New Scientist

WEEKLY April 30 - May 6, 2016

On the cover

28

Anomalies

Seven hints of science beyond what we know

Cover image
Chiko

Who threw out the protons?

Comb LHC's trash for a mystery prize

Jacob Aron

IF IT doesn't show up anywhere, maybe it got thrown out. That's where one team of particle hunters think their quarry might be hiding – as a signal in the energies of protons discarded by the Large Hadron Collider.

Last December, researchers at CERN, the particle physics laboratory near Geneva, Switzerland, presented the first results from the recently retooled LHC. Hints of a new and unexpected particle with a mass of around 750 gigaelectronvolts (GeV) set theorists aflutter trying to figure out its origin.

Normally, two beams of protons circle its 27-kilometre ring and smash together inside four detectors – ATLAS, CMS, ALICE and LHCb – producing showers of particles. When the collider restarts next month, these will be scanned for the mystery particle.

Now Risto Orava of the University of Helsinki, Finland, and his colleagues are proposing a hack to allow a new kind of search.

Often, the colliding protons survive their encounter and pass right through the detectors, moving at a slight angle to the rest of the beam. These protons are no longer being kept on track by the LHC's massive ring of magnets and could damage the machine, so are traced and safely disposed of by the 4000 little detectors of what is known as the beam loss monitoring (BLM) system.

Orava's team say this is a missed opportunity: the BLM

"Wayward protons could damage the LHC so are disposed of, but this is a missed opportunity"

could search for new physics. That's because measuring the difference in proton energy before the collision and once in the BLM gives the energy of any particles created – another way to get a peek at the 750 GeV particle.

The team reckon this method could detect 5000 such events this year, versus the 20 or so presented last December. "It's a tremendous difference," says Orava.

Using the BLM in this way will require connecting its detectors on either side of the main experiments with optical fibres. This would allow the system to exactly time the arrival of protons, confirming whether two from the same collision have hit two detectors at the same time.

"In principle I think the idea is sound," says John Jowett of CERN. But more work is needed to find out how easy it would be to connect the detectors and whether they would give a clean signal. "They don't completely cover all the possible sources of background (noise) for this type of measurement or how practical the whole thing is."

The idea isn't without precedent, says Tara Shears of the University of Liverpool, UK. "Before the Higgs discovery, there were proposals to detect it using these sorts of processes, with dedicated proton detectors about 400 metres away from LHC experiments," she says. Physicist and TV presenter Brian Cox was one of those backing the scheme.

Orava is confident his team can make it work. "This is cheap and quick – it's taking the infrastructure of the LHC and using it for a test of physics," he says. ■

LHC RING AS A NEW PHYSICS SEARCH MACHINE

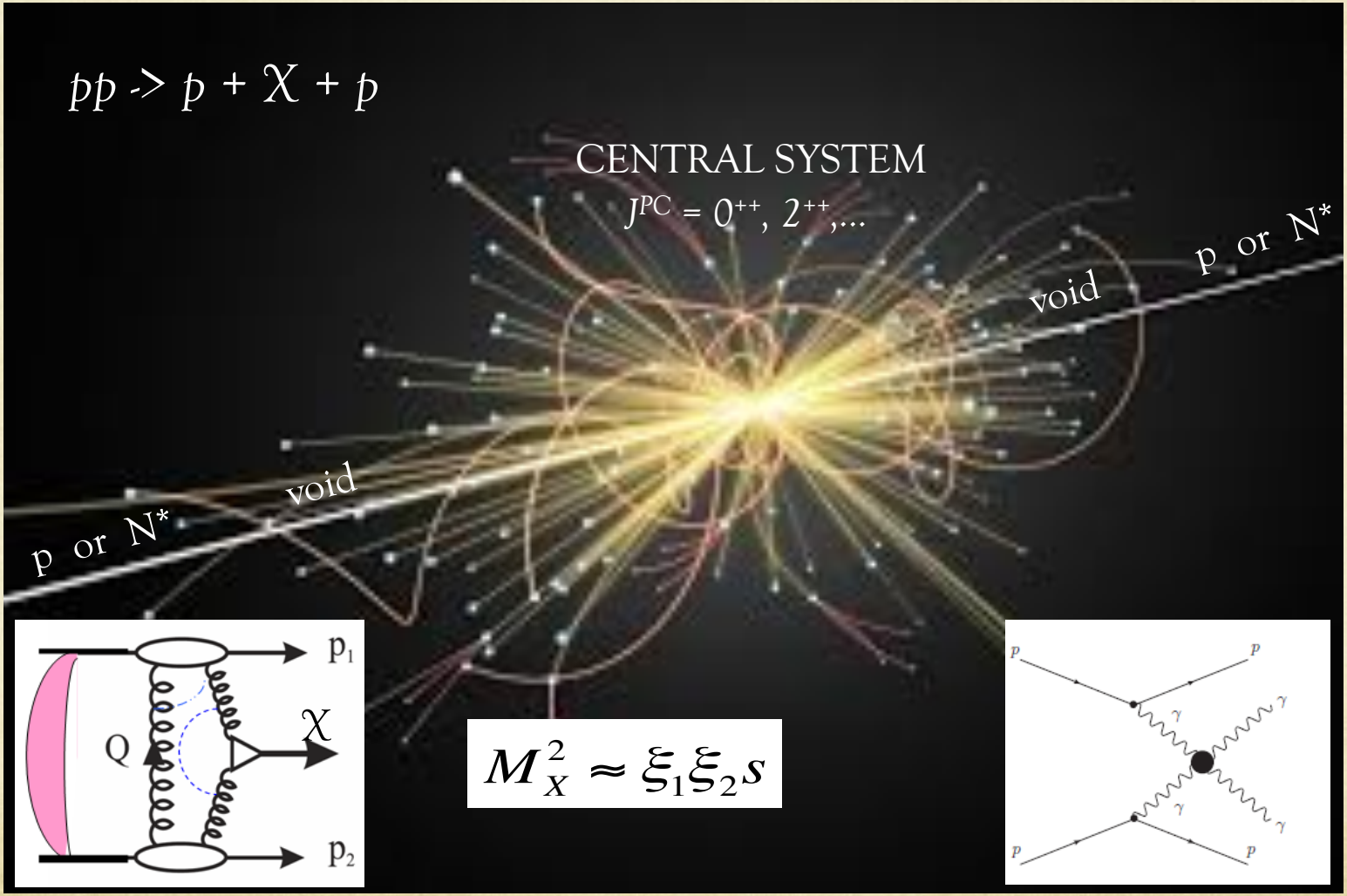
Risto Orava
University of Helsinki, Helsinki Institute of Physics, CERN

THE PLAN

- BACKGROUND
  - CENTRAL EXCLUSIVE PRODUCTION
  - PRESENT CEP TAGGING APPROACHES
  - THE LHC BLM* SYSTEM
- SCANNING FOR MASSIVE PARTICLES
  - CEP PROTONS EXITING THE LHC RING
  - TAGGING MASSIVE NEW PARTICLES IN CEP
  - FURTHER DEVELOPMENT
  - SUMMARY

* Not to be confused with Brodsky et al.!

