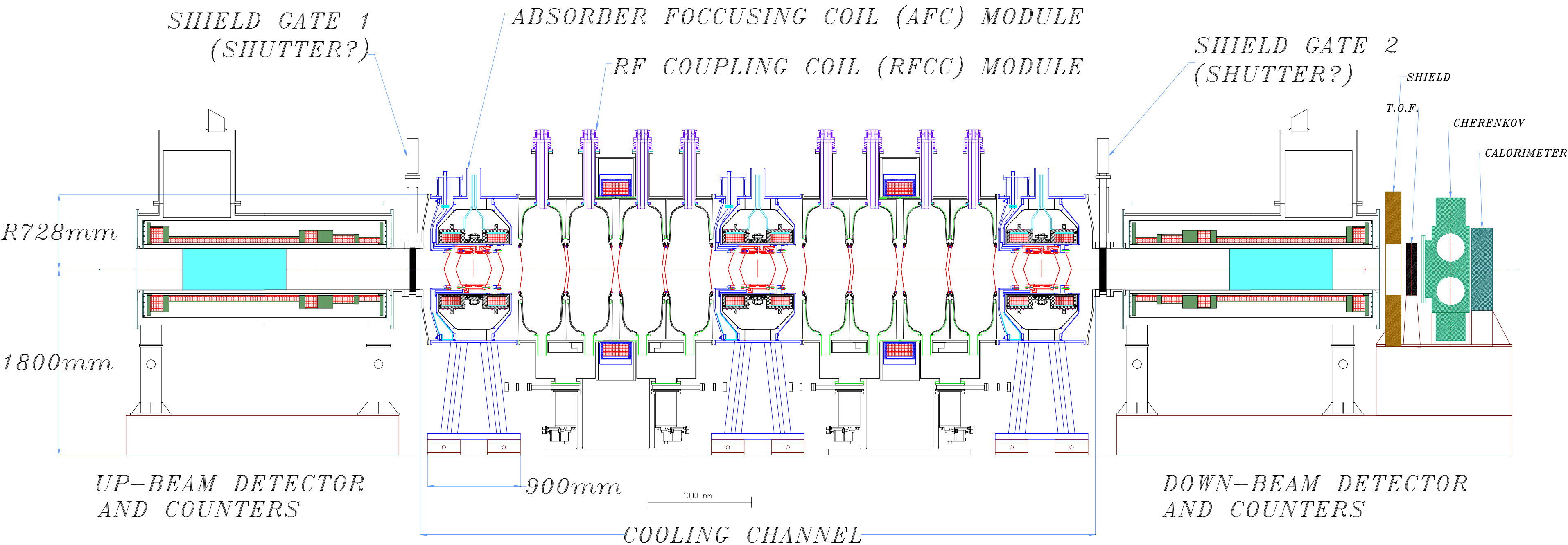
Imperial College London

K. Long, 28 April, 2004

The Muon Ionisation Cooling Experiment

… MICE overview and approach

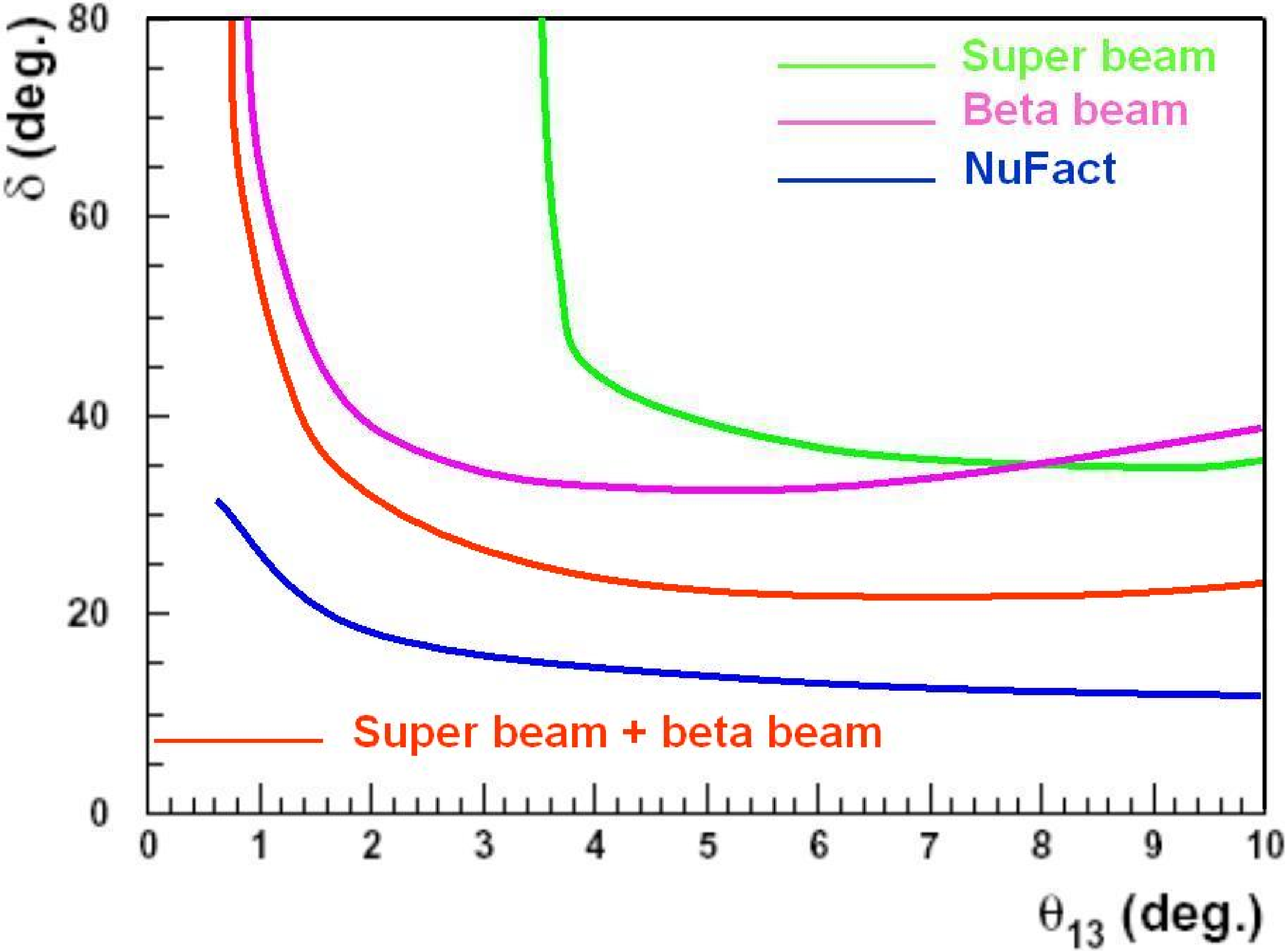


Contents:

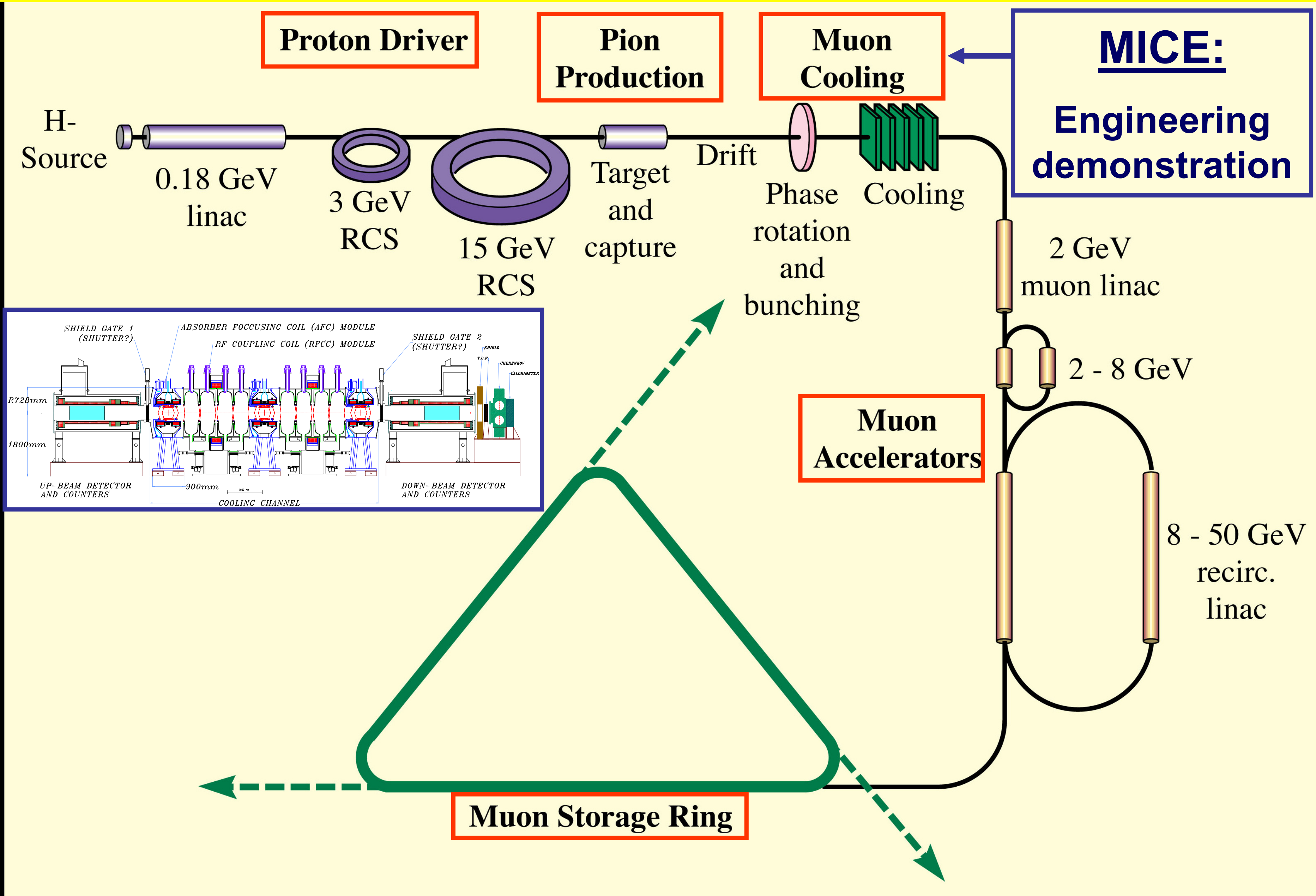
- Motivation
- Approval and funding: status
- MICE apparatus: status
- Summary and outlook

