The Abdus Salam International Centre for Theoretical Physics

United Nations Educational, Scientific and Cultural Organization

IAEA International Atomic Energy Agency

SMR/1842-13

International Workshop on QCD at Cosmic Energies III

28 May - 1 June, 2007

Lecture Notes

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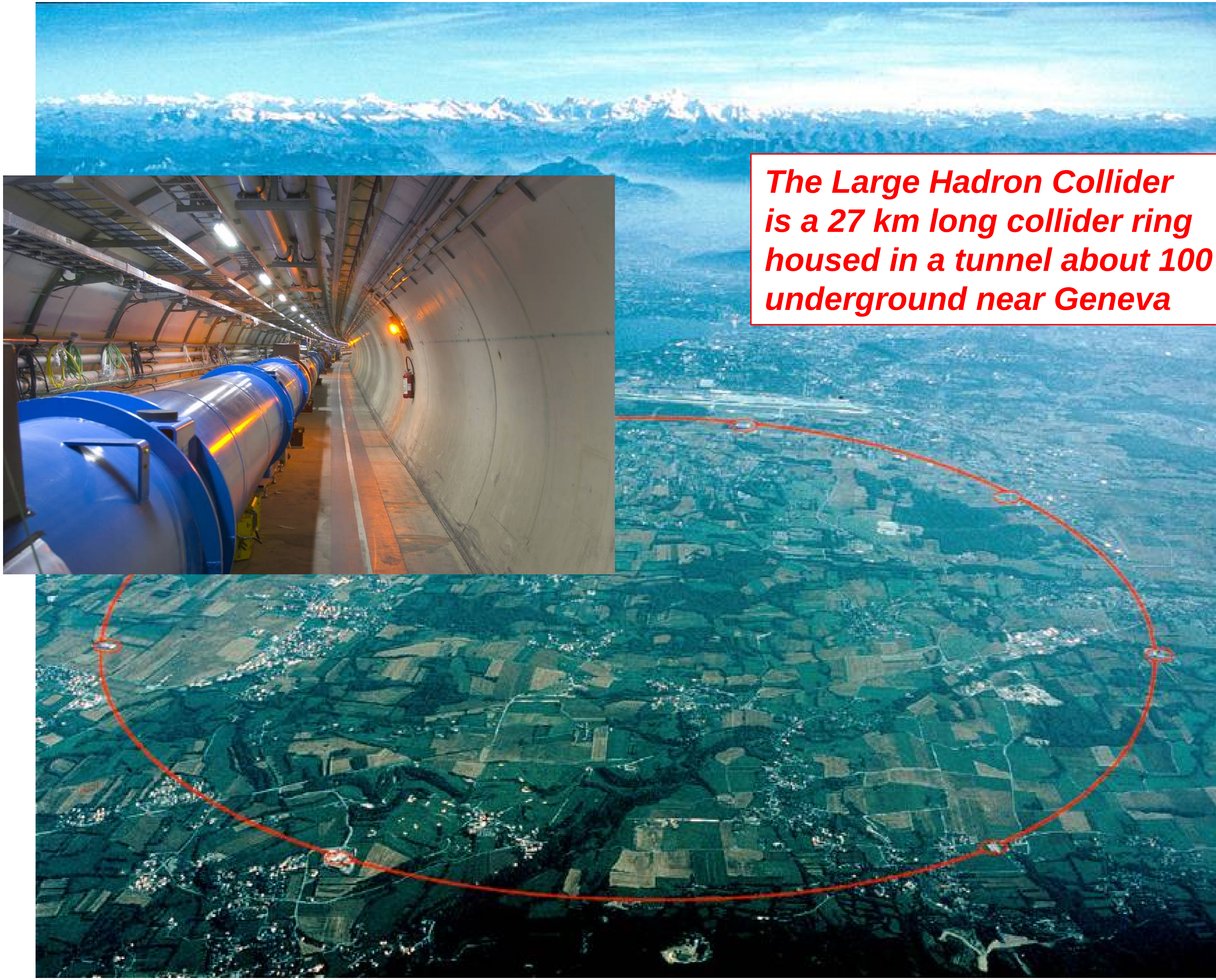
Forward Physics with ATLAS