CENTRAL EXCLUSIVE PRODUCTION



GLUON vs. PHOTON INDUCED PRODUCTION

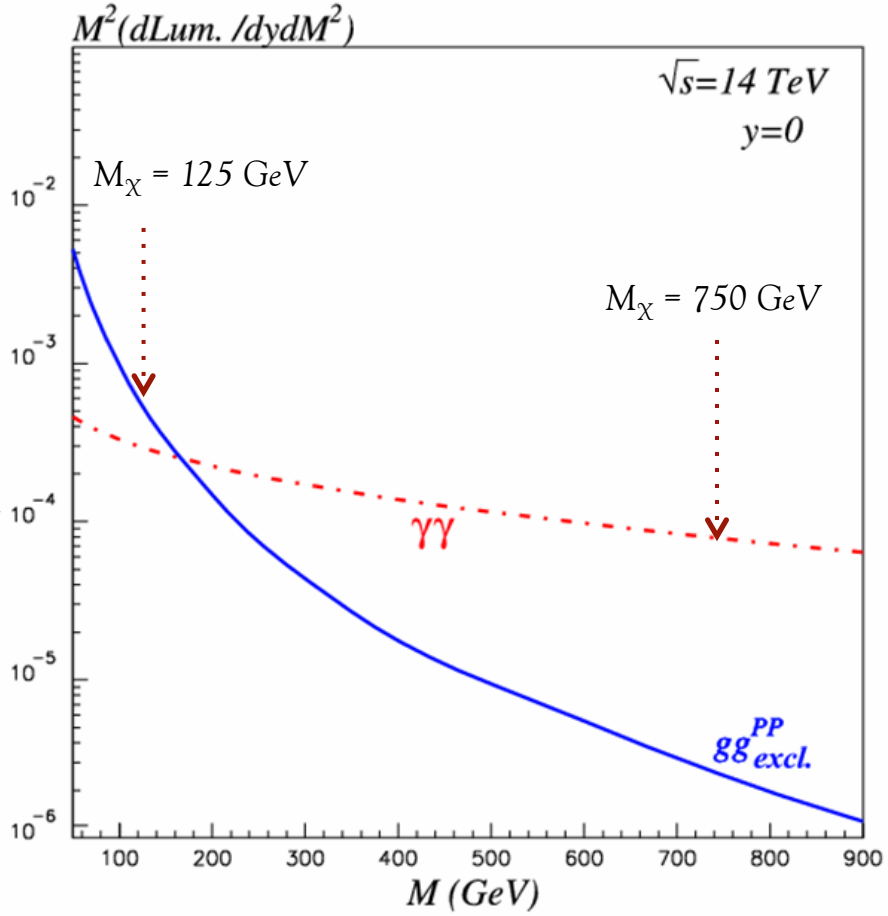
$\sigma(\gamma\gamma \to SMH) \approx 0.1\, fb$

$\sigma(PP- > SMH) \approx 3\, fb$

$\alpha_s^{\,2}/8 \to \alpha^2$

QCD 'radiation damage' in action

exclusive production strongly dominated by $\gamma\gamma$ at large M_χ!



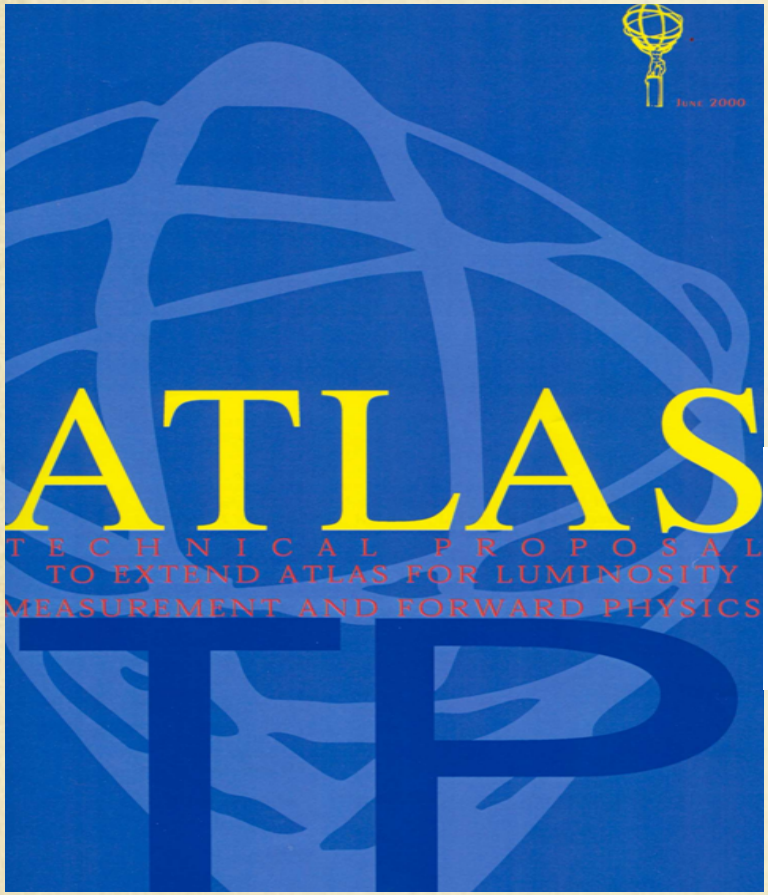
KMR: arXiv 0111078(2001)

see also: KMOR, Eur.Phys.J.C19:313 (2001).

THE HELSINKI GROUP: A SHORT HISTORY OF FORWARD PHYSICS INITIATIVES

- **Full Acceptance Detector** – J. Bjorken **1991**
- **FELIX LOI** **1997**
- **TOTEM LOI** **1997**
- **ATLAS TDR: Proposal to extend ATLAS for Forward Physics** **2000**
- **TOTEM TDR** **2004**
- **FP-420** TDR (CERN-LHCC-2005-025) **2005**
- **Prospects of Diffractive and Forward Physics at the LHC** (CMS/TOTEM, CERN-CMS/TOTEM Note 2007-002) **2006**
- **Central Diffraction in LHCb** (JINST 4(2009)P11019 **2009**
- **Forward physics with rapidity gaps at the LHC (CMS)** (JINST 4(2009P10001) **2009**
- **Central Diffraction at ALICE** (JINST 6(2011)P02010) **2010**
- **Turning the LHC ring into a new physics search machine (arXiv:1604.5778)!!** **2016**

PROPOSAL TO EXTEND ATLAS

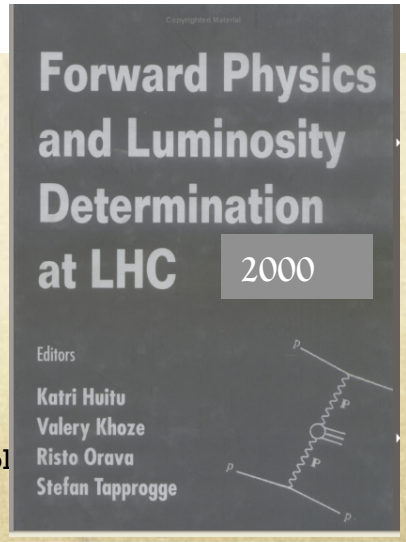


Proposal to Extend
ATLAS
for Luminosity Measurement
and Forward Physics

June 2000

H. Ahola[1], M. Battaglia[2], O. Bouianov[3,4], M. Bouianov[2,3], G. Forconi[4], E. Heijne[5], J. Heino[4], V. Khoze[6], A. Kiiskinen[4,7], K. Kurvinen[4], L. Lahtinen[4], J.W. Lamsa[8].