Motivation: NF physics case

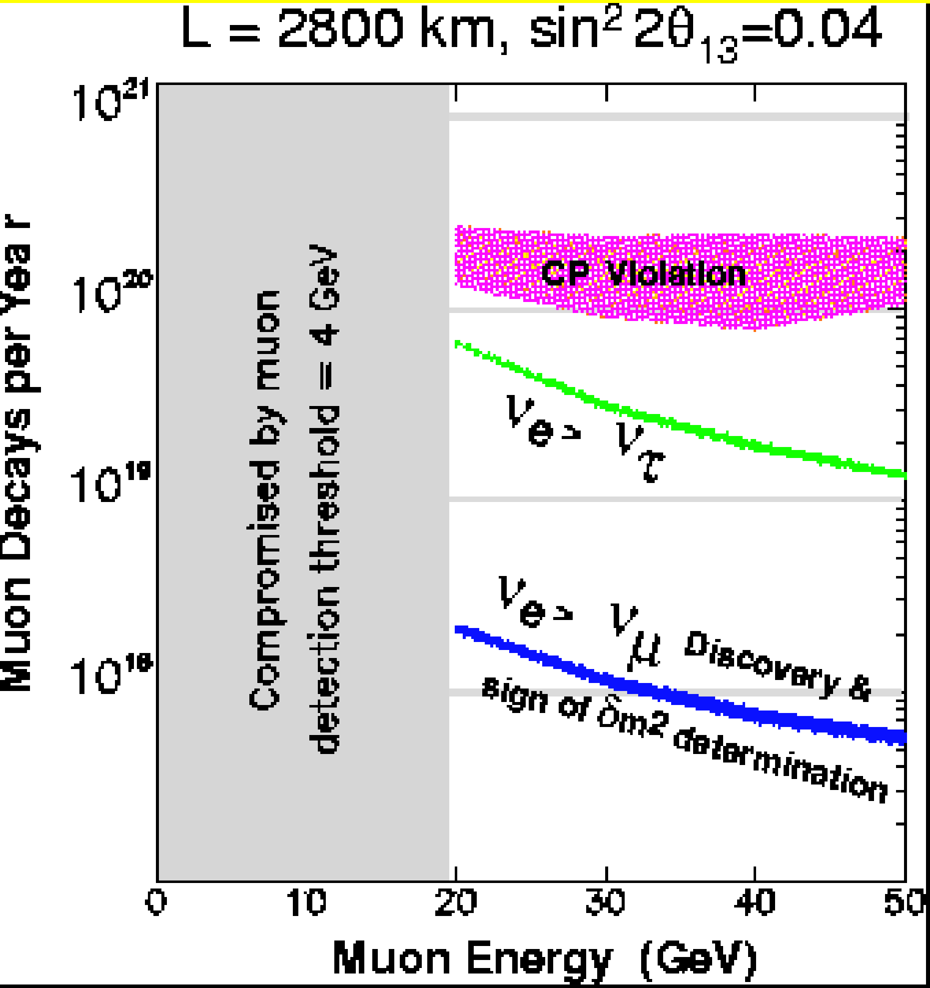
3 sigma sensitivity



Motivation: NF concept



Motivation: ionisation cooling

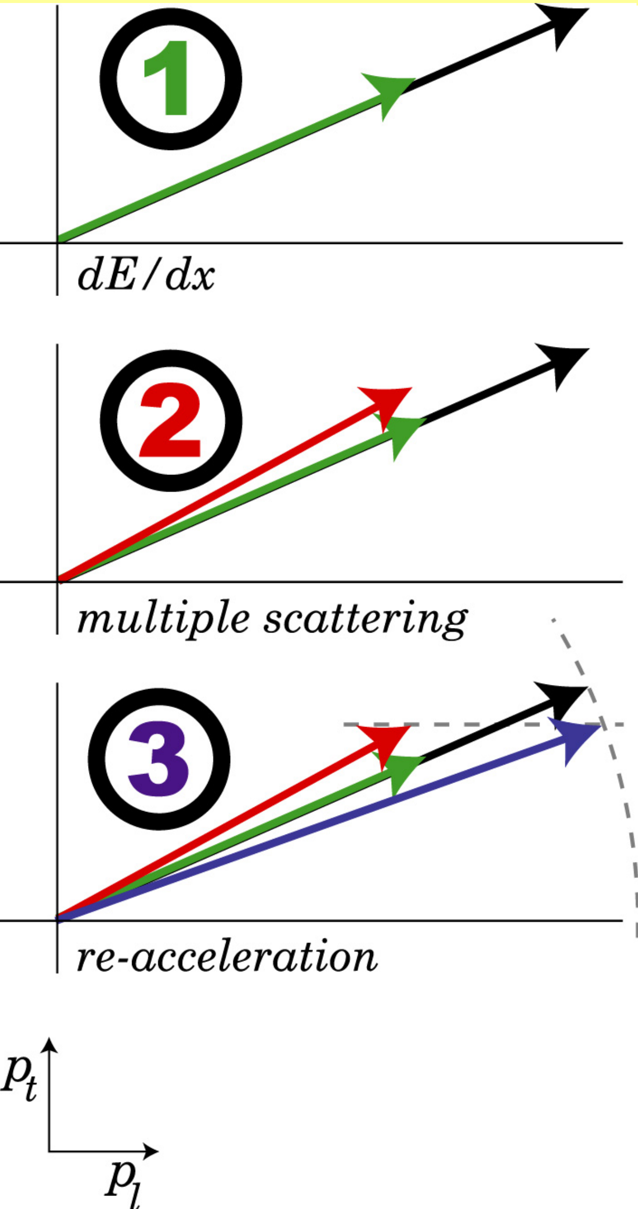


- Physics reach increases with neutrino flux
- Maximise stored muon intensity
- Implies:
  - Require to capture and store as many of the 'decay' muons as possible
    $\Rightarrow$ ***Cool muon beam***

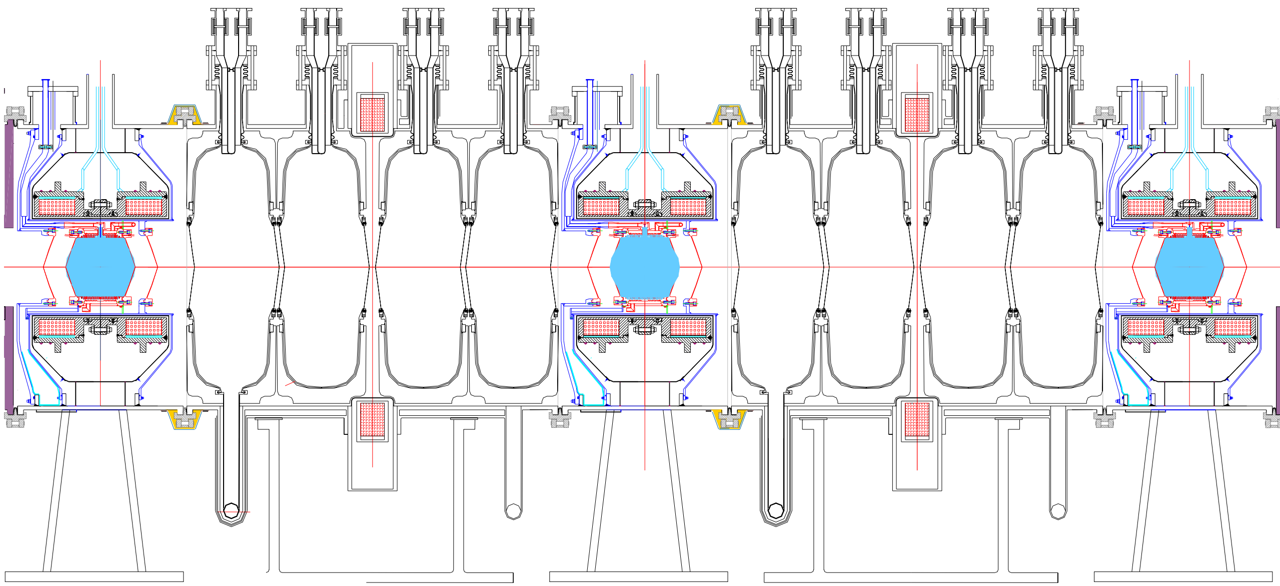
Short muon lifetime requires novel technique:
IONISATION COOLING

Motivation: cooling technique

Principle



Practice

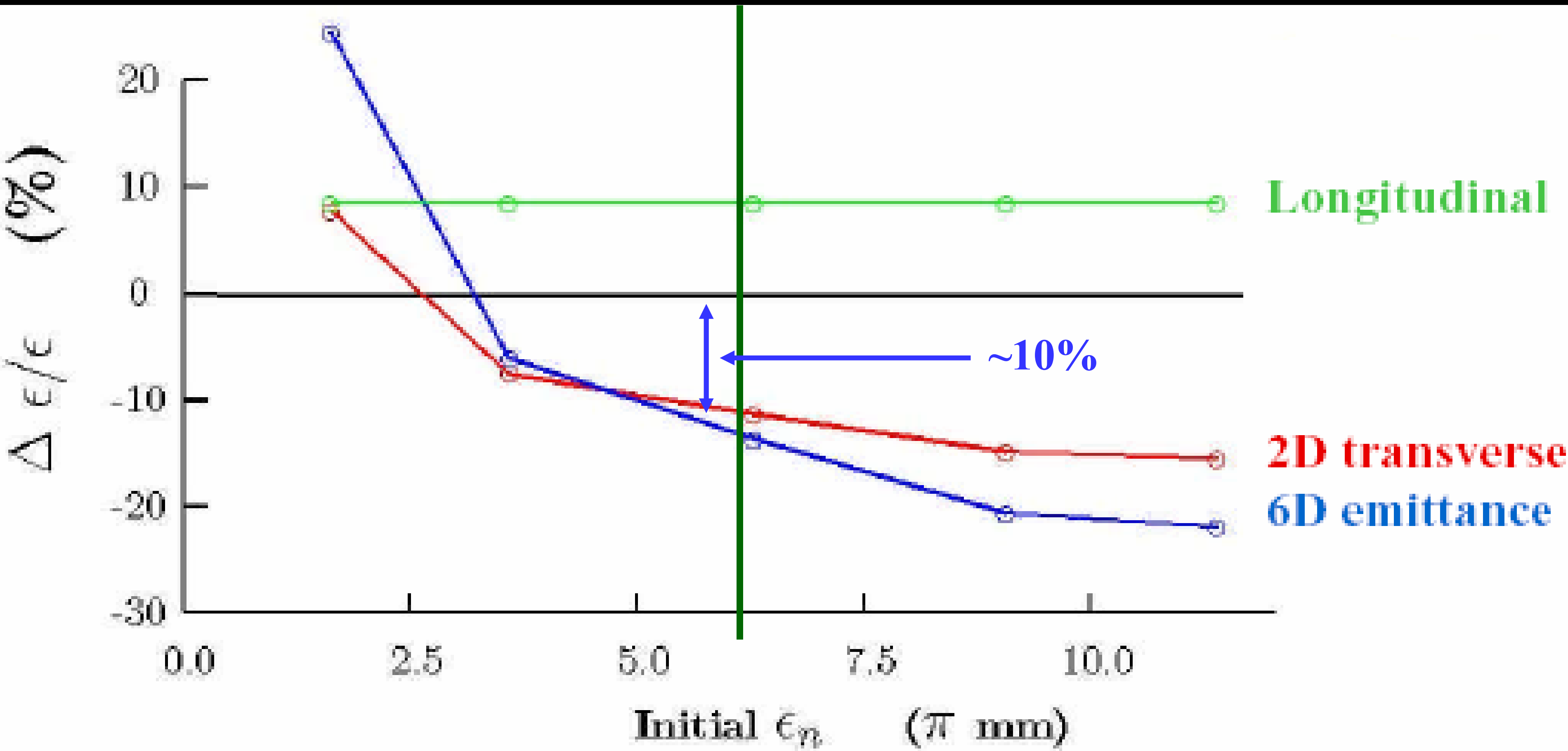


MICE:

- Design, build, commission and operate a realistic section of cooling channel
- Measure its performance in a variety of modes of operation and beam conditions

i.e. results will allow NuFact complex to be optimised

Motivation: measurement precision



$$\Rightarrow \sigma\left(\frac{\Delta\varepsilon}{\varepsilon_{in}}\right) << 0.1 \qquad \text{Goal}: \sigma\left(\frac{\Delta\varepsilon}{\varepsilon_{in}}\right) = 0.001$$

Approval and funding: status

- Proposal:
  - Submitted to CCLRC and PPARC 10 January 03
- Peer review:
  - International Peer Review Panel (Chair Astbury): Report of IPRP 20May03: 'strongly recommends approval of the project'
  - UK: PPARC Projects Peer Review Panel: 03Jun03: Recommended funding for UK contribution of £12.5M
- Research Councils UK:
  - Allowed project to proceed to Gateway Process

Approval and funding: status

- CCLRC (24Oct03; J. Wood, Chief Exec.):
  - ‘Accepts the strong endorsement of the proposal by the Astbury panel and consequently considers the proposal to have full scientific approval’
  - ‘Approves the project subject to satisfactory passage through the Gateway’
- Office of Science and Technology:
  - Gateway Process (UK procedure for large capital projects):
    - Gateway 0: ‘Business need’ – passed
    - Gateway 1: ‘Business case’ – passed on amber
    - Gateway 2/3: ‘Procurement strategy’ – goal summer/autumn 04; requires indications that international funding will be forthcoming

MICE collaboration & int^{l} fund^{g} stat

Europe

Louvain la Neuve, Saclay, Bari, LNF Frascati, Genova, Legnaro, Milano, Napoli, Padova, Roma III, Trieste, NIKHEF, Novosibirsk, CERN, Genève, ETH Zurich, PSI, Brunel, Edinburgh, Glasgow, Imperial College, Liverpool, Oxford, RAL, Sheffield

Japan

KEK, Osaka University

United States of America

ANL, BNL, FNAL, IIT, Chicago Enrico Fermi Inst., LBNL, UCLA, NIU, Mississippi, Riverside

European, Japanese and US bids submitted and being defended with energy and enthusiasm

MICE constitution:

- Has been adopted following approval:

Collaboration board

Chair: Dornan – acting

1 rep. per institute

Spokesmen

Spokesman: Blondel

Deputy: Zisman

(to be confirmed)

Technical board

Chair: TC: Drumm
Deputy TC: Bross

Cool. Chan.: Zisman
Detectors: Bross, Palladino
SW: Torun
Integration: Black Ivanyushenkov,
Safety: Baynham
Ex officio: Blondel