Henri Kowalski
DESY

Trieste, 31st of May 2007



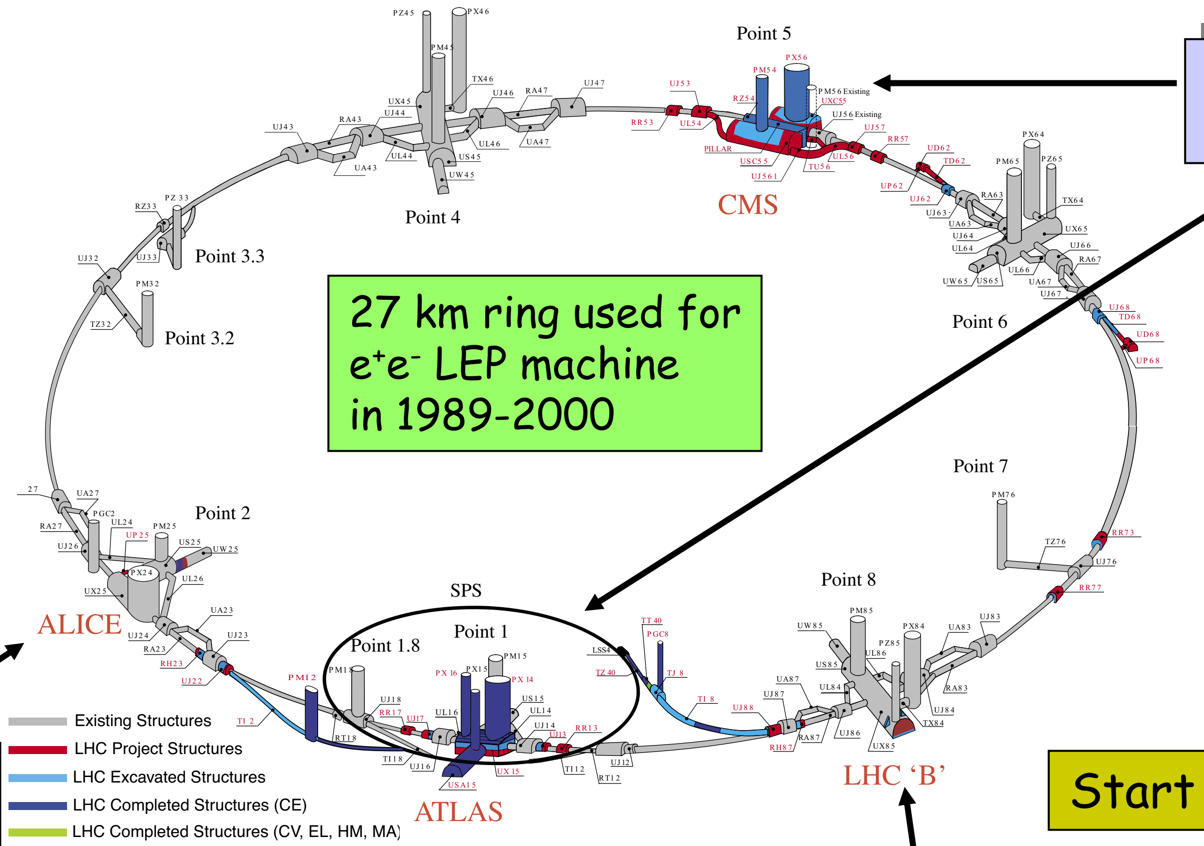
The Large Hadron Collider is a 27 km long collider ring housed in a tunnel about 100 m underground near Geneva

LHC

pp

- $\sqrt{s}$ = 14 TeV (7 times higher than Tevatron/Fermilab)
  → search for new massive particles up to m ~ 5 TeV

- $L_{design} = 10^{34}\ cm^{-2}\ s^{-1}$ (>10² higher than Tevatron/Fermilab)
  → search for rare processes with small σ (N = Lσ)