H. Ahola[1], M. Battaglia[2], O. Bouianov[3,4], M. Bouianov[2,3], G. Forconi[4], E. Heijne[5], J. Heino[4], V. Khoze[6], A. Kiiskinen[4,7], K. Kurvinen[4], L. Lahtinen[4], J.W. Lamsa[8], E. Lippmaa[9], T. Meinander[1], V. Nomokonov[4], A. Numminen[4], R. Orava[2,4], K. Piotrzkowski[10], M. White[4], M. Ryynänen[1], L. Salmi[4,7], J. Subbi[9], K. Tammi,[4], S. Tapprogge[4], T. Taylor[5]



Helsinki Group, 2000

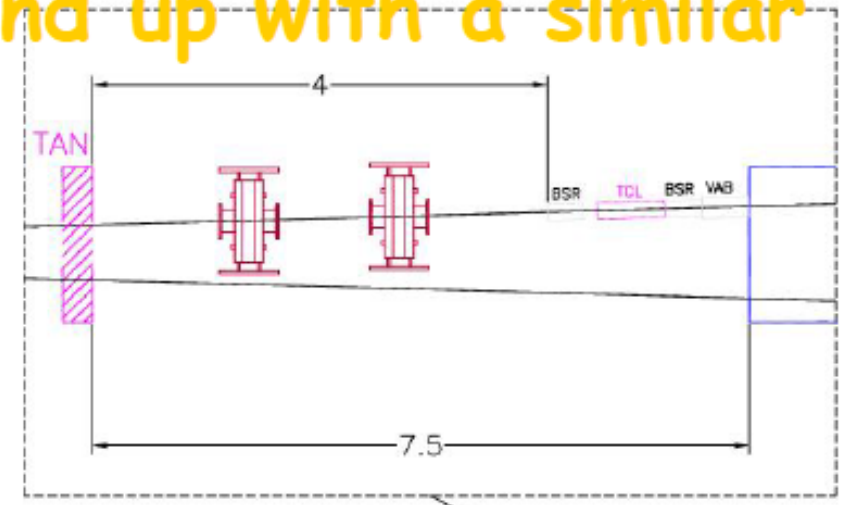
Diffraction at LHC
(How to turn LHC into a 14 TeV Gluon Factory ?)

Risto Orava

University of Helsinki
and
Helsinki Institute of Physics

Workshop on Diffractive Physics
4. – 8. February 2002
Rio de Janeiro, Brazil

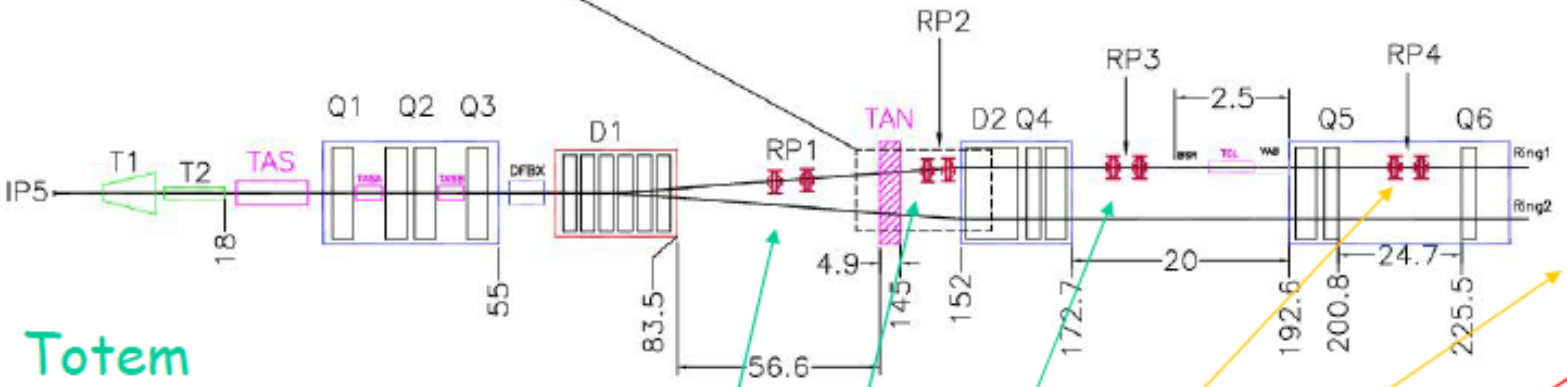
LHC optics (v6.3) layout: Two studies end up with a similar detector lay-out



Collimators and Absorber

TAS: Beam Absorber (Secondaries) between the IP and Q1
TASA: Beam Absorber (Secondaries) between the Q1 and Q2
TASB: Beam Absorber (Secondaries) between the Q2 and Q3
TCL: Long Collimator

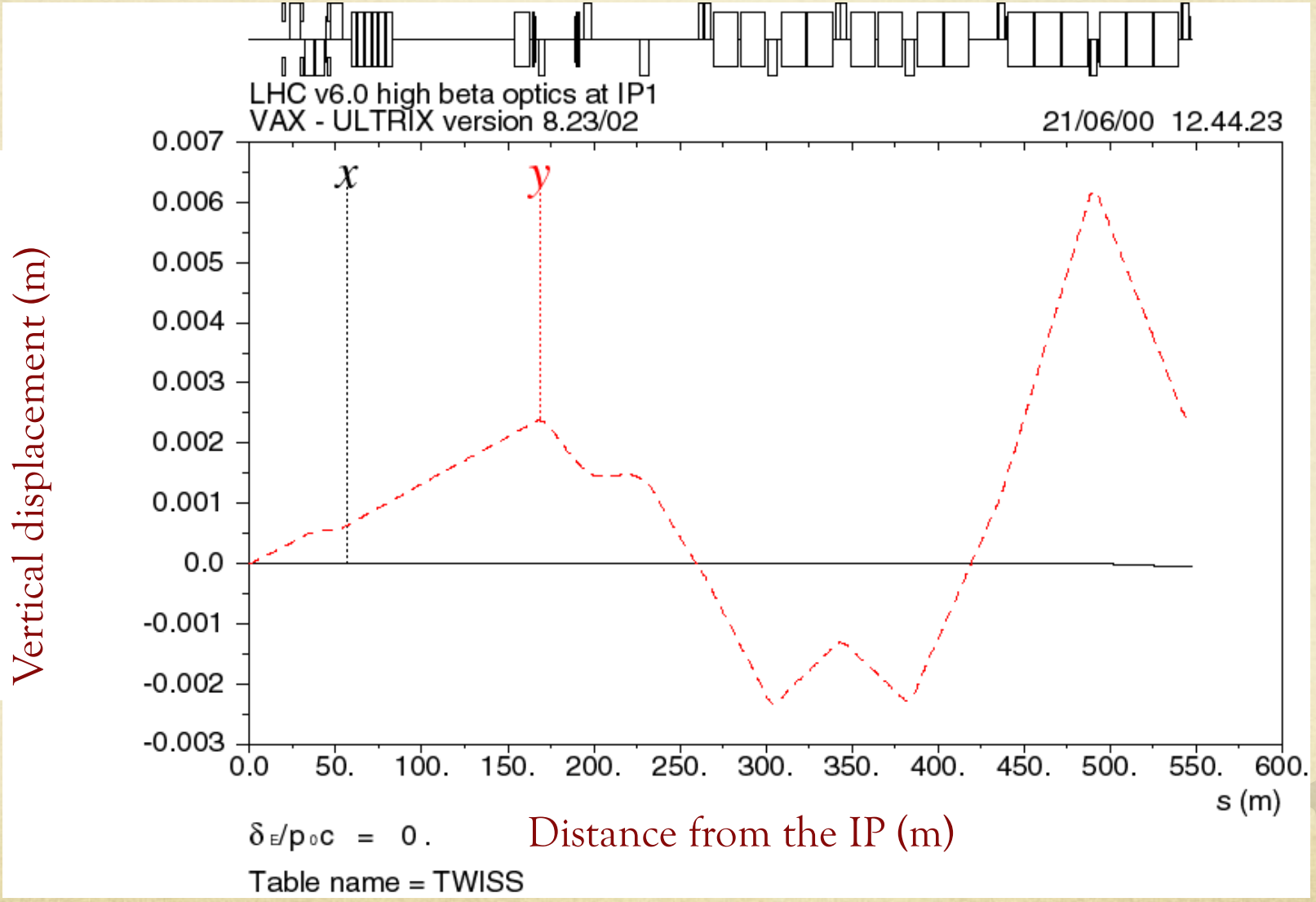
BSRT: Synchro radiation telescope alignment



Totem

Optimized detector locations: 90m, 150m, 180m, 210m, 240m, >400m?