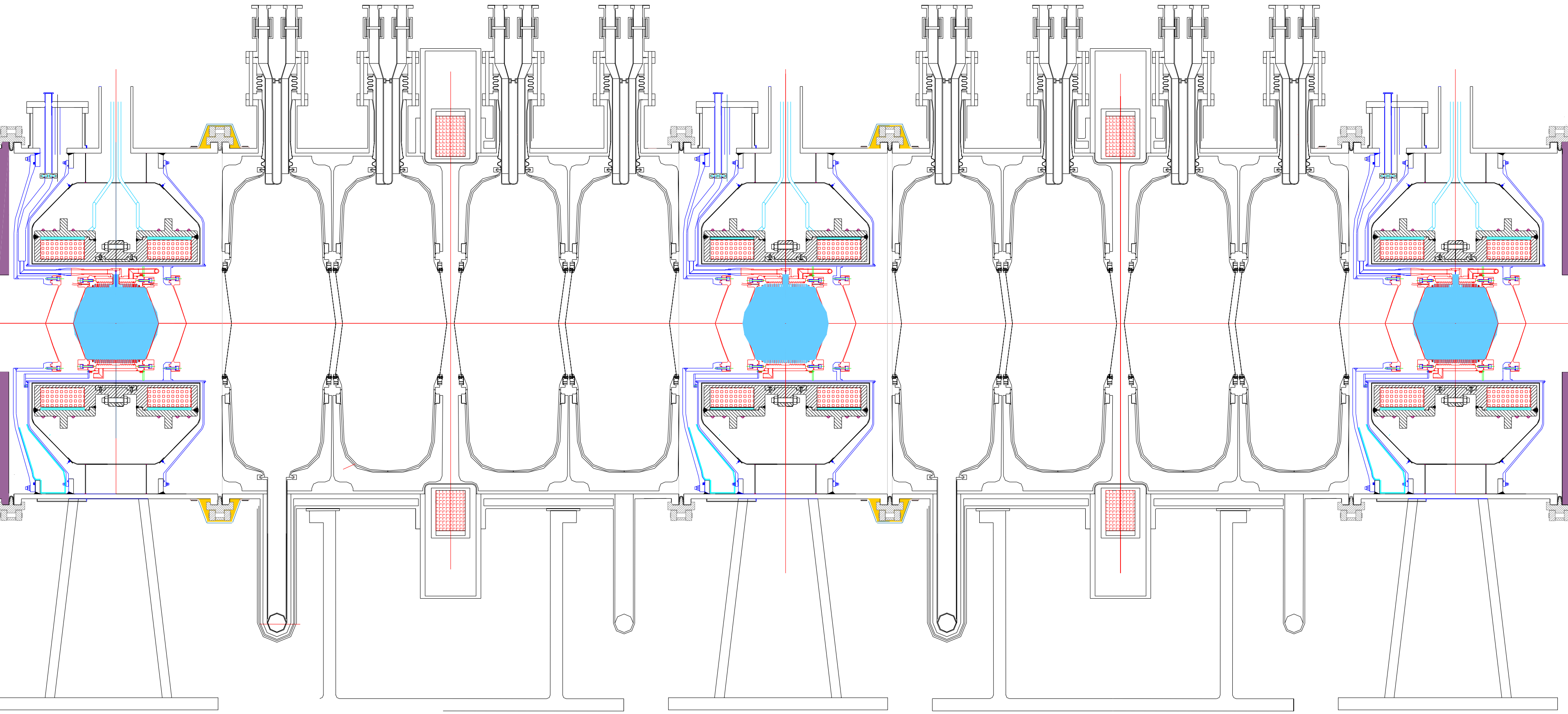
Executive board

Chair: Spoke^{mn}: Blondel

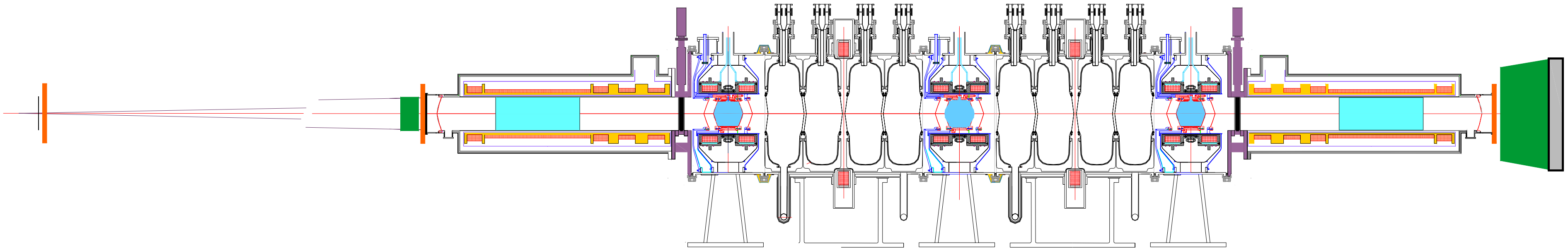
Deputy: Zisman
Tech. Coor.: Drumm
ISIS: Drumm
CB chair: Dornan
SW coor.: Torun
EU: Haseroth, Palladino
Jp: Kuno, Yoshimura
UK: Edgecock, Long
USA: Bross, Kaplan
Invitation: Geer

Election for CB chair in progress

Apparatus: cooling channel

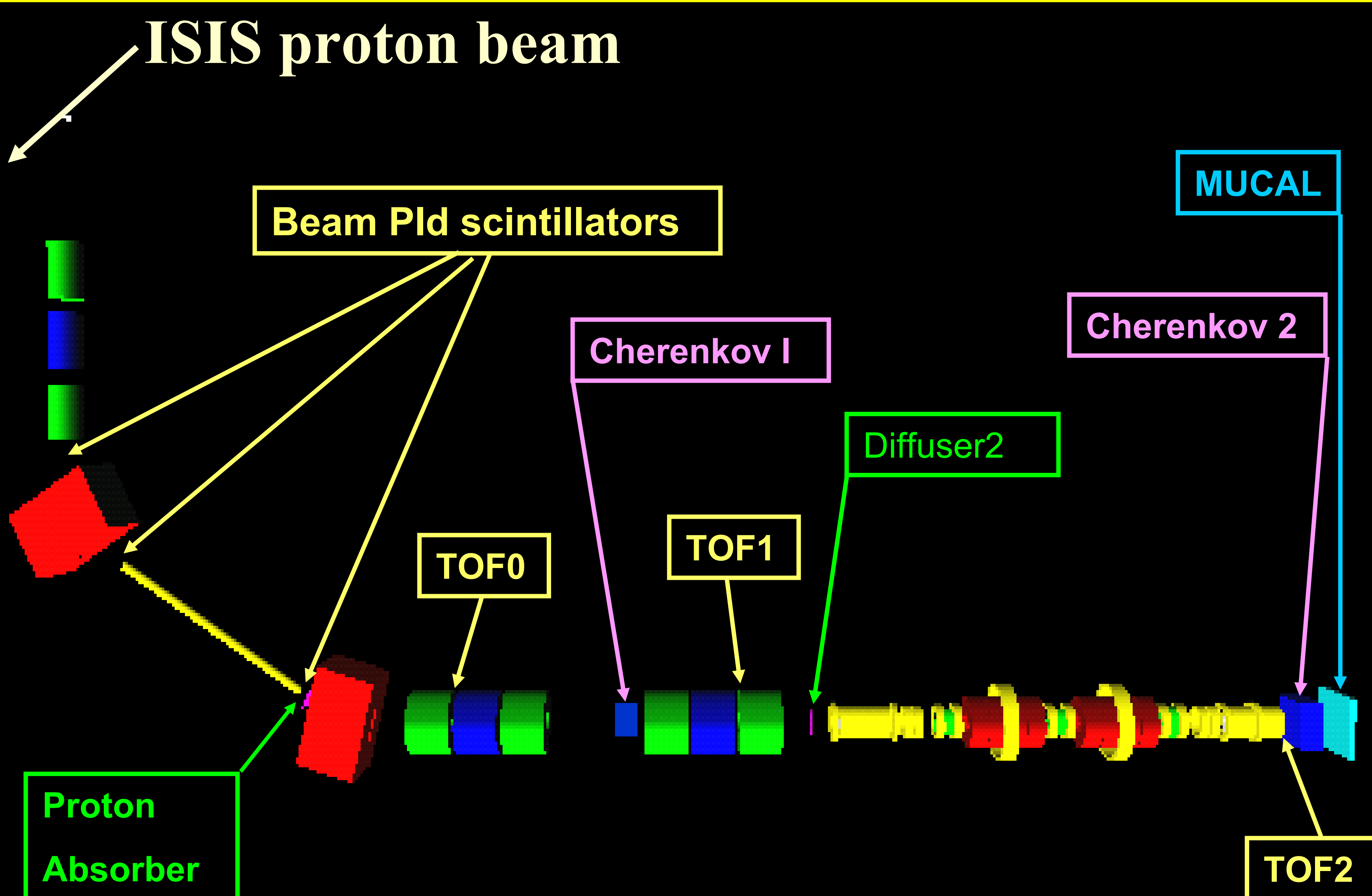


Apparatus: instrumentation



- Particle identification
  - Upstream: π – μ separation
    - Time-of-flight measurement
    - Cherenkov
  - Downstream: μ – e separation
    - Cherenkov
    - Electromagnetic calorimeter
- Spectrometers:
  - Position, momentum, emittance measurement

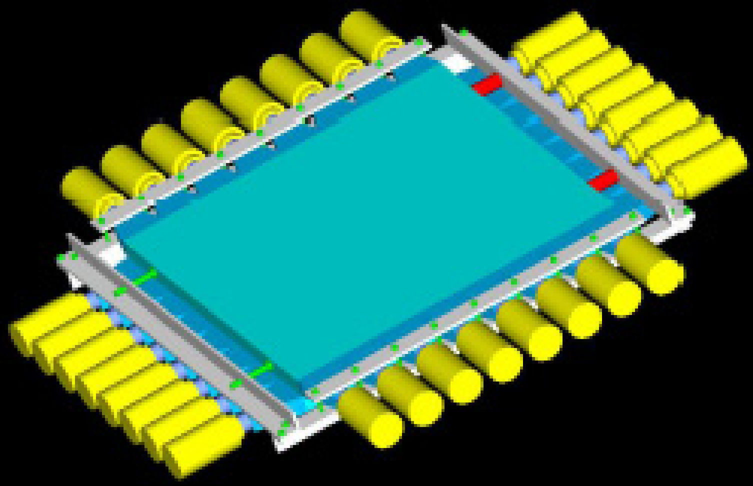
Apparatus: PId – overview



Apparatus: PId: Time of flight

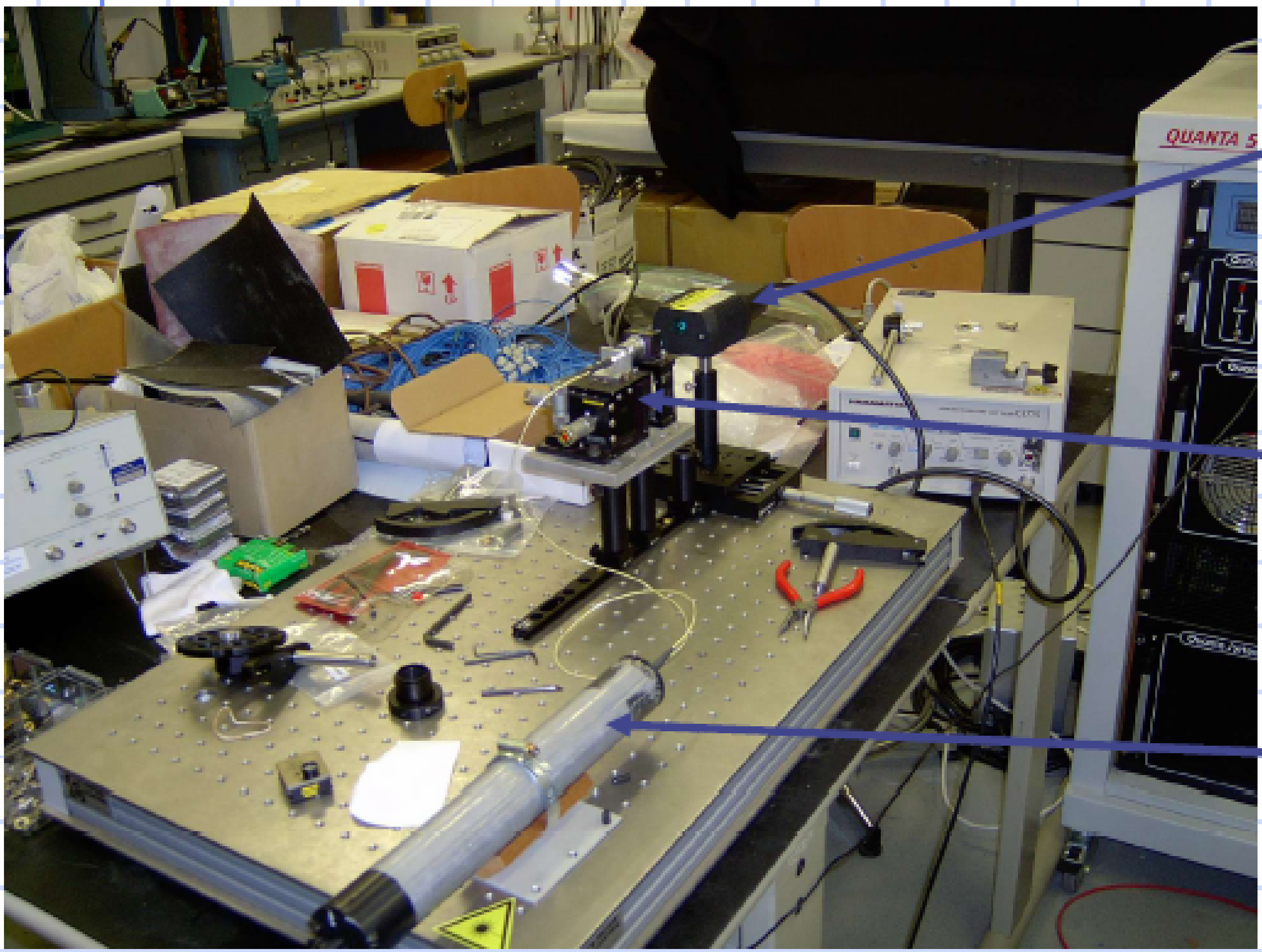
Milan

- **Specification: time-difference resolut^{n} 70ps**
- **Tasks:**
  - **TOF0 – TOF1: π/μ separation**
  - **TOFs: measurement of muon phase w.r.t. RF**
  - **Trigger and trigger time**
- **Principal challenges:**
  - **Rate in upstream TOFs**
  - **Time-difference resolution**



