FCC expts request for High Energy beamlines

interpreted as "collider experiments request for test-beams"

Based on past experience, but particularly LHC

The FCC experiments request for test and calibration beams will be very substantial

The need for such beams recurs throughout the lifecycle of the experiment, from concept and evolution through early operation.

- Concept. Detector R & D . Examining potential- no specific requirements yet.
- Conceptual design, choice of detector technologies leading to LOI/TP/CDR
- Technical design & review, prototypes construction and testing leading to TDR
- Construction & Calibration of production elements
- Commissioning & early data-taking
- Identification & study of systematic effects

Thanks to: Ana Maria Henriques Correia, Marcello Mannelli, Ludovic Pontecorvo, Werner Riegler, Fabiola Gianotti for their input.

Timeline of test-beam requirements

1) Early stages:

Tests of small prototypes of specific detector elements (trackers, calorimeters)
typically for days – weeks, to establish basic properties:
position, energy and time resolution, uniformity of response, noise levels etc
response to beam bunch structure (synch tests & out of time pile-up)
magnetic field tolerance
radiation tolerance via delivery of vastly accelerated doses

Progresses through successively larger prototype units, iterating towards final module sensors, size, readout, trigger capability and production quality

2) Intermediate stages:

Production high statistics calibration of some, or even all, production modules of particular detectors (especially calorimeters)

Timeline of test-beam requirements

3) Nearing completion

Combined detector "sector tests", (trackers, calorimeters, muon detectors, with realistic services (fluids, power, cable routing) probably including integrated magnets,

--> approaching the complexity and longevity of fixed target experiments

4) Complete & Operational

Sector test continues as test bed of production quality to investigate anomalies & systematics

As for LHC testing, calibration and sector-test facilities of general purpose experiments will require more or less dedicated installations in beamline for as much as a decade.

Recall LHC history

1990 (t0-18)Birth of LHC project + Detector Research and Development Committee
~50 detector R & D projects approved and funded
adequate test beam facilities existed worldwide
SSC R & D programme already launched & ran concurrently until 1993

1992/3(t0-16) Birth/shotgun marriages/shootouts of LHC Collaborations

TP technologies mostly based on DRDC (or SSC) R & D

1995/96(t0-12) ATLAS/CMS approval. DRDC & generic R& D over.

1995-2000: Technical Design Reports
(-13<t0<-8) (Magnets & infra, Trackers, Em & Had cals, Muon systems, Trigger/DAQ)

dedicated beamlines for testing prototypes of different detection layers separately
need for 40Mhz time structure identified.

Recall LHC history

2000-2007: Response mapping & calibration of pre-production module
(-8<t0<-1) and feedback to production lines & detailed design
Calibration of production modules, all/samples

about half of the total beamlines dedicated to LHC expts
(complex, specialised long-term facilities with magnets, DAQ , infra)

eg CMS used about 65 weeks of test beam time per year,
distributed amongst 5 beamlines at CERN

40MHz beams available from 2000

Full scale multi-detector slice tests in the last ~ 2 years
--> large scale experiments in their own right

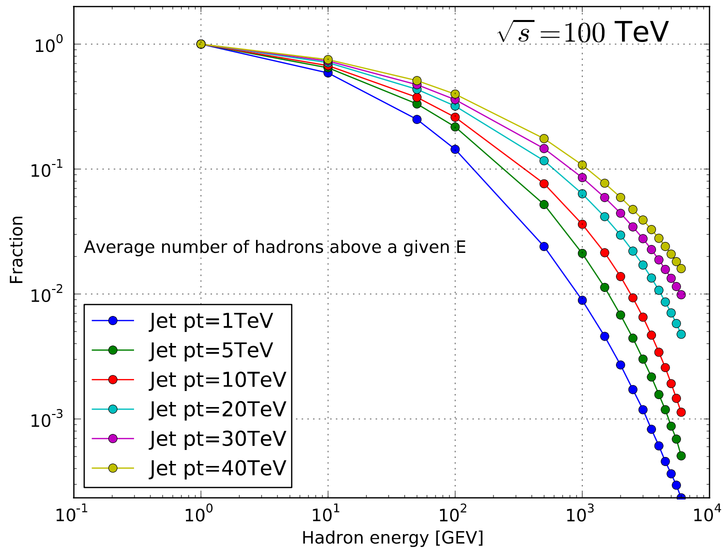
2008-2012
0< t0 <+3): study of systematic effects using spare production modules
and maintained slice configurations