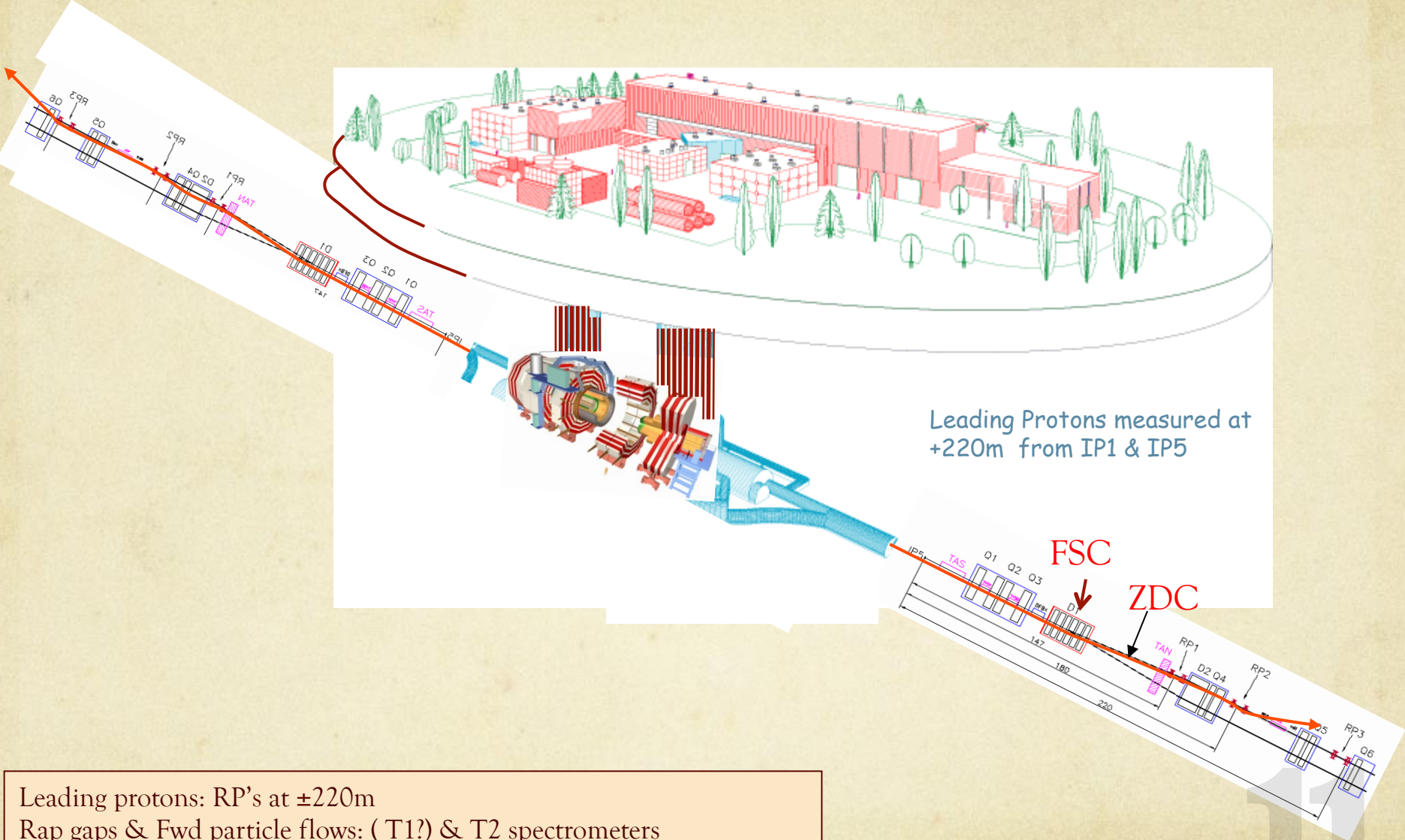
BEAM LINE AND RUN CONDITIONS



Vertical displacement (m)

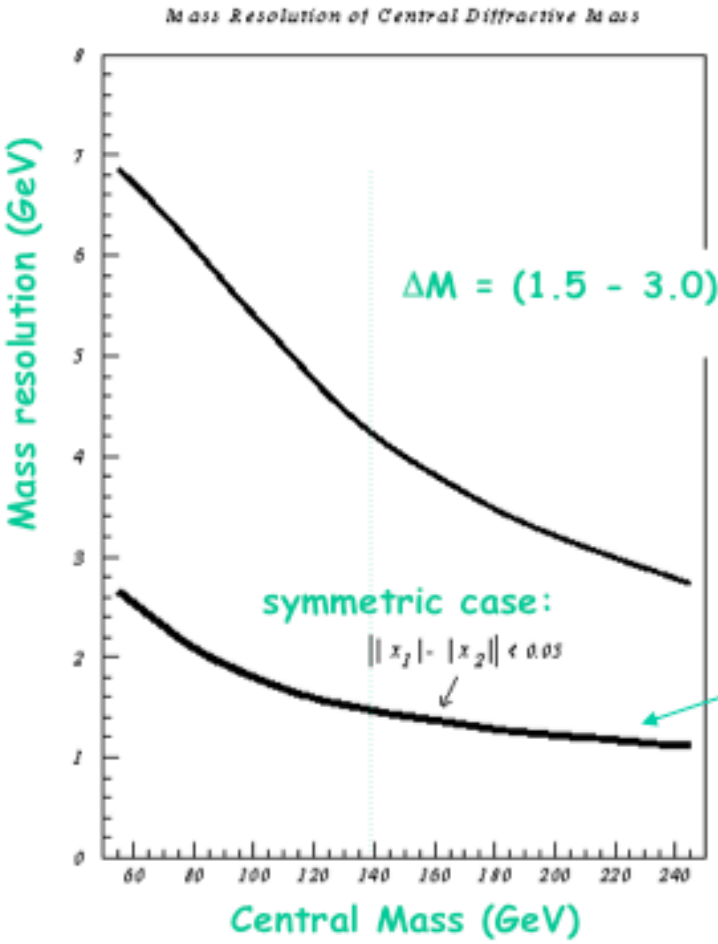
Distance from the IP (m)

measuring the left-over protons in cep – the traditional approach



Leading protons: RP's at ±220m
Rap gaps & Fwd particle flows: (T1?) & T2 spectrometers
Fwd energy flows: Castor (?) & ZDC's(?)
Fwd counters at: ±60m to ±100 (140)m – FSCs..?