Apparatus: PId: ToF R&D

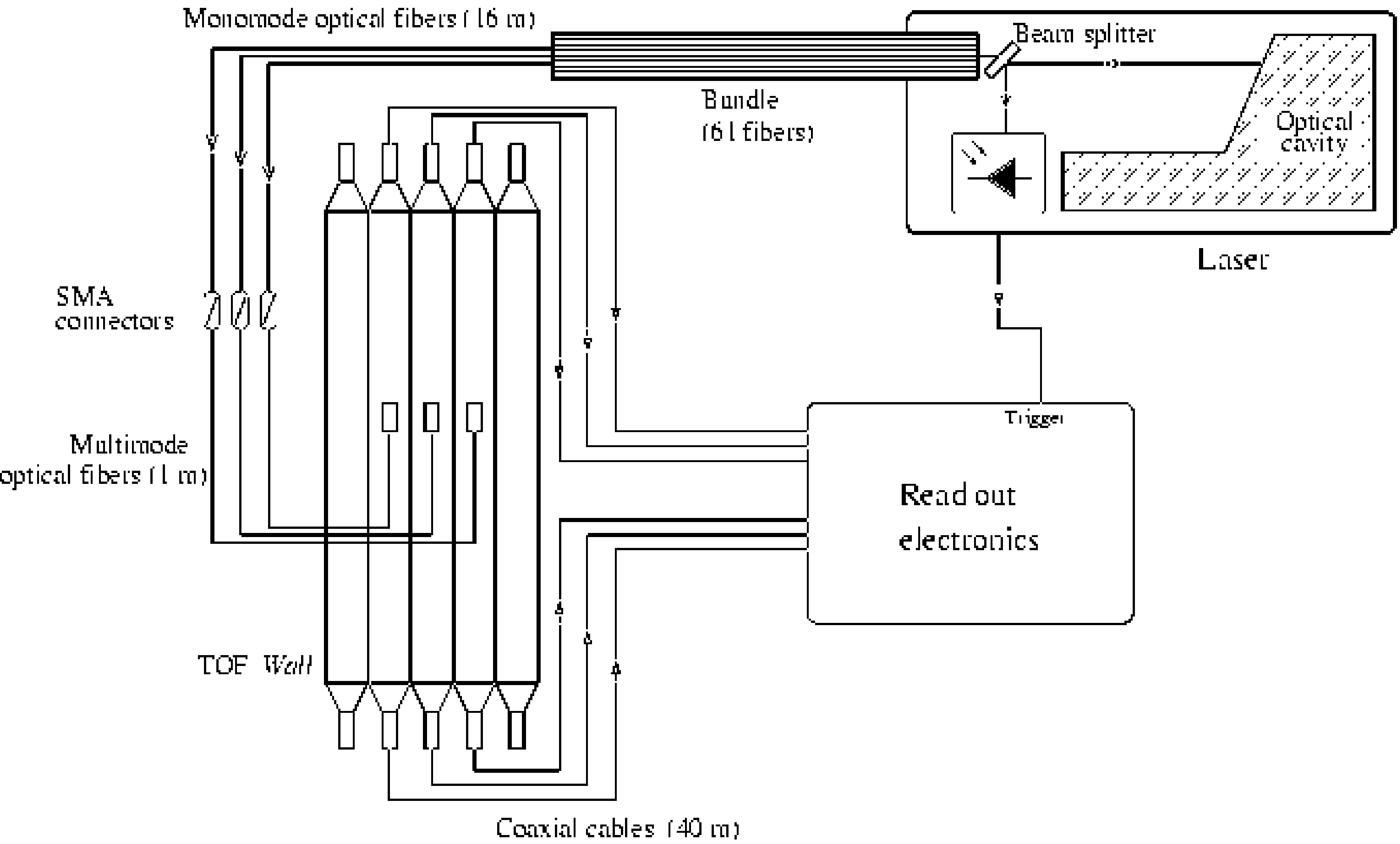
Test setup for study of rate effects



- Light source: Hamamatsu fast laser ($\lambda \approx 405$ nm, FWHM 35 ps, .17 mW power)
- Optical system: x,y,z micrometric movement to inject light into a CERAM/OPTEC multimode fiber (spread 14 ps/m)
- PMT under test (R7761, ...), output to SILENA MCA
- All tests to be redone at LASA with B-field

Apparatus: PId: ToF calib^{n} syst.

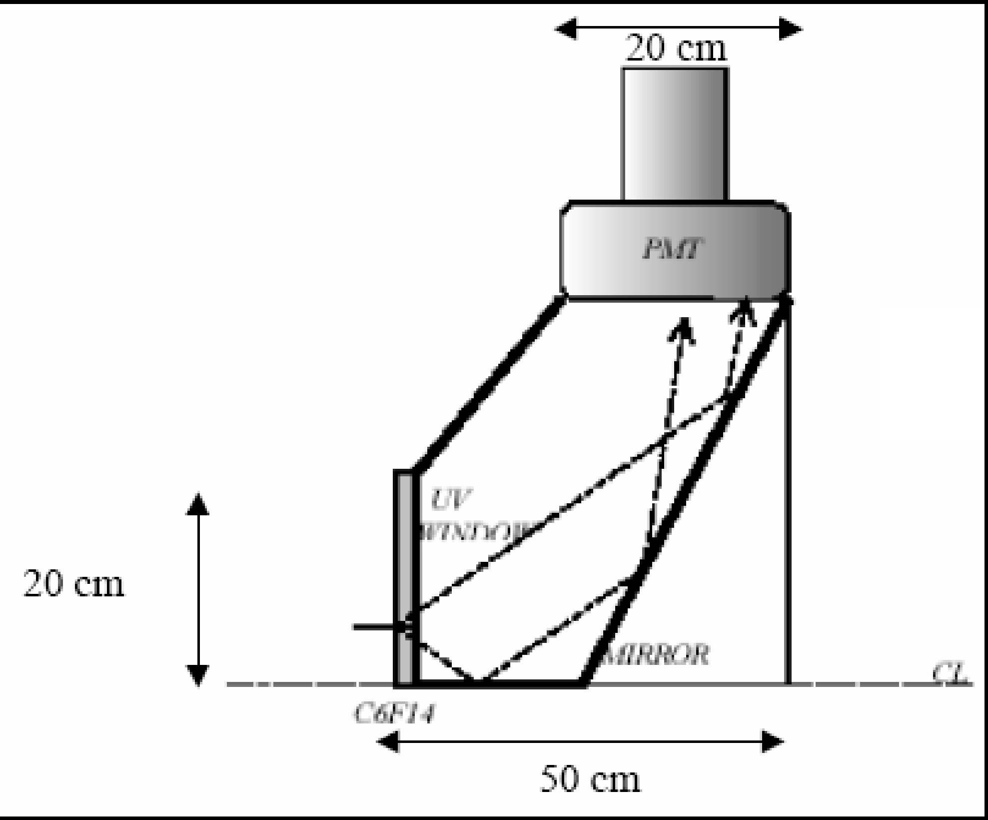
Calibration: tracks in overlaps plus laser system