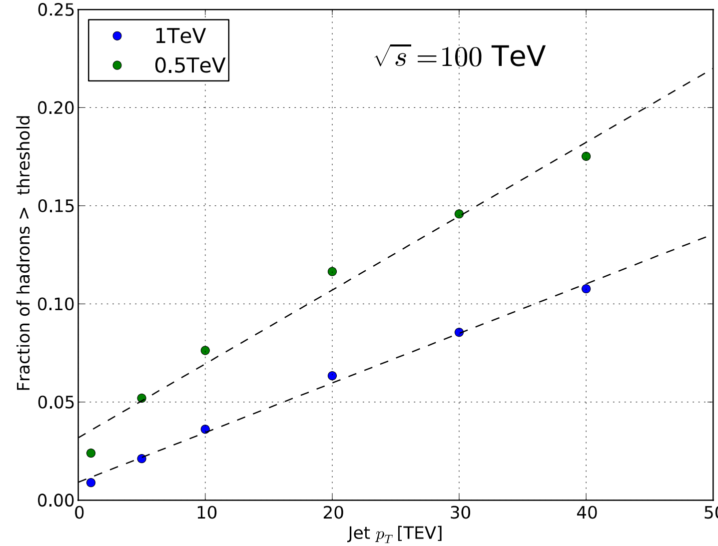
Argument for TeV test-beams?

1)Calorimetry and jet reconstruction:

A) Leading particle in a jet can carry significant fraction (~10%) of jet energy

C. Helsens





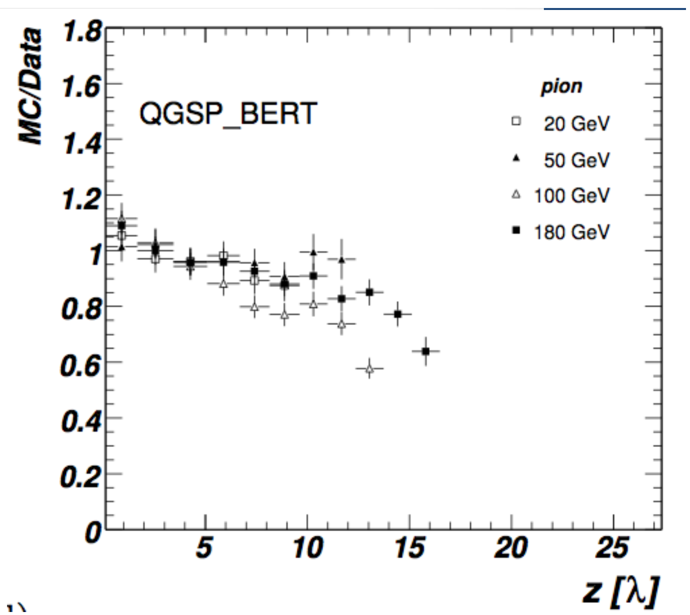
eg In a 30 TeV jet, 8% of hadrons have energy > 1 TeV,