DPE Mass Measurement at 400m



Mass resolution vs. central mass assuming $\Delta x_F/x_F = 10^{-4}$

ΔM = (1.5 - 3.0) GeV ($\Delta x_F/x_F = (1\text{-}2)\times 10^{-4}$)

≈ 65% of the data

20 GeV < M_X < 160 GeV

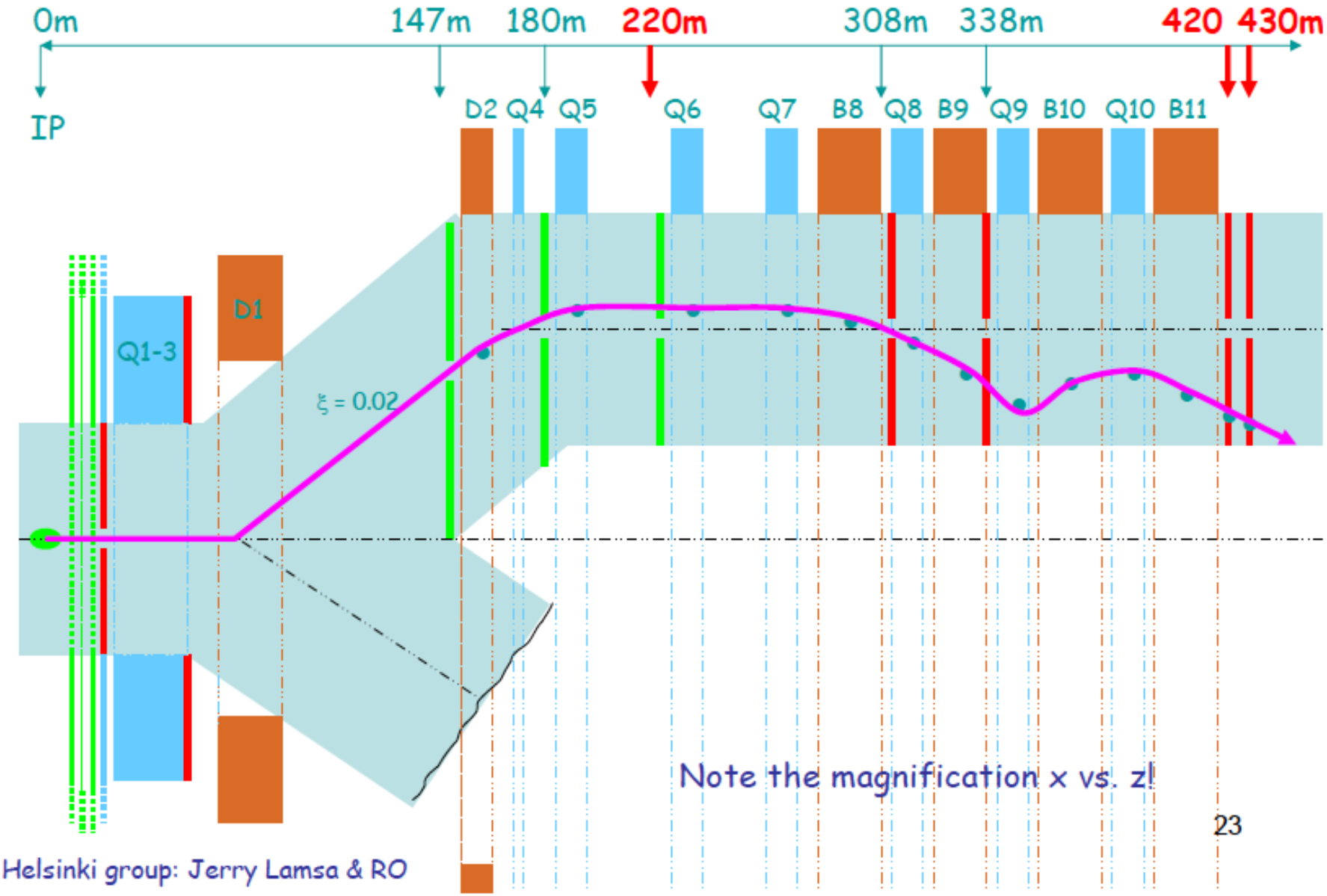
(M_{Xmax} determined by the aperture of the last dipole, B11,
M_{Xmin} by the minimum deflection = 5mm)

Helsinki group/J.Lamsa, R.O.

SCANNING FOR MASSIVE NEW PARTICLES

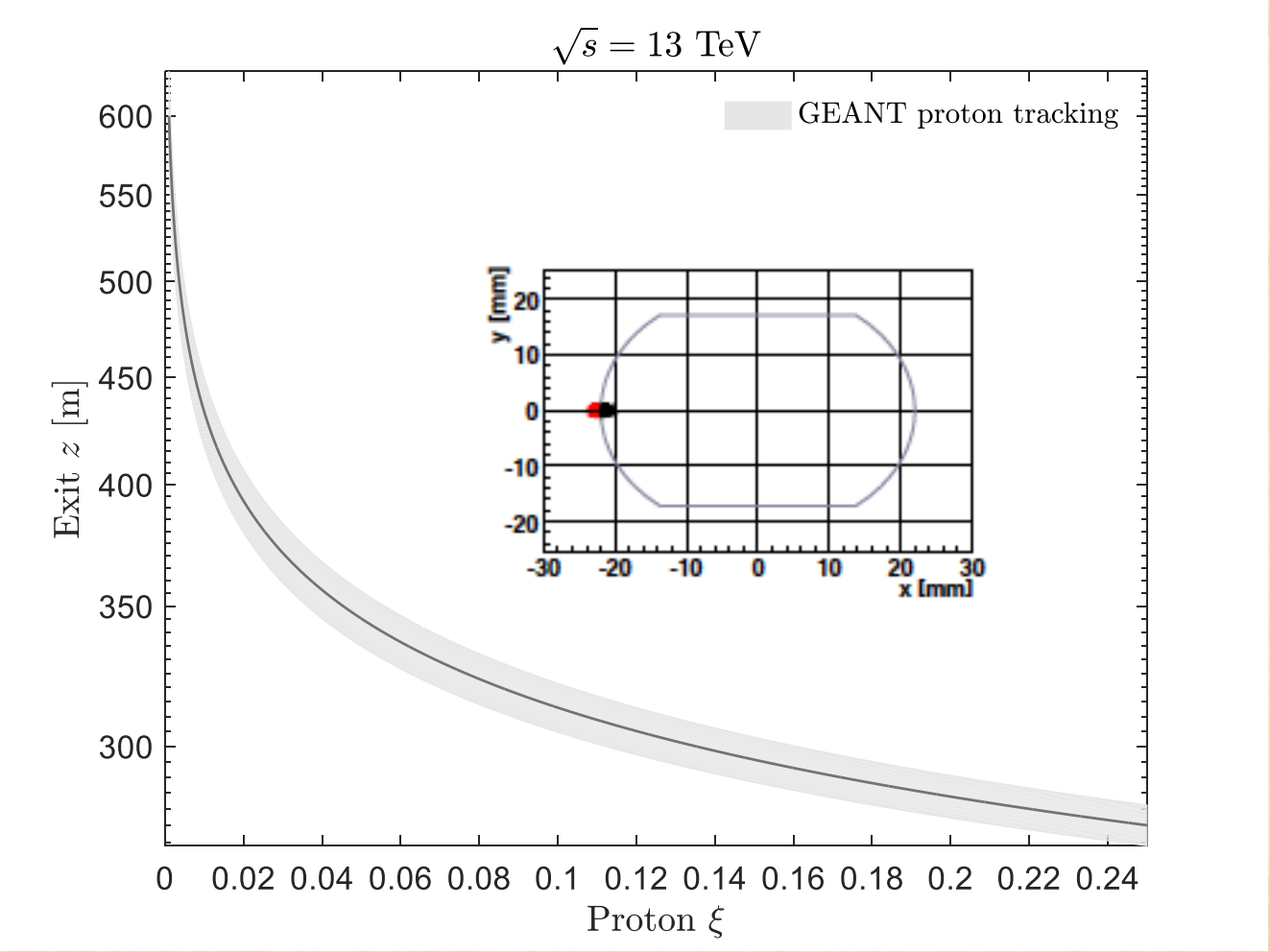
(RECYCLING THE LEFT-OVER PROTONS)