27 km ring used for e^+e^- LEP machine in 1989-2000

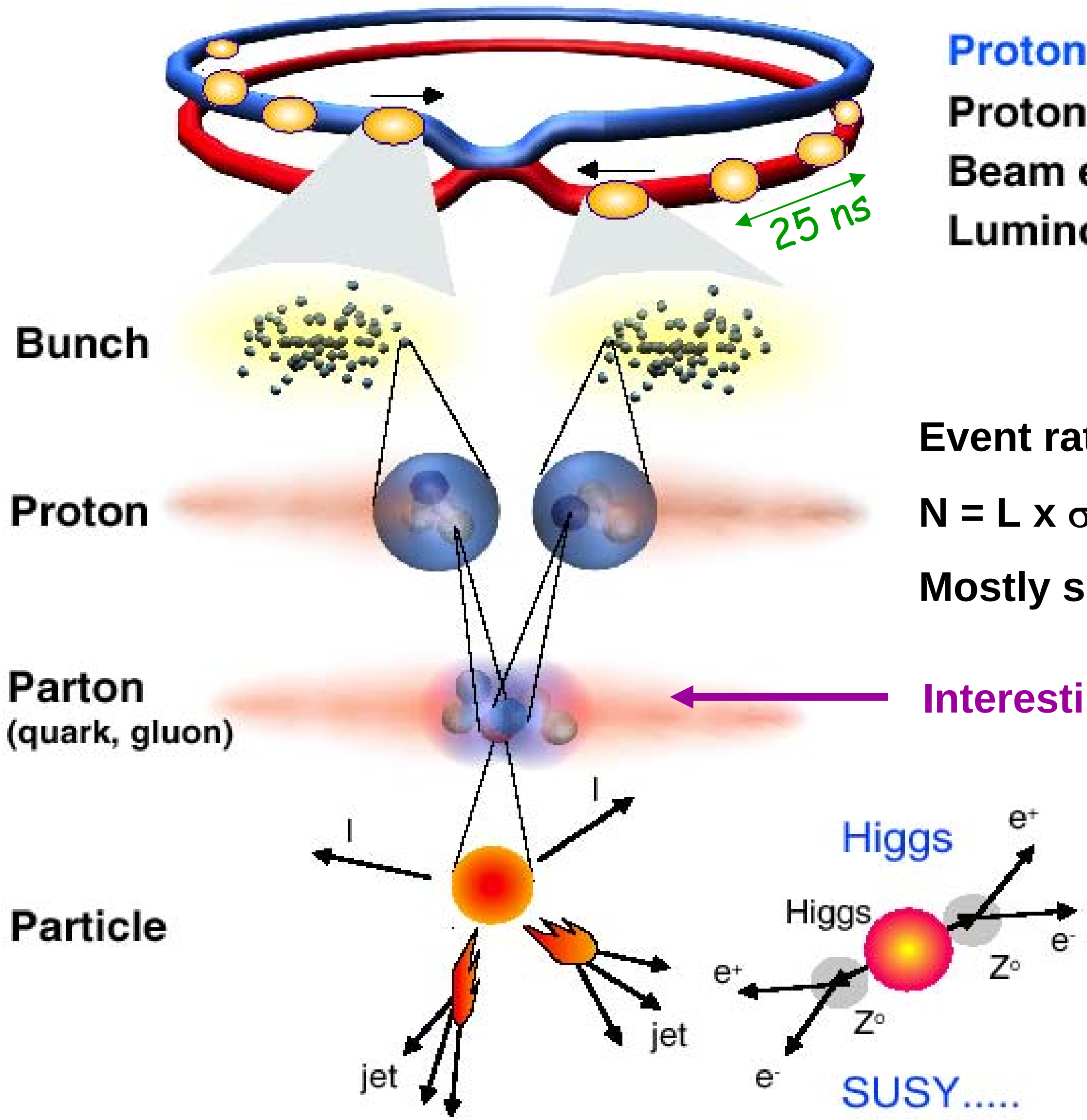
ATLAS and CMS : pp, general purpose

ALICE : heavy ions

LHCb : pp, B-physics

Start : November 2007

Collisions at LHC



Proton-Proton	
Protons/bunch	10^{11}
Beam energy	7 TeV (7×10^{12} eV)
Luminosity	10^{34} cm^{-2} s^{-1}

