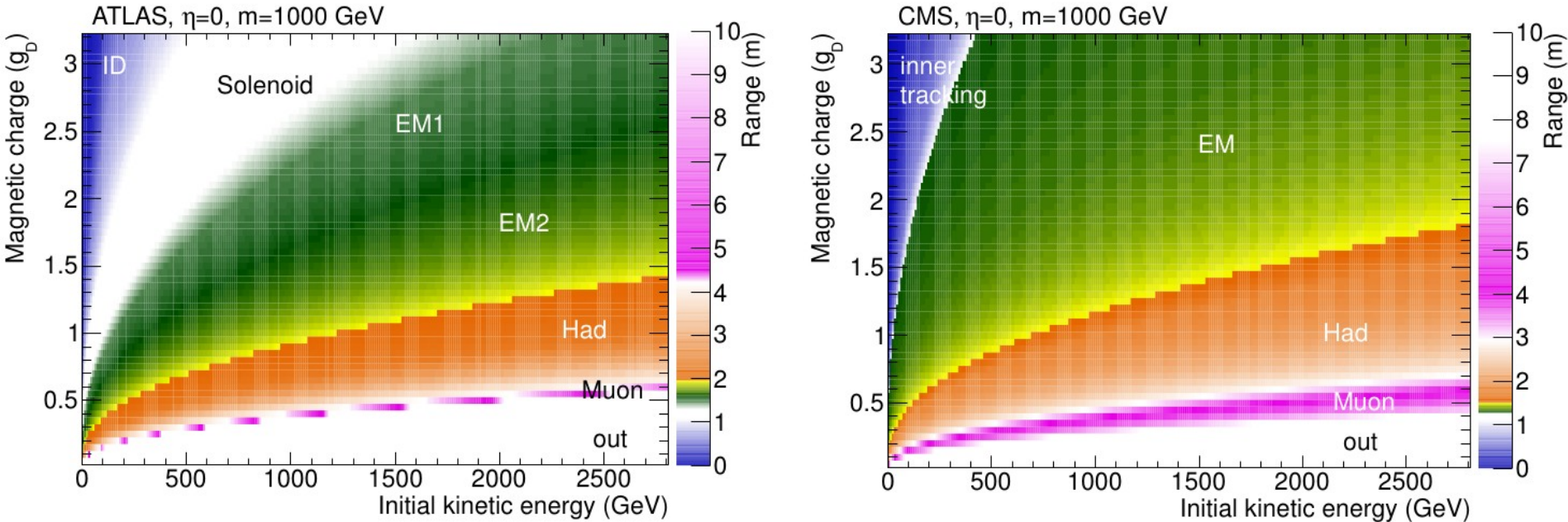
No Bragg peak!

Dirac monopole: $|g_D| = 68.5 \rightarrow$ several thousand times greater dE/dx than a minimum-ionising $|z|=1$ particle