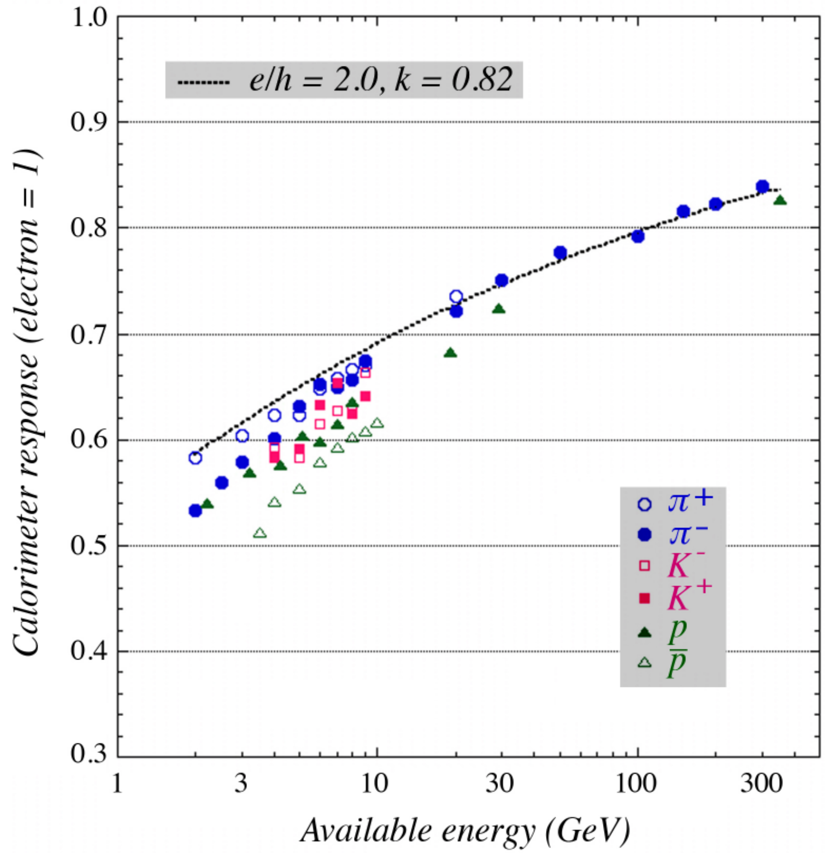
and on average ~1 of ≥5TeV)

Argument for TeV test-beams?

B) Response generally not linear
:electromagnetic & hadronic responses not equal
:ratio varying with energy and with incident particle

-Hadronic showers are also not yet perfectly simulated (not as broad or long as in data).
Simulation/data is energy dependent:





Argument for TeV test-beams?

To start physics operations with well calibrated jet energy measurement, need to:

-calibrate response of calorimetry system to few TeV π,p beams compared with e- of same energy.

- tune Monte Carlo simulations used to extrapolate/interpolate

[LHC GPE's used 350GeV calibrations to establish JES for (most of) Run 1 analyses]

As at LHC, data taken at FCC will eventually (year or two) allow an equivalent or better calibration…

2) Other justifications for TeV beams:

- measure calorimeter leakage …this contributes to the constant term , which dominates the resolution at high energy [π,p beams]

-check muon energy loss and identification/measurement philosophy

- measure muon identification rate and hadron misidentification rate (due to punch-through and decays) [π,μ beams]

To be thought about whether it make sense to have a GIF like facility on a TeV μ beamline to simulate key radiation field from collision products or if GIF++(+) will do.

Reminder: still need lower energy beams!

Calorimetry:

Majority of energy in jets is carried by very low energy particles
eg TeV gluon jet, 50% of energy carried by particles of < 25 GeV

--> Lower energy calibrations are also critical for: accurate reconstruction of jets
mitigation of pileup
--> not so easy to extract from data, especially when pileup already present

Ideal is overlapping set of test-beams providing O (10GeV), O(100Gev) & O(1TeV)

If particle flow methods are chosen for calorimetry, then quite complete dedicated set-ups with magnet, tracker and calorimeters may be needed quite early on.

Low energy beams also suitable for:

~All the basic detector R & D (equivalent DRDC) (for FCC-ee, hh and eh)
Much of the production calibration (especially inter-calibration)

Further remarks

An FCC GPE sector test setup will be 20m long , permanent and will need sophisticated services

TeV π and μ, p beam characteristics to be thought about (momentum bite, intensity, purity)

High purities are desirable. Interesting to know what intensity would be available

Could be a case for neutron beam? if that is possible

Understanding response of energy measuring system (esp particle flow based) to neutrals is crucial

ee and hh (and eh) collider detector development are not unlikely to overlap…

Conclusions

2015/16 would not be too early to start a generic FCC detector technology R & D programme requiring existing test-beams & irradiation facilities

All existing PS and SPS extracted beams and CERN irradiation facilities required (scaled up in intensity if possible)

+ test magnets

+ beams/reactors in other worldwide locations

There is a good case for test beams with p/π/μ/e energies up to a few TeV.

Needed when the first full scale prototypes of sub-systems become available ie at ~ t0 – 13

FCC bunch timing structure should also be available

Need dedicated test facilities for each experiment as prototypes designs converge and sophisticated production calibration and “slice-tests” get underway ie at t0-10 at latest

(interference with continued LHC collider operation?)