Leading Proton Detection-An Example



Helsinki group: Jerry Lamsa & RO

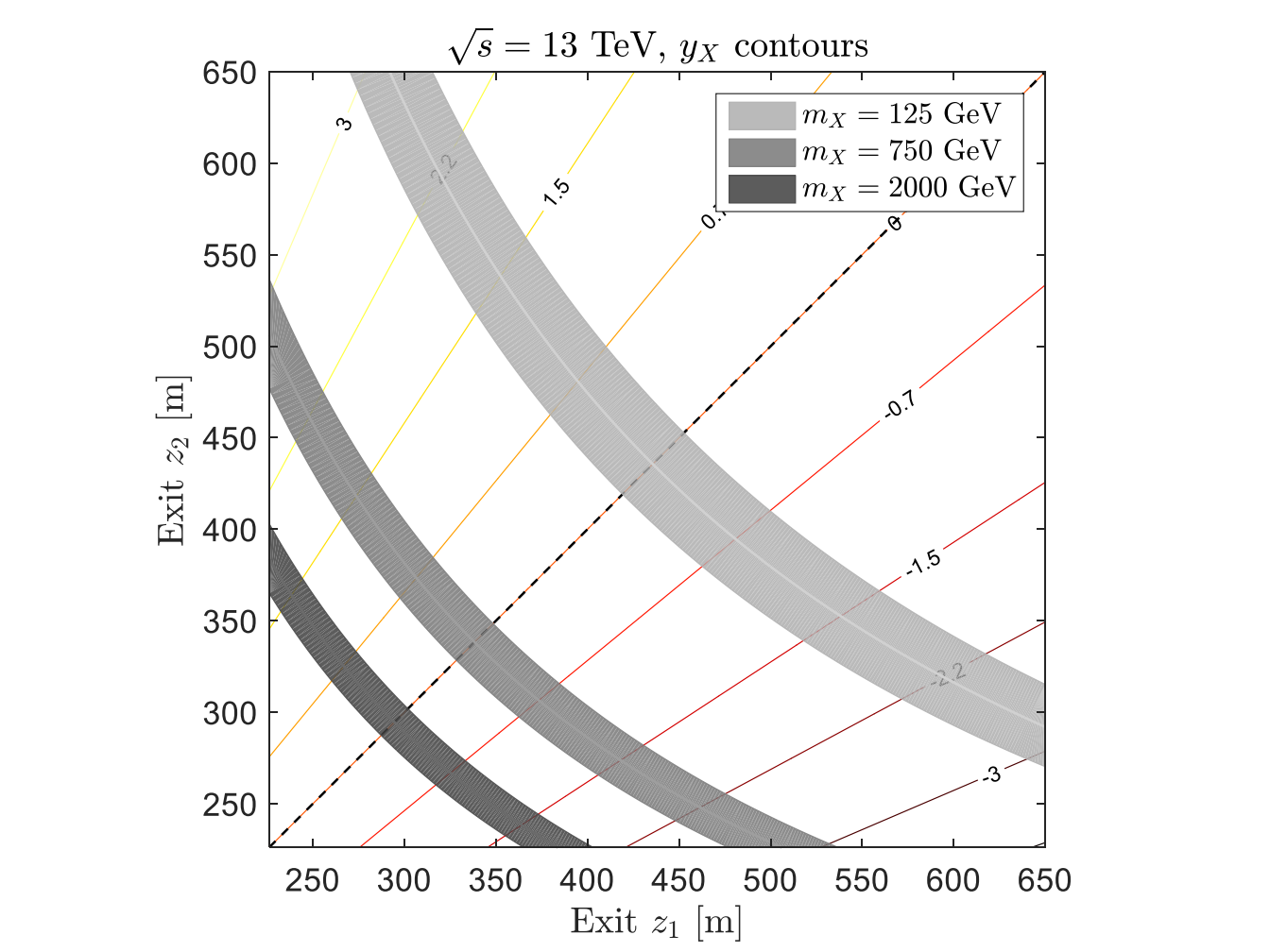
PROTON EXIT POINTS vs. ξ



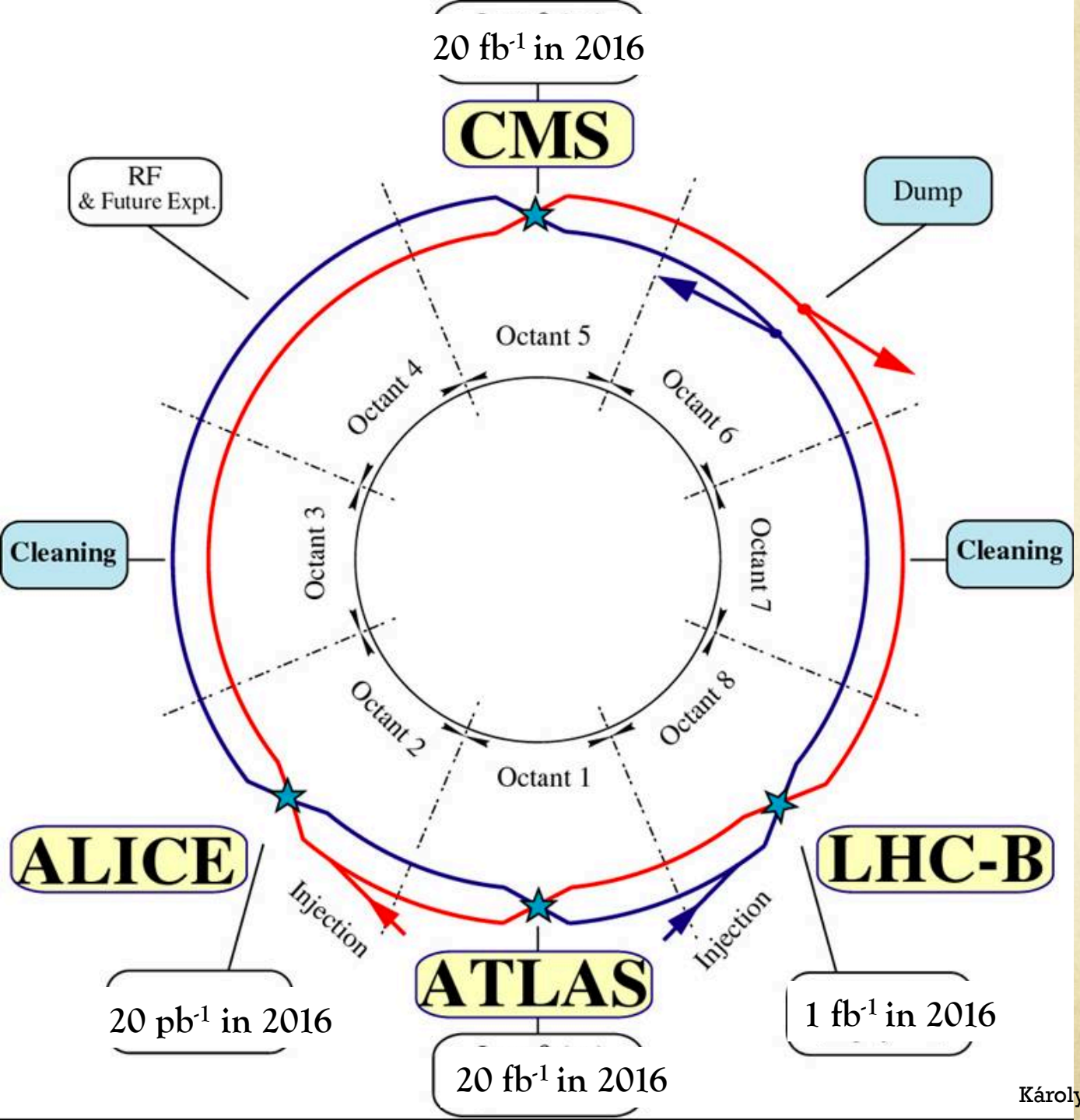
arXiv:1604.5778