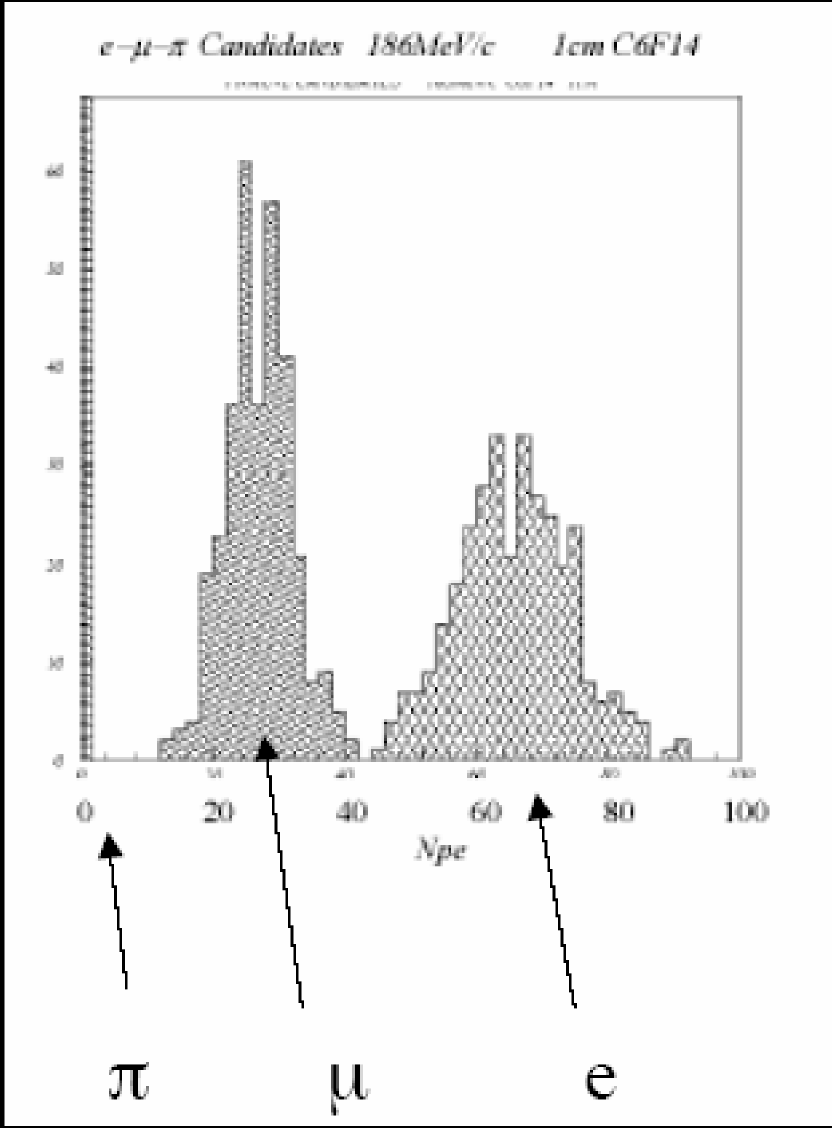


Apparatus: PId: up^{strm} Cherenkov

U-Mississippi

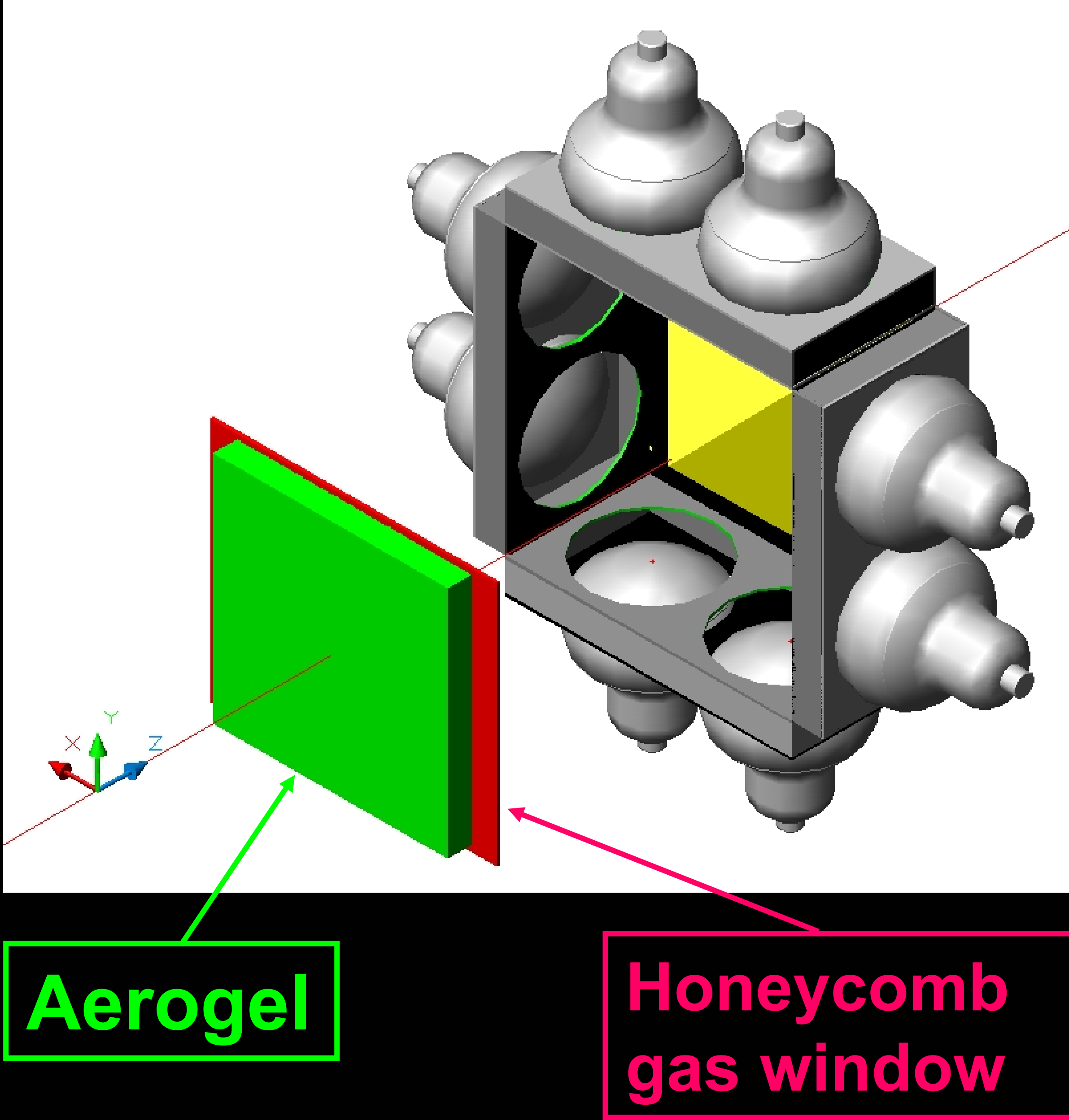
- Tasks:
  - π / μ separation





Apparatus: PId: dn^{strm} Cherenkov

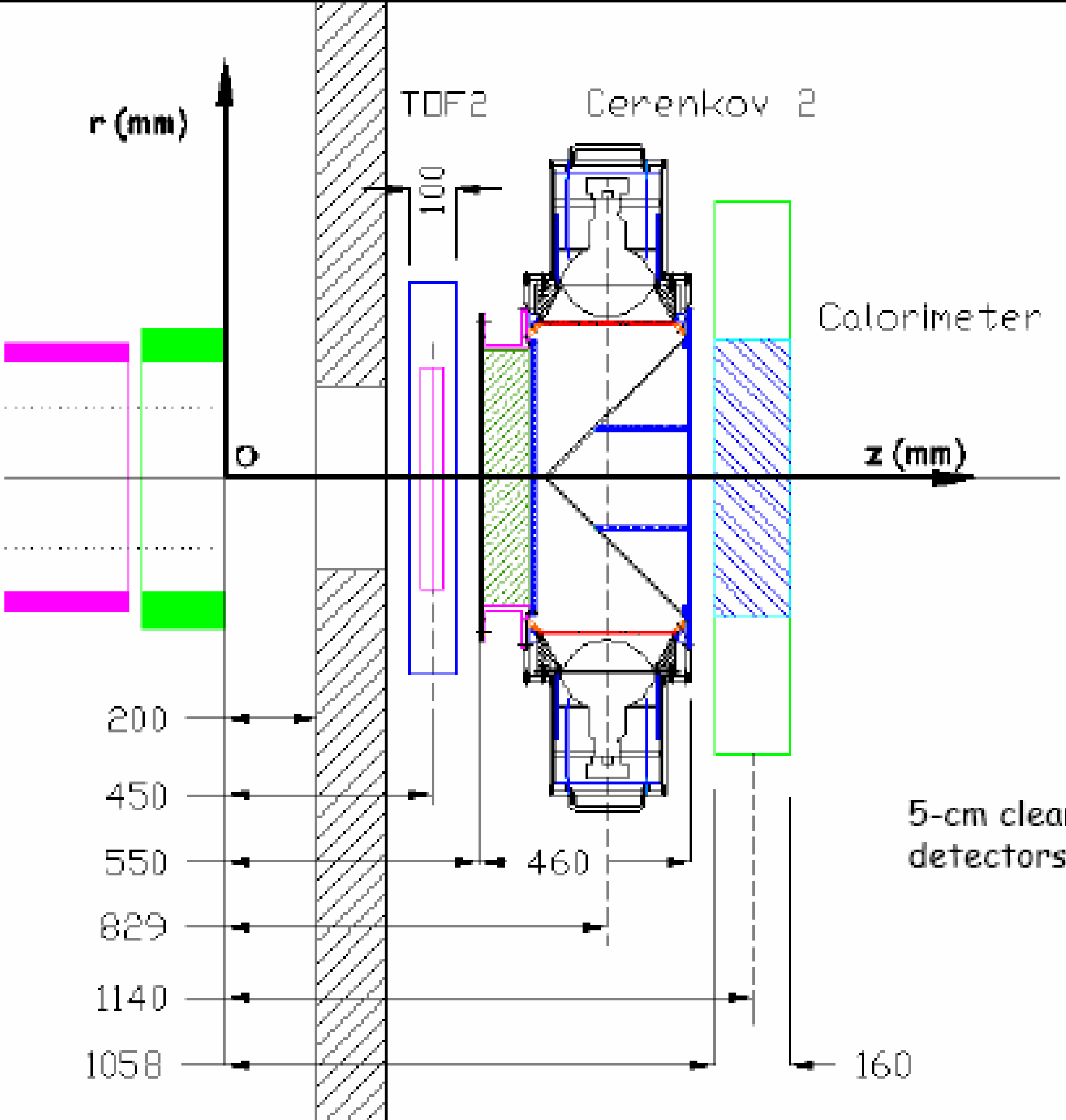
- Task:
  - μ/e separation
- Challenge:
  - Operation in fringe field of detector solenoid