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Range of monopoles in ATLAS and CMS
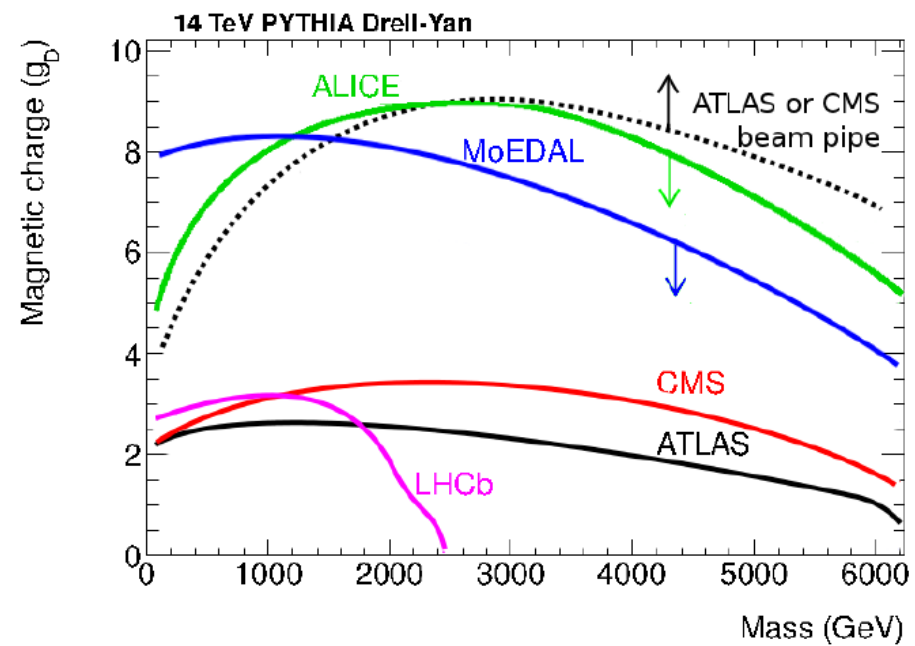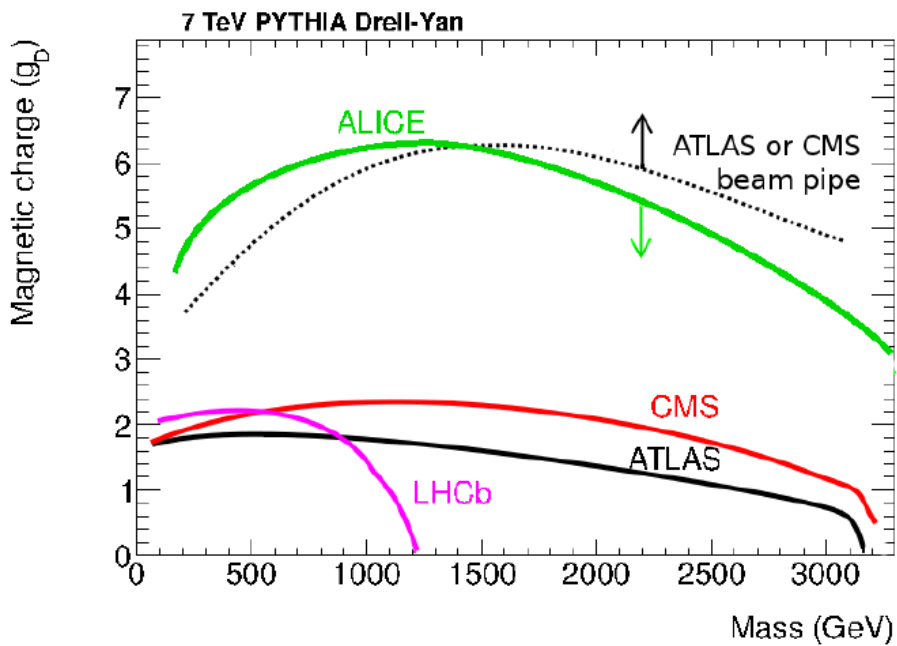
arXiv:1112.2999 (2012)