Event rate in ATLAS :

$N = L \times \sigma$ (pp) ≈ 10^9 interactions/s

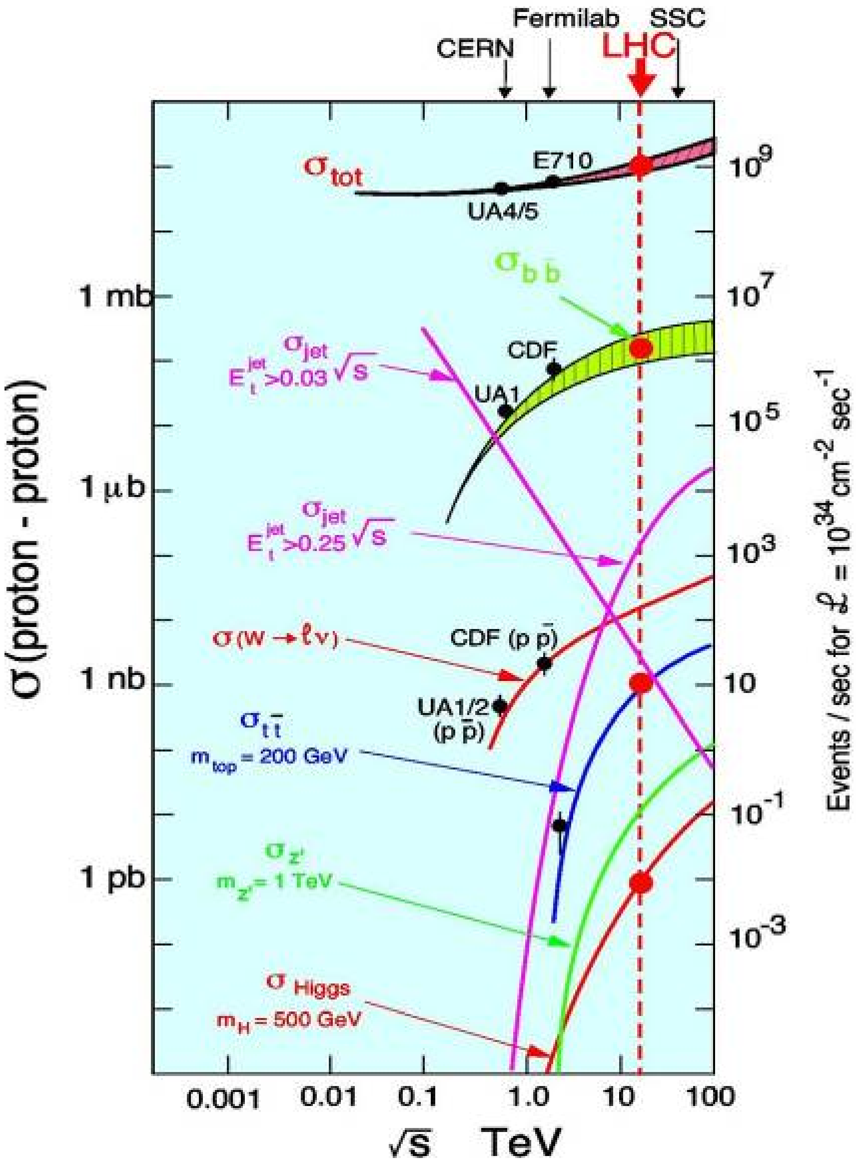
Mostly soft (low p_T) events

Interesting hard (high-p_T) events are rare

Selection of 1 in 10,000,000,000,000

→ very powerful detectors needed

Cross Sections and Production Rates



Rates for L = 10^{34} cm^{-2} s^{-1}: (LHC)

• Inelastic proton-proton reactions:	**10^9 / s**
• bb pairs	**5 10^6 / s**
• tt pairs	**8 / s**
• W → e ν	**150 / s**
• Z → e e	**15 / s**
• Higgs (150 GeV)	**0.2 / s**
• Gluino, Squarks (1 TeV)	**0.03 / s**

LHC is a factory for:
top-quarks, b-quarks, W, Z, ……. Higgs, ……

(The challenge: you have to detect them !)