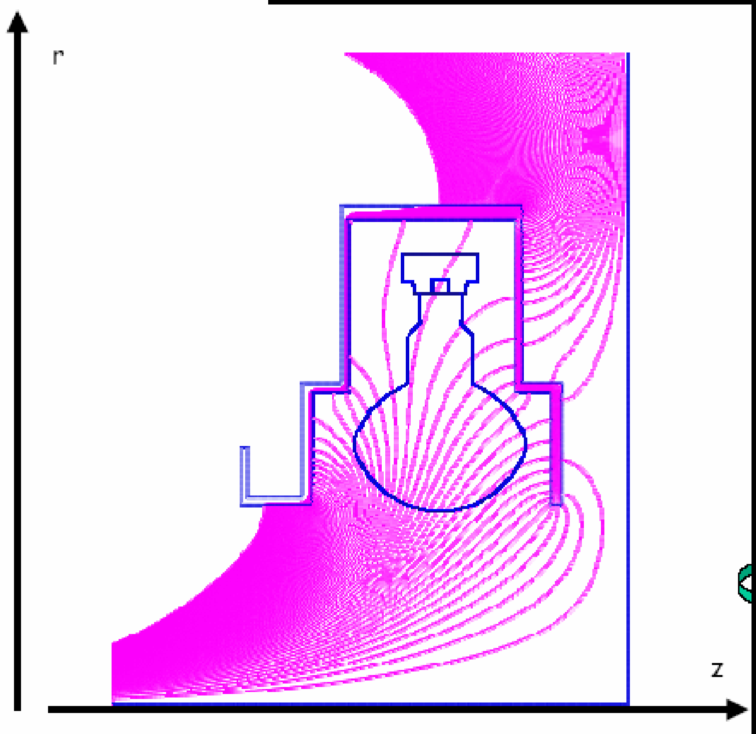
Louvain

Apparatus: PId: dn^{strm} Cherenkov

- Layout and magnetic shielding



5-cm clearance between detectors

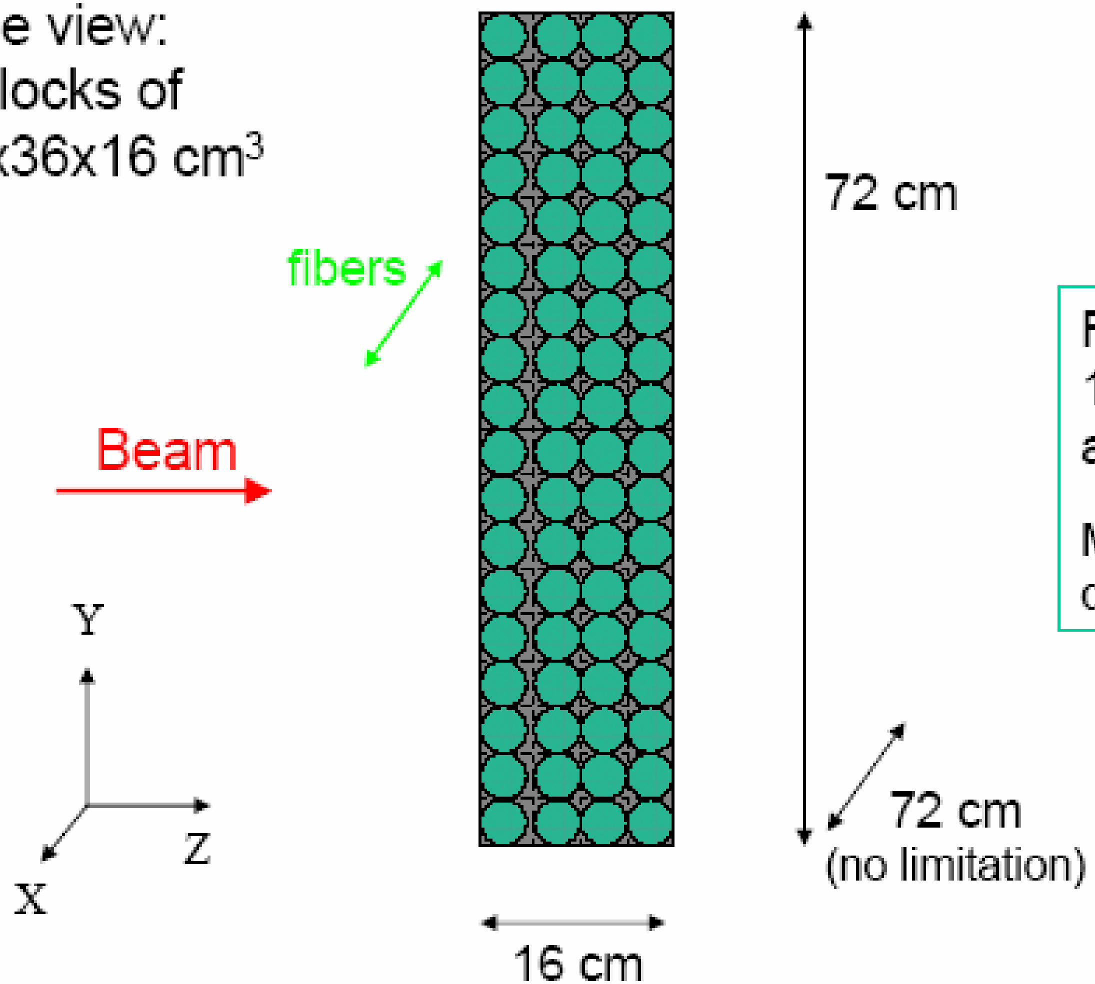


Apparatus: PId: MUCAL

- **Task:** μ/e separation — Rome III

Scintillating fibers embedded in grooved lead layers

Side view:
2 blocks of
$72x36x16\ cm^3$

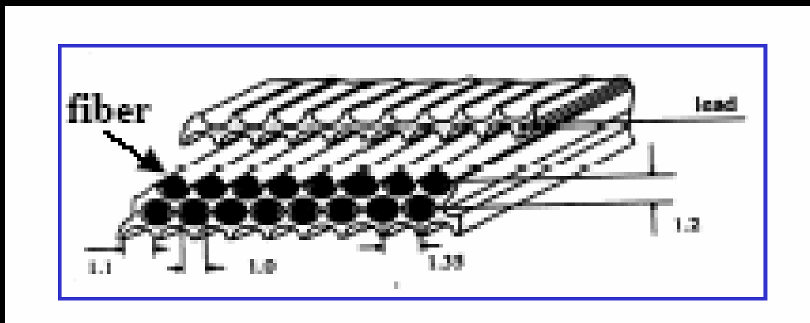


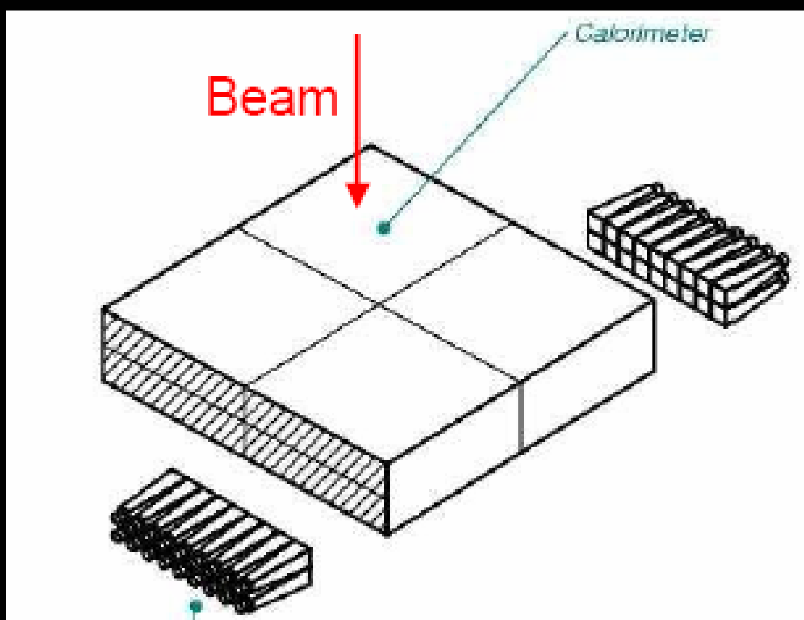
Readout:
18 PMTs per layer
at both ends

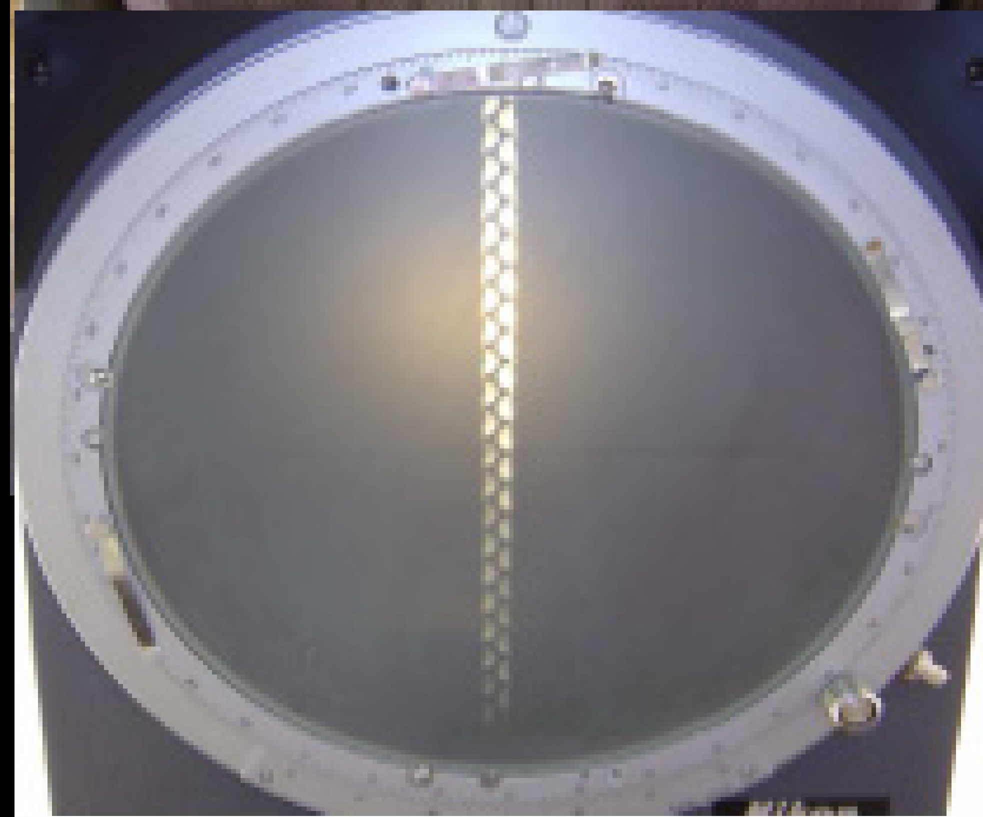
Minimum cell size $4x4cm^2$
due to PMT support

Apparatus: PId: MUCAL

- Construction: 0.3 mm lead; 1 mm fibre

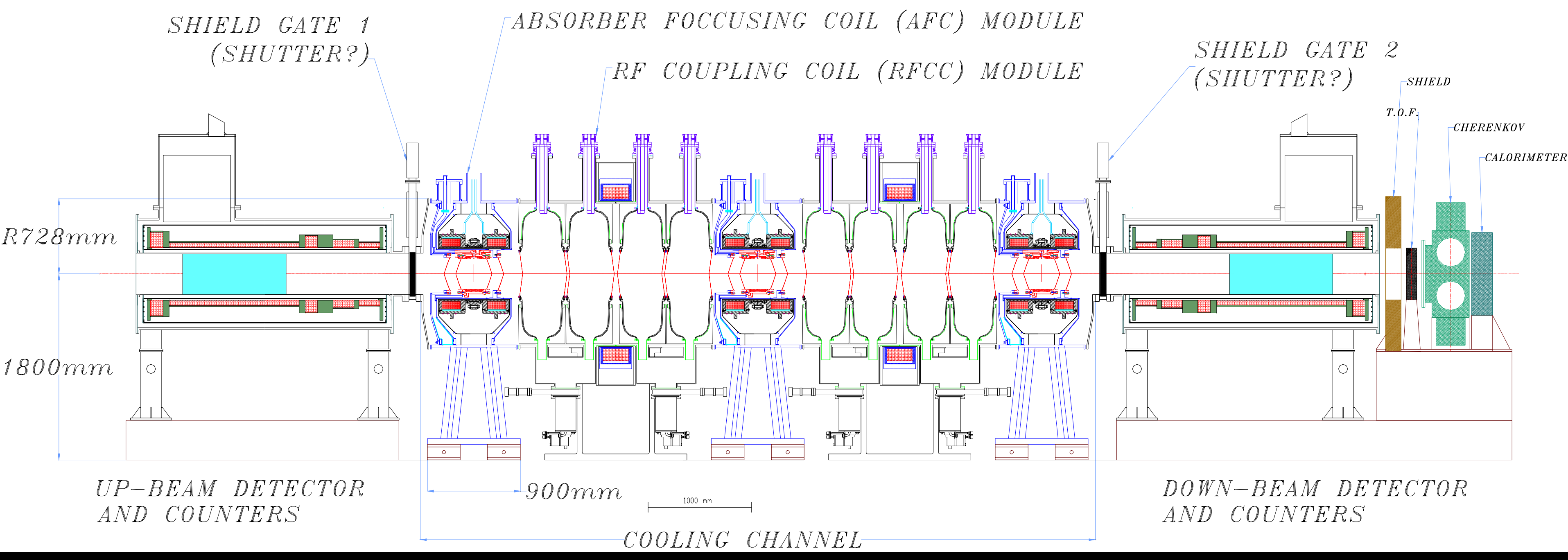






Apparatus: spectrometers

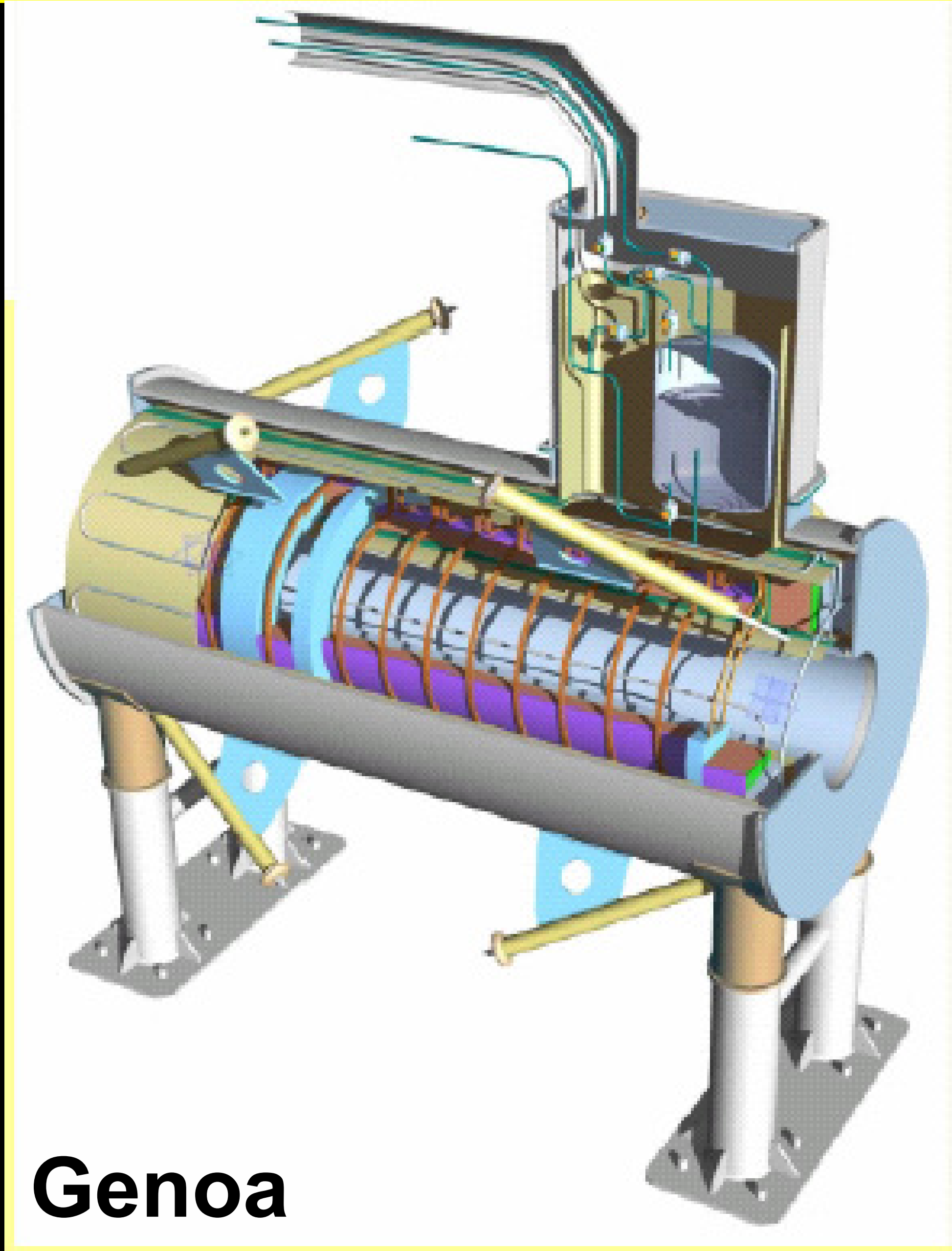
- Tasks:
  - Muon momentum (energy) and position (time) Resolution: better than 10% of beam spread
  - Emittance: fractional change in emittance to 0.1%



- Principle challenge: (see A.Blondel; MuTAC03)
  - Pattern recognition in presence of X-ray bg

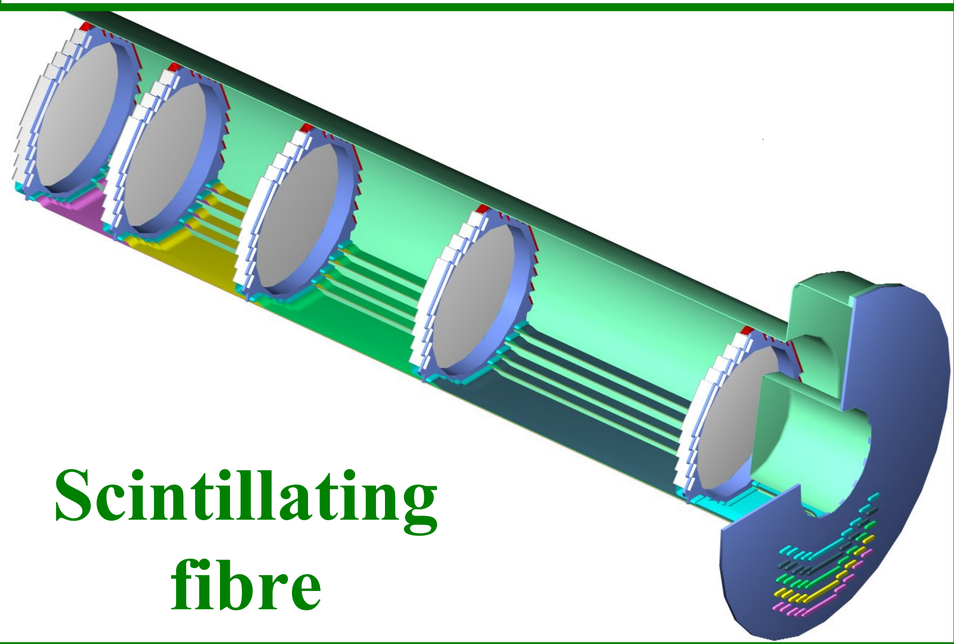
Apparatus: spectr^{mtr}: solenoid

- Specification:
  - 4 T field, 40 cm bore
- Challenges:
  - Many coils; one cryostat
    - Matching coils at each end of solenoid
  - Tracker services; magnetic field monitoring