The proton transverse momentum is smeared by *50 MeV*, which would be in accord with $ds/dp_t \propto exp(-20p_t)$.

PROTON PAIRS IN CEP: EXIT POINTS



arXiv:1604.5778



THE LHC

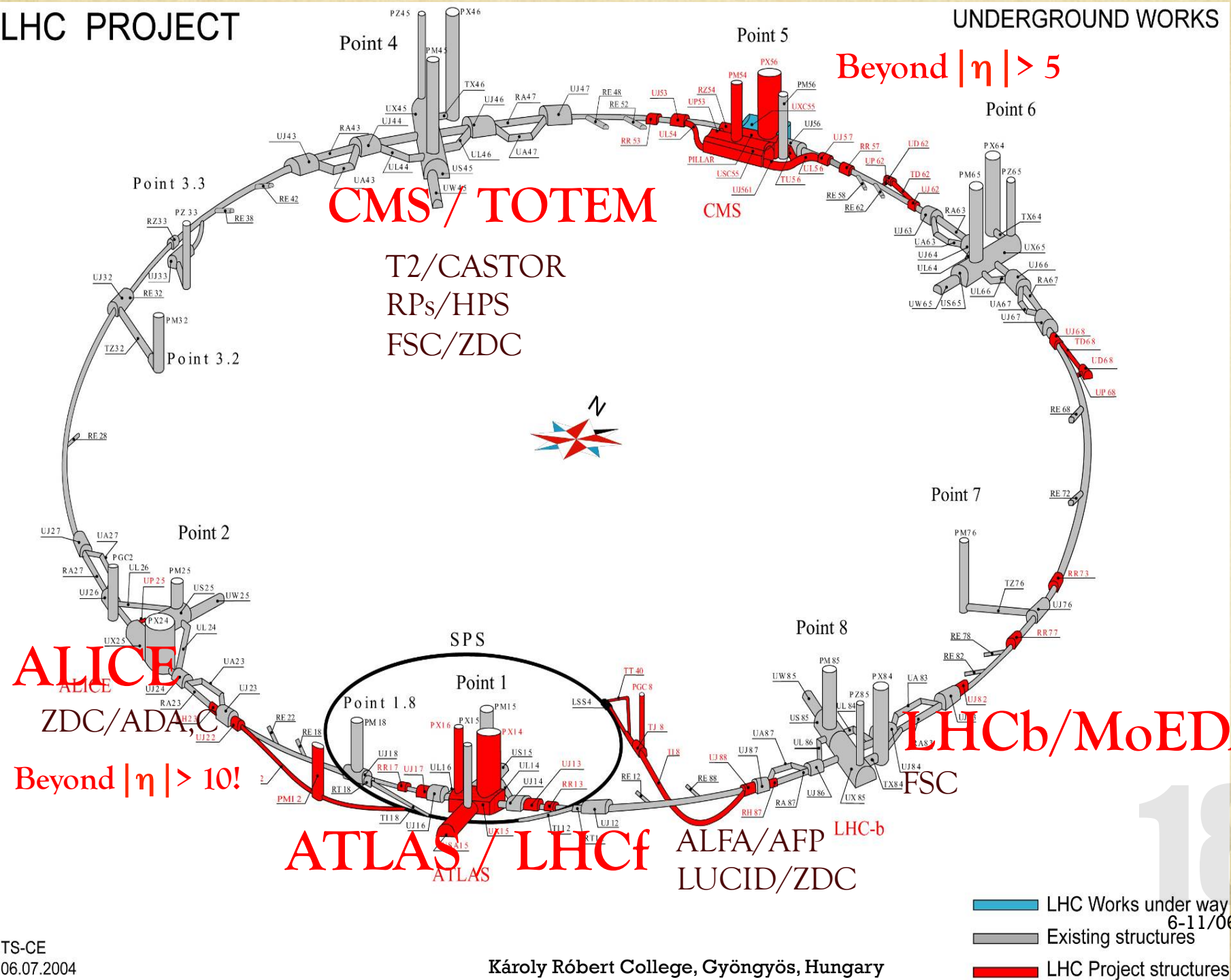
high

vs.