The ATLAS physics goals

Search for the Standard Model Higgs boson over ~ $115 < m_H < 1000$ GeV

Search for physics beyond the SM (Supersymmetry, q/ℓ compositeness, leptoquarks, W'/Z', heavy q/ℓ, Extra-dimensions, ….) up to the TeV-range

Precise measurements :

- **-- W mass**
- **-- top mass, couplings and decay properties**
- **-- Higgs mass, spin, couplings (if Higgs found)**
- **-- B-physics (complementing LHCb): CP violation, rare decays, B^0 oscillations**
- **-- QCD jet cross-section and α_s**
- **-- etc. ….**

Study of phase transition at high density from hadronic matter to plasma of deconfined quarks and gluons (complementing ALICE).
Transition plasma $\rightarrow$ hadronic matter happened in universe ~ 10^{-5} s after Big Bang

Etc. etc. …..

ATLAS Collaboration

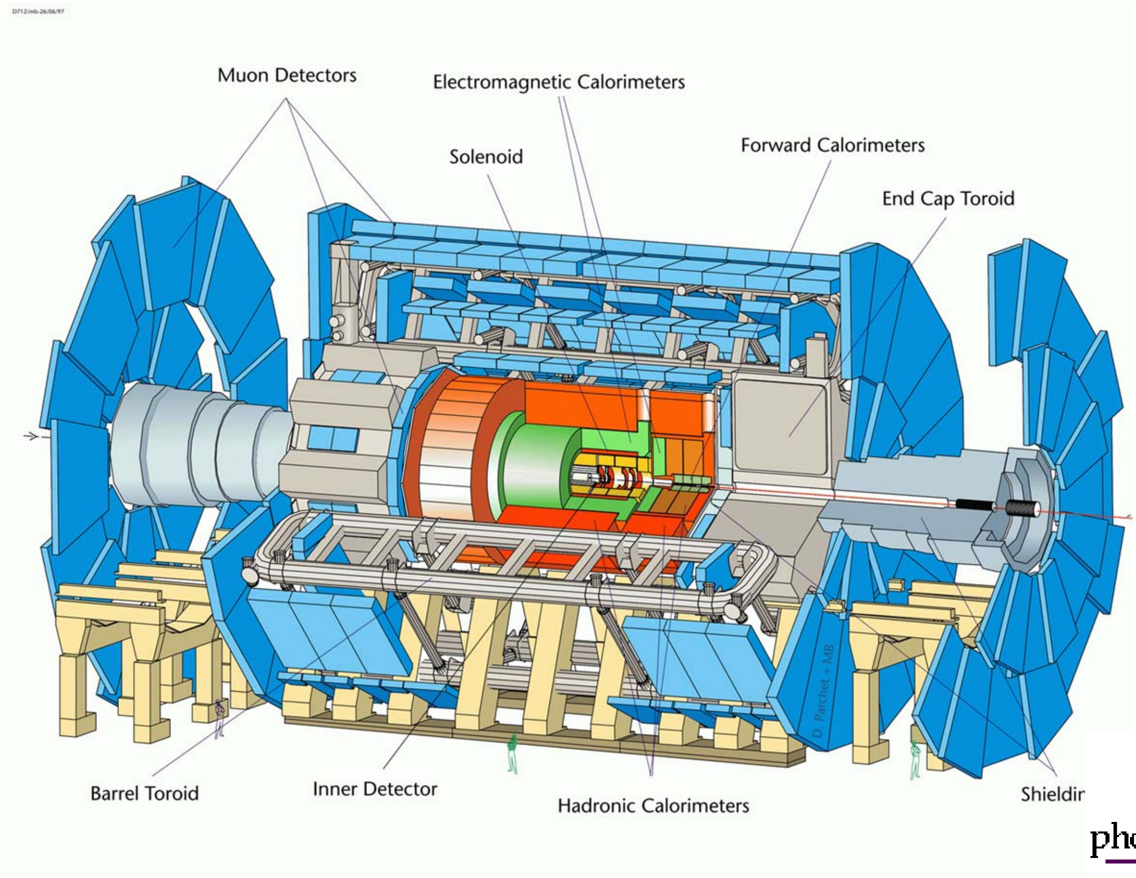
(As of the October 2005 RRB)