Need of EM trigger limits the ATLAS and CMS sensitivities to relatively low charges or high energies
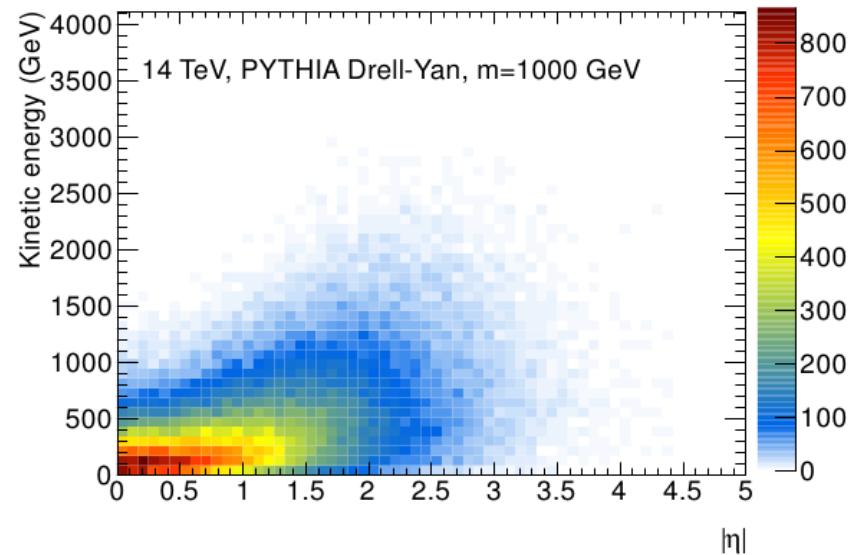
Reach in mass and charge
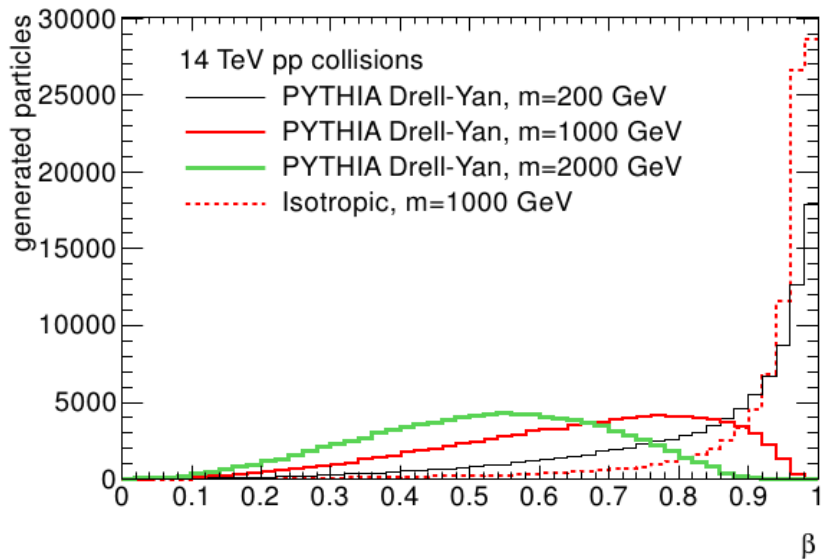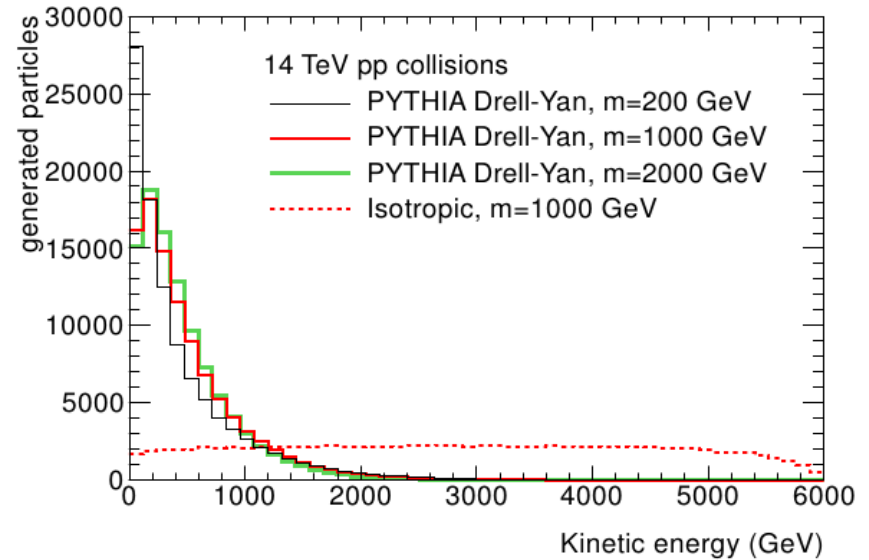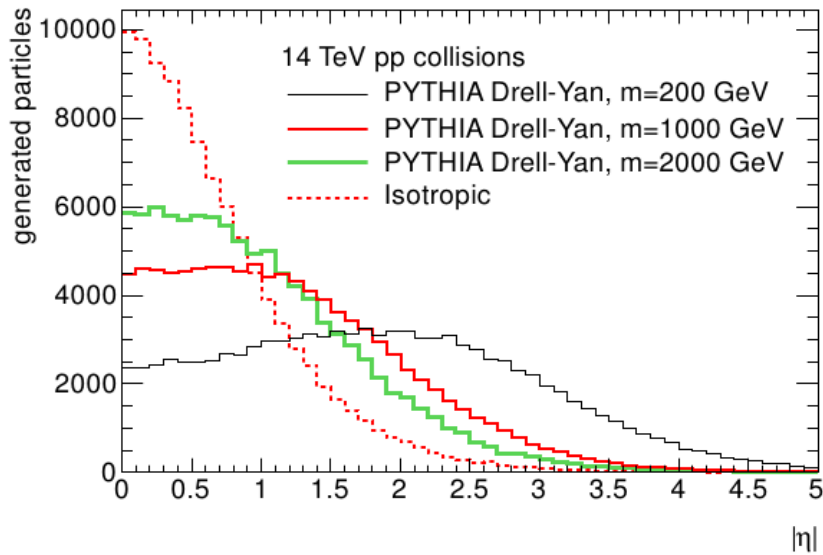## (> 5% acceptance)

arXiv:1112.2999 (2012)

Heavy particle production kinematics

MMT (2 layers) – approximate cost

- Aluminium
  - 130 kg at CHF 3.-/kg → CHF 390.-
- Module manufacturing
  - CHF 1500.-
- Encasing manufacturing
  - CHF 1500.-
- SQUID use:
  - 3136 modules at 50 modules/hour → 63 hours at CHF 250.-/hour → CHF 15750.-
- Transport CERN-Zurich-CERN
  - CHF 1200.-
- TOTAL: CHF 20'340.-