low/moderate

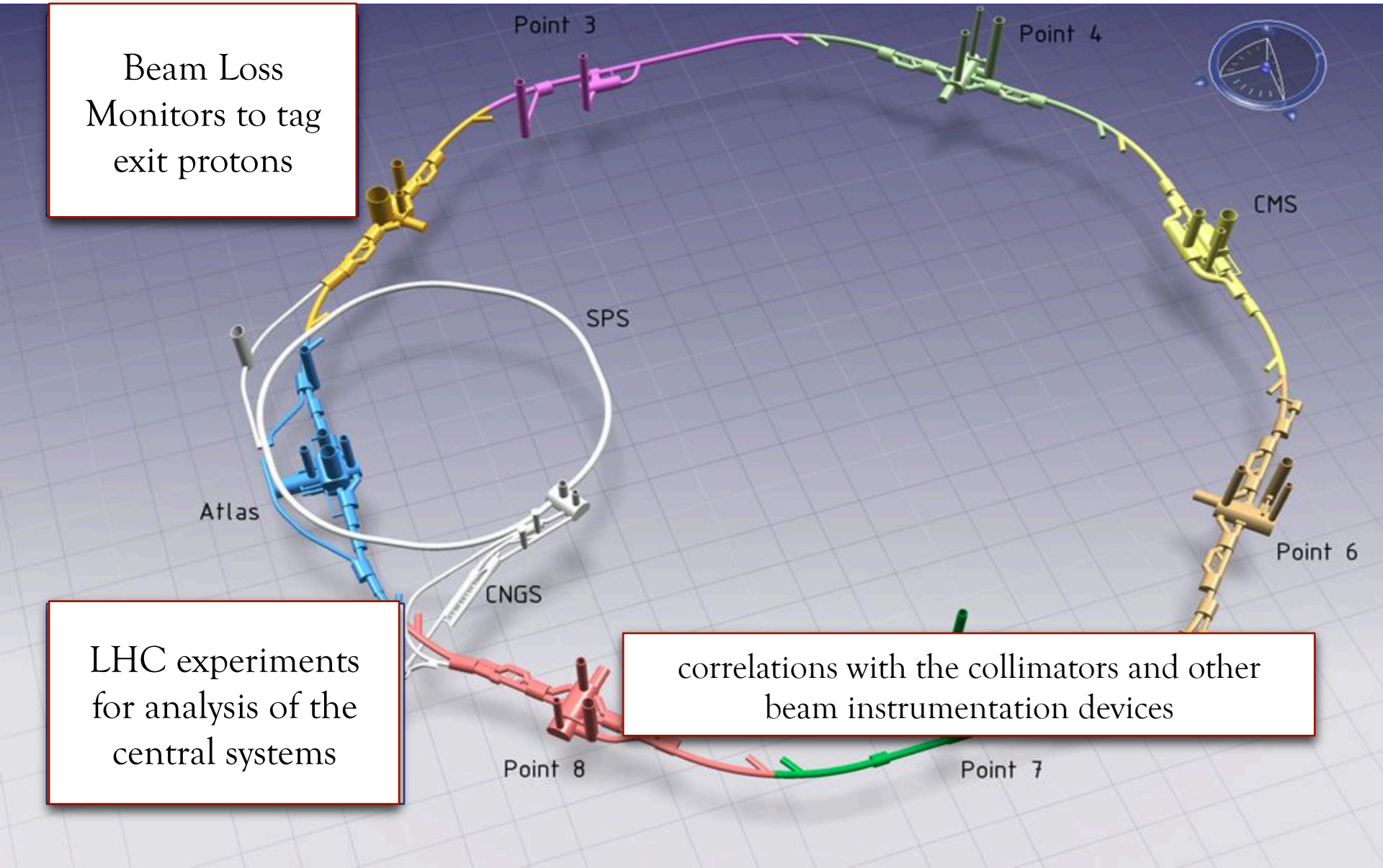
luminosity

physics


LHC PROJECT
UNDERGROUND WORKS
Point 4
Point 5
Point 6
Point 7
Point 8
Point 1
Point 2
Point 3.3
Point 3.2
Point 1.8
SPS
Beyond |η| > 5
CMS / TOTEM
CMS
T2/CASTOR
RPs/HPS
FSC/ZDC
ALICE
ALICE
ZDC/ADA,C
Beyond |η| > 10!
LHCb/MoEDAL
FSC
ATLAS / LHCf
ATLAS
ALFA/AFP
LUCID/ZDC
LHC-b
LHC Works under way
Existing structures
LHC Project structures

LHC RING AS A NEW PHYSICS SEARCH MACHINE

Beam Loss Monitors to tag exit protons



LHC experiments for analysis of the central systems

correlations with the collimators and other beam instrumentation devices

THE MACHINE


dipole
quadrupole
over 3500 BLM detectors
along the LHC ring

A LOCATION AT 230 METERS

SUMMARY

- HEAVY STATES PRODUCED IN CEP ARE SCANNED – INDEPENDENTY OF THEIR DECAY MODES - BY USING THE PROTON EXIT POINTS ALONG THE LHC RING
- PROMISING WAY OF SEARCHING FOR INVISIBLE DECAYS –TURNING LHC INTO A DARK MATTER FACTORY!?
- FIRST CANDIDATE EVENTS BEING LOOKED AT, ACCEPTANCE x EFFICIENCY CALCULATIOS ONGOING
- THE METHOD CAN BE EXTENDED TO ALL LHC IPs; CORRELATIONS WITH EXISTING DETECTORS, COLLIMATORS etc. WILL BE EXPLOITED
- AUTOMATIC SCANNING OF THE BLM DATA WILL BE SOON AVAILABLE
- TRIGGERING OF THE CEP EVENT CANDIDATES vs. CENTRAL MASS TO BE REALISED

ALICE FORWARD DETECTORS GEOMETRIC ACCEPTANCE

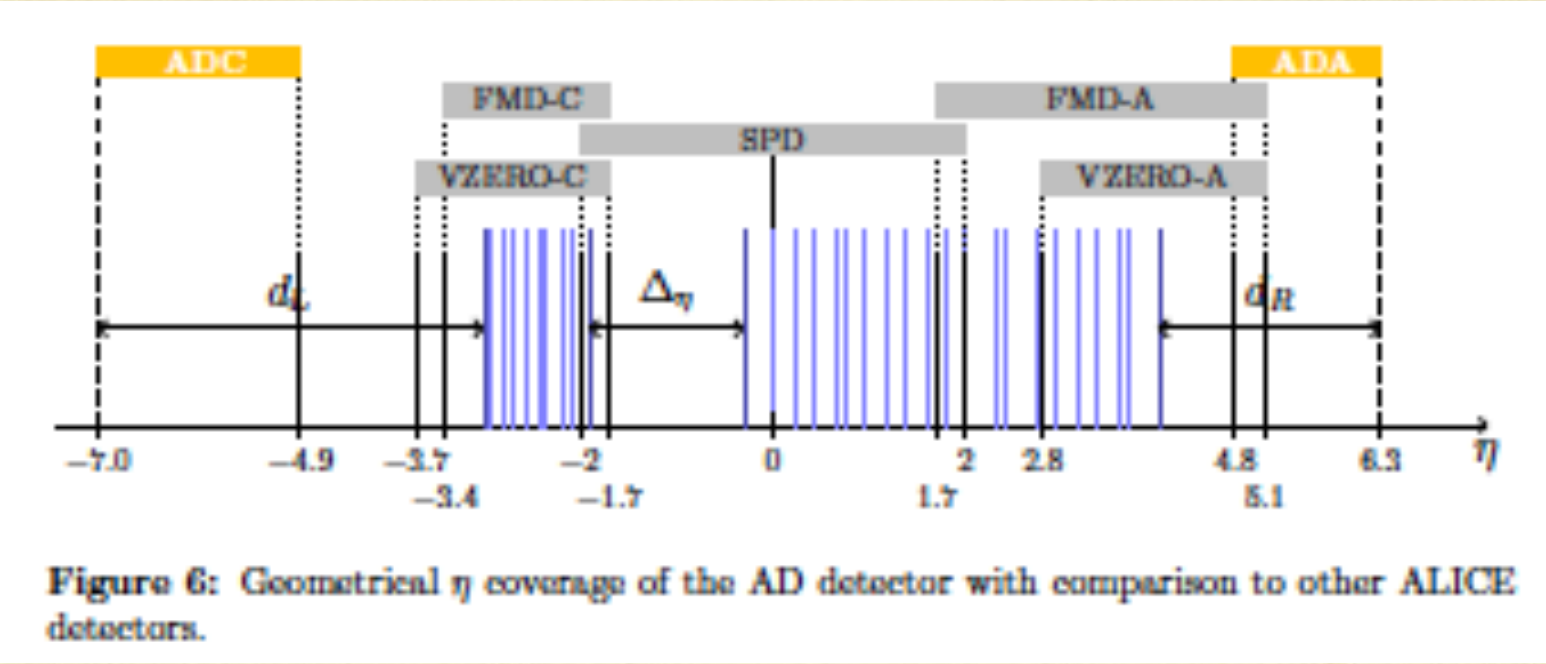


Figure 6: Geometrical η coverage of the AD detector with comparison to other ALICE detectors.

- THE EFFECTIVE ACCEPTANCE OF THE ALICE AD DETECTORS EXTENDS UP TO $\eta = \pm 10$
- Zero Degree Calorimeters (ZDN & ZDP) COMPLEMENT THE ACCEPTANCES: leading neutron/gamma detection at 0^0

$pp \rightarrow N^* + \pi^+\pi^- + N^*$, with $N^* \rightarrow n\,\pi^+$