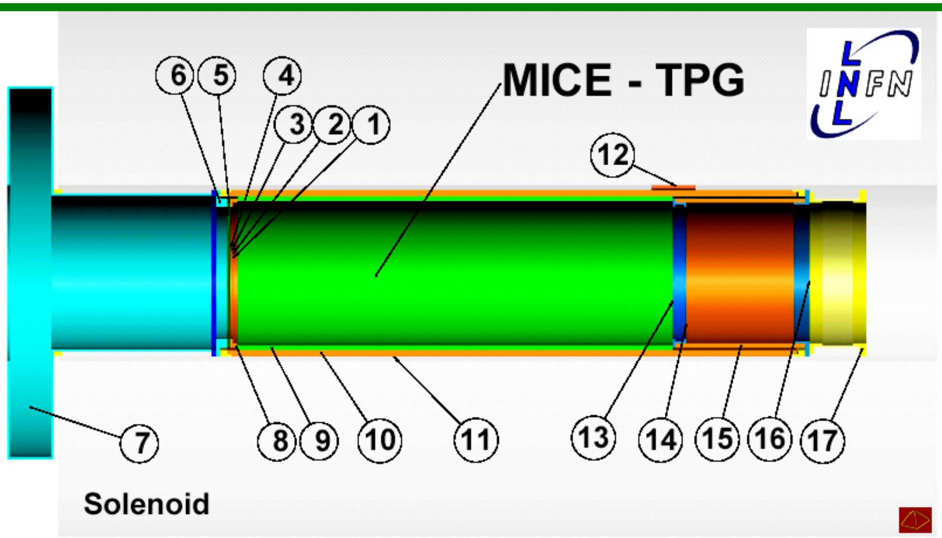


Apparatus: spectr^mtr: tracker

Baseline	Fallback



Scintillating fibre



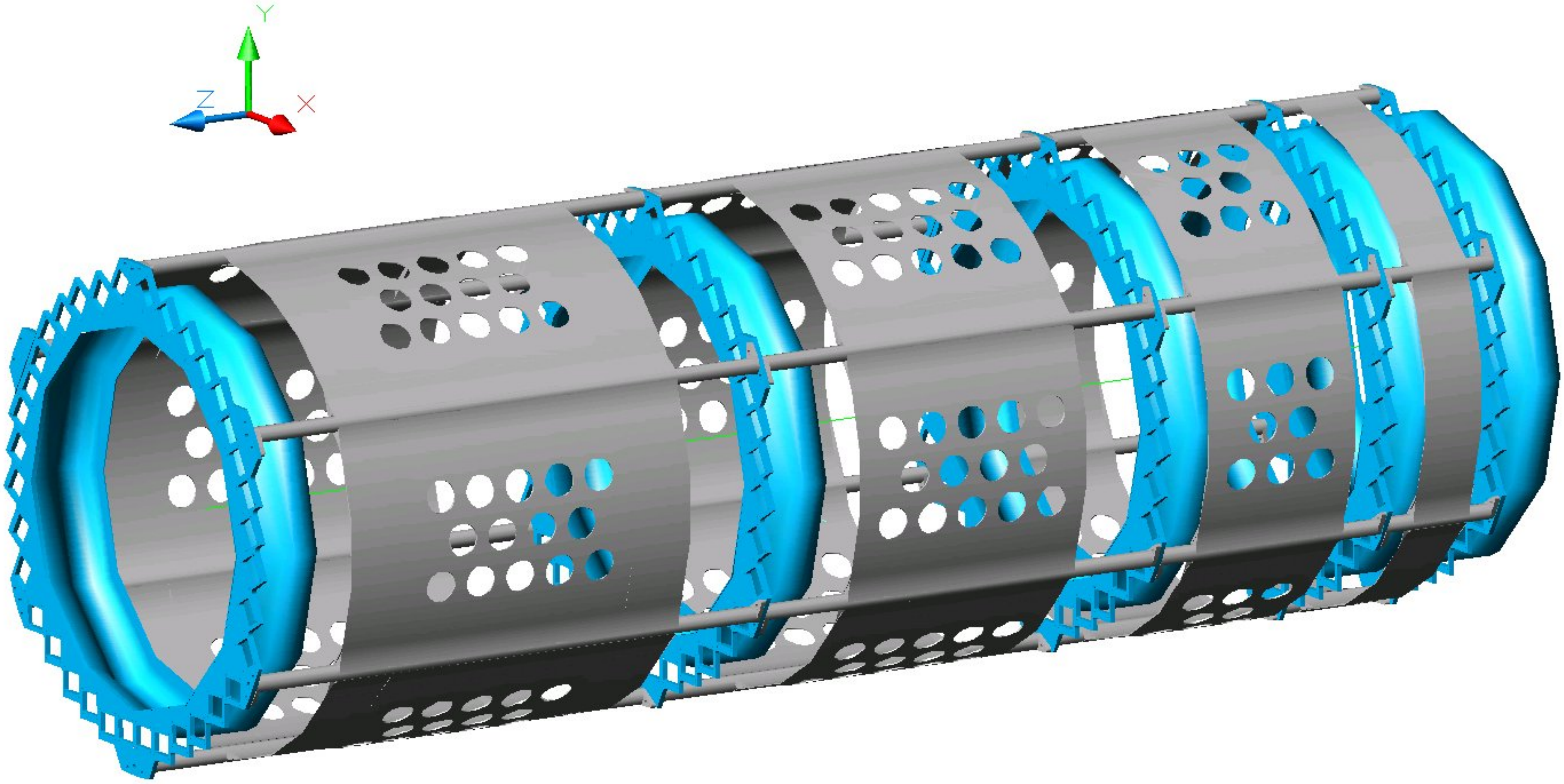
TPG – TPC with GEM readout

- No active electronics/HV close to liquid hydrogen absorber
- No copper close to RF (no pickup)
- 350 μ fibre: 3-fold doublet; 0.35% X_0
- VLPC read-out: high quantum-efficiency, high gain

- Light gas (0.15% X_0)
- Many points per track
- High precision track rec^n possible
- Large integration time
- Effect of X-rays on GEMs

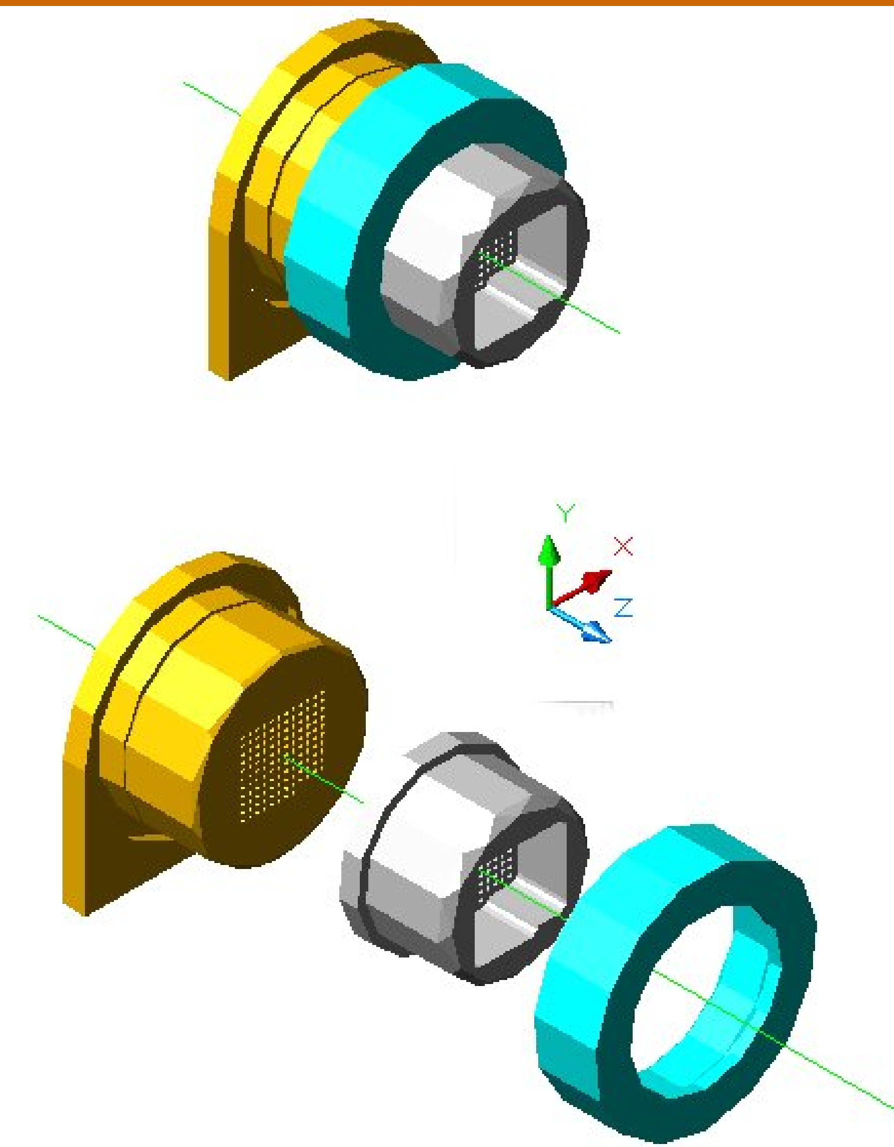
Apparatus: spectr^{mtr}: tracker

- **Mechanical design: status**



Apparatus: spectr^{mtr}: tracker

- Optical connectors:



Bulkhead connector

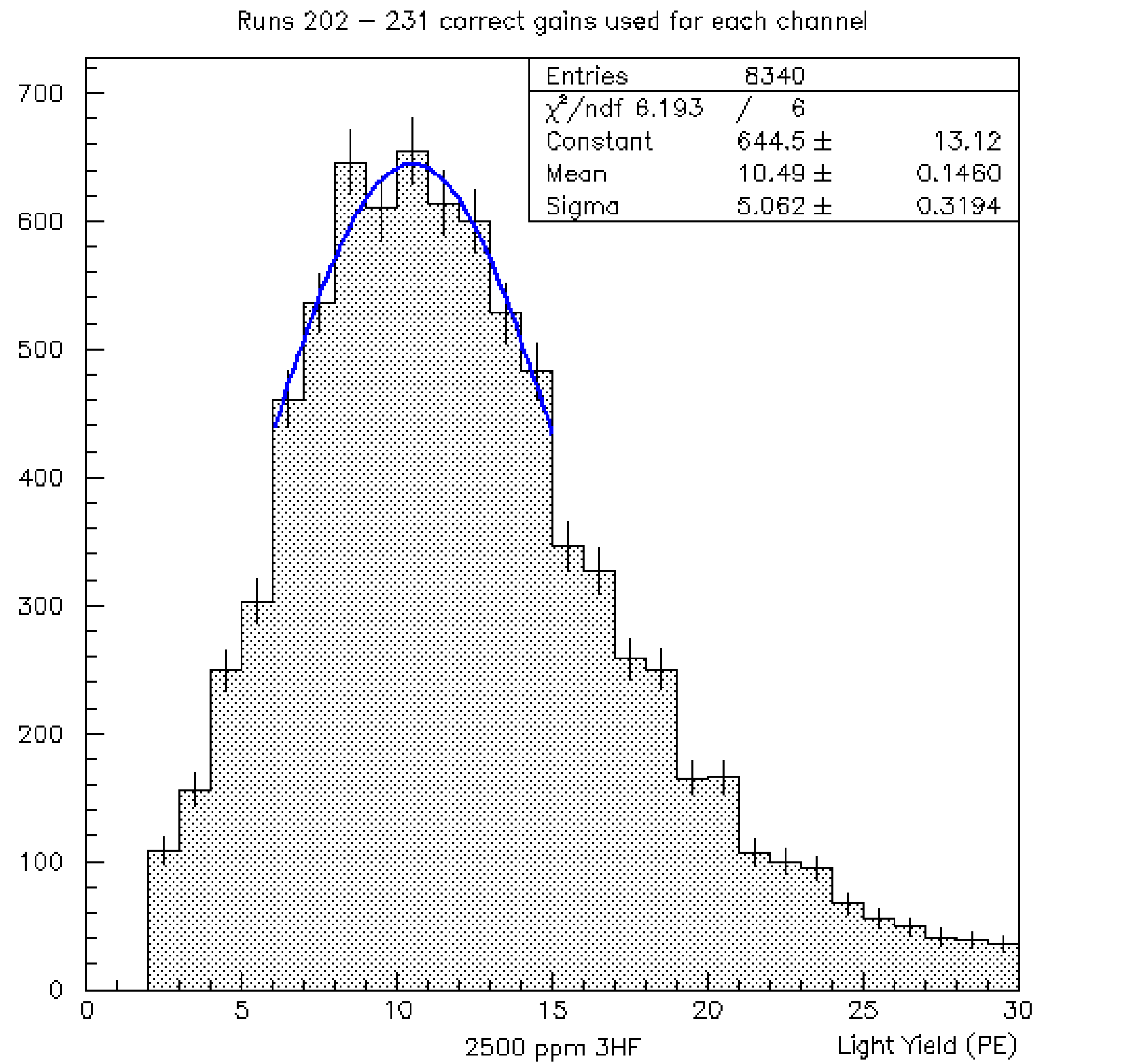
Station connector

Seven 350 μm scint. fibres read out through one 1 mm clear fibre

7-fold reduction in channel count ⇒ significant cost saving

Apparatu

- Prototype:



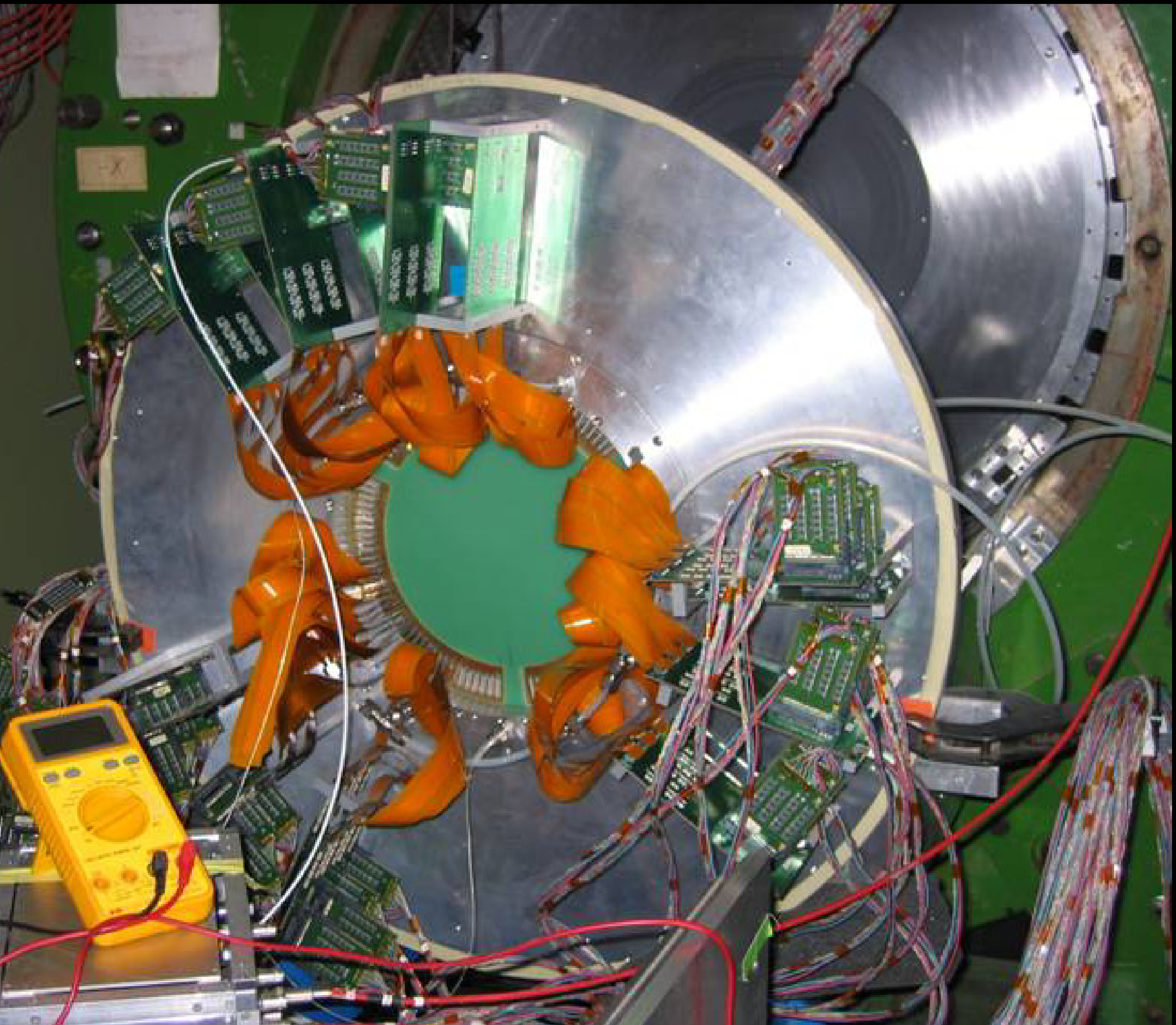
Apparatus: spectr^{mtr}: tracker

- Prototype performance:
  - Most probable light yield: 10.5 – 11 p.e.
    - Expectation based on D0 experience ~10 p.e.
  - Resolution: 442 ± 4 (stat) ± 27 (syst) μm
    - Expectation from fibre geometry: 424 – 465 μm (single fibre bunch or two fibre bunch)
  - Efficiency: (99.7 ± 0.2)%
    - Poisson expectation for 10 p.e. signal 99.7%
  - Dead channels 0.2% (two channels)
    - 0.25% assumed in G4MICE simulation based on D0 experience
- Planning test beam at KEK (then RAL):
  - Additional station – finalise fabricat^{n} techniques
  - Magnetic field: verify pattern recognition and momentum measurement

Apparatus: spectr^{mtr}: tracker

- Fallback:
  - Time-projection chamber with GEM readout

Bari, Legnaro, Napoli, Trieste, Geneva



Test of TPG head using HARP TPC field cage

Operation:

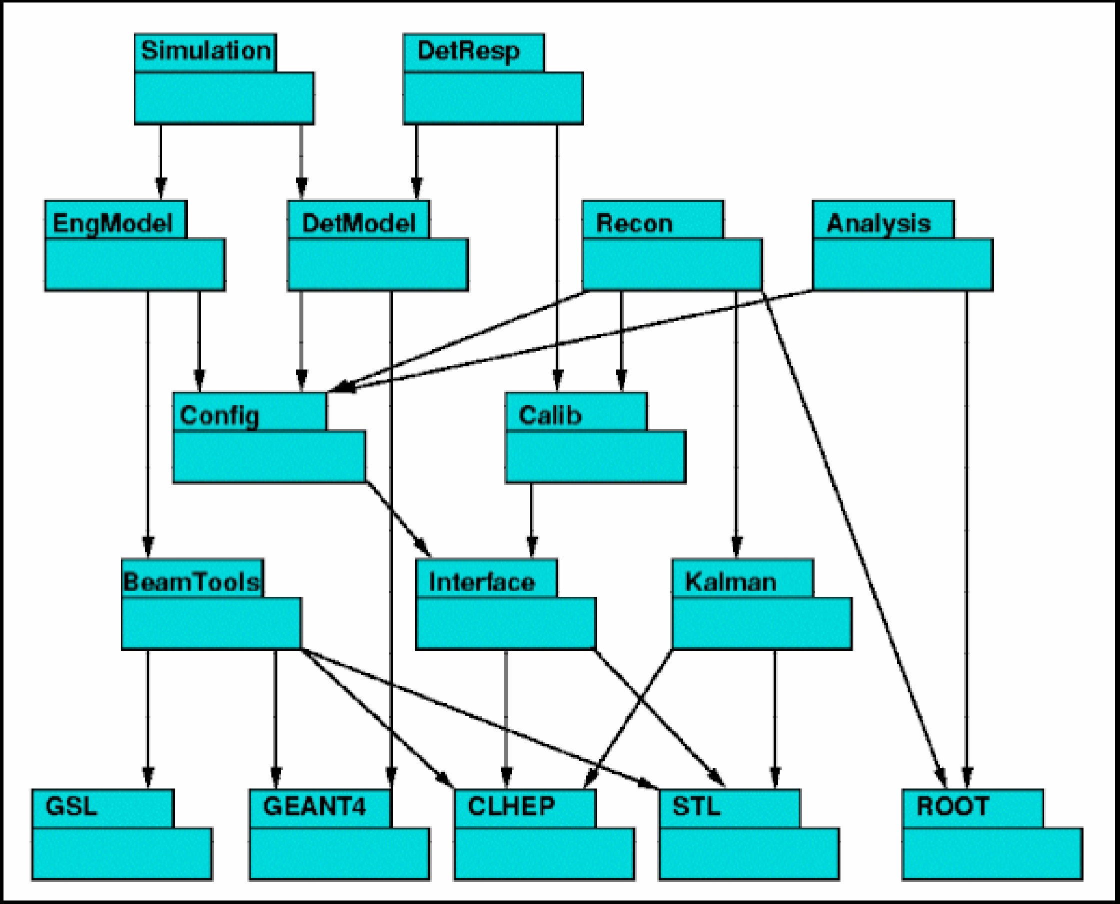
with cosmics
March 2004

with beam
May 2004

Apparatus: software – G4MICE

– Contributions from EU, Jp, US and UK

- Beam line and MICE simulation in Geant
- Presently in transition phase:
  - S/w required to:
    - meet requir^{ments} of component design and optimisation;
    - evolve into final product^{n} framework.



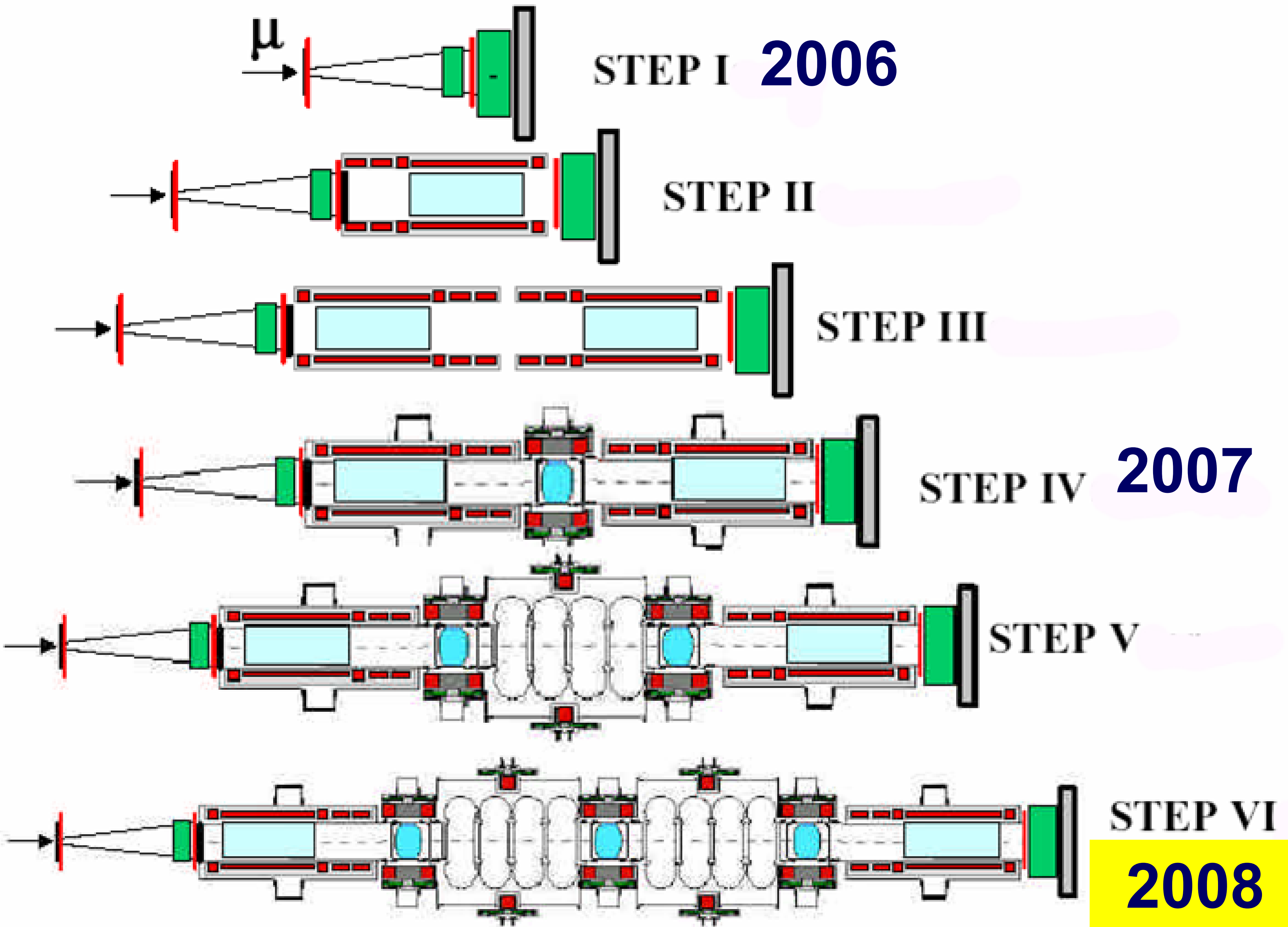
Summary

- Substantial technical progress last year:
  - Beam line & infrastructure (see PD)
  - Experiment:
    - Cooling channel:
      - Detailed design of absorber/focus-coil assembly; cavity/coupling-coil module.
      - Prototyping of key components well advanced
    - Instrumentation:
      - Detailed design of particle identification system
      - Detailed design of spectrometer solenoid
      - Spectrometer instrumentation:
        - Baseline technology chosen (fibre)
        - First prototype performing to specification
        - Development plan well established

Summary and outlook

- Approval and funding: substantial progress
  - Scientific approval (GW 0&1 and CCLRC)
  - Indication of substantial funding for UK contributions, subject to successful passage through Gateway
- Support & enthusiasm! Examples:
  - EU: Design of spectrometer solenoid
  - Jp: Manufacture of MICE absorber vessel
  - US: Substantial contributions to cooling channel
  - UK: Breaking into ISIS vault from MICE Hall
- Near term challenges:
  - Indication of international commitment becoming urgent
  - Prepare for and pass Gateway 2&3 ('procurement plan'): *goal SUMMER/AUTUMN 2004*
  - MuTAC endorsement of MICE programme and US contribution and
    MuTAC recognition of importance of early indication that US support will in due course be forthcoming
    highly valuable to MICE

Outlook:



Near term critical path analysis

- To keep MICE on schedule 2004 – 2006
  - UK: require to make beam line preparations
    - New internal target
    - Design & build stands
    - Purchase power supplies, test beam line elements
    - Purchase refrig^{tor} for decay solenoid and comm^{ission}
    - Install rail system, shielding etc.
  - Requires success at Gateway 2/3
    - Which requires indications of support from US (and EU, Jp)
    - US responsibilities not (yet) on critical path
      - 1st cavity module required in 2007
- Critical issue therefore:
  - Early indication of US support for MICE