34 Countries
153 Institutions
1650 Scientific Authors total
(1330 with a PhD, for M&O share)

New applications for CB decision:
UN La Plata, U Buenos Aires (Argentina)
TU Dresden, U Giessen (Germany)
U Oregon, U Oklahoma (US)

New application for CB announcement:
DESY, Humboldt U Berlin (Germany)
SLAC, New York U (US)

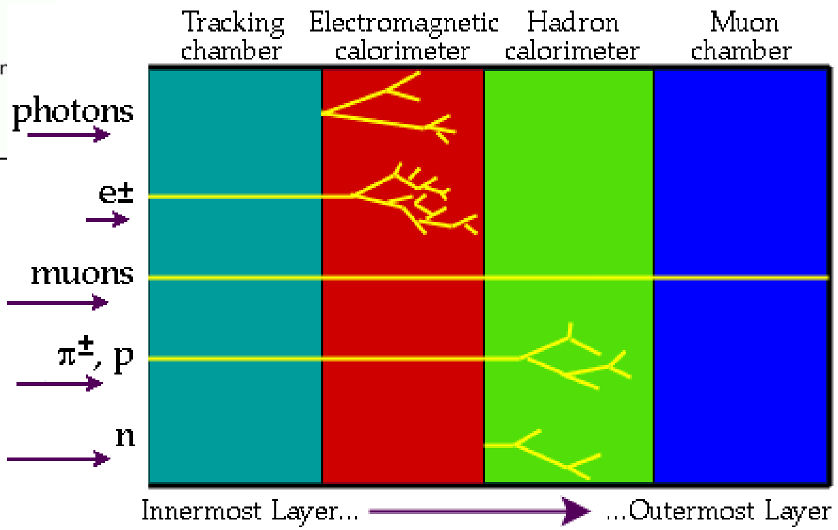
Albany, Alberta, NIKHEF Amsterdam, Ankara, LAPP Annecy, Argonne NL, Arizona, UT Arlington, Athens, NTU Athens, Baku, IFAE Barcelona, Belgrade, Bergen, Berkeley LBL and UC, Bern, Birmingham, Bologna, Bonn, Boston, Brandeis, Bratislava/SAS Kosice, Brookhaven NL, Bucharest, Cambridge, Carleton, Casablanca/Rabat, CERN, Chinese Cluster, Chicago, Clermont-Ferrand, Columbia, NBI Copenhagen, Cosenza, INP Cracow, FPNT Cracow, Dortmund, JINR Dubna, Duke, Frascati, Freiburg, Geneva, Genoa, Glasgow, LPSC Grenoble, Technion Haifa, Hampton, Harvard, Heidelberg, Hiroshima, Hiroshima IT, Indiana, Innsbruck, Iowa SU, Irvine UC, Istanbul Bogazici, KEK, Kobe, Kyoto, Kyoto UE, Lancaster, Lecce, Lisbon LIP, Liverpool, Ljubljana, QMW London, RHBNC London, UC London, Lund, UA Madrid, Mainz, Manchester, Mannheim, CPPM Marseille, Massachusetts, MIT, Melbourne, Michigan, Michigan SU, Milano, Minsk NAS, Minsk NCPHEP, Montreal, McGill Montreal, FIAN Moscow, ITEP Moscow, MEPhI Moscow, MSU Moscow, Munich LMU, MPI Munich, Nagasaki IAS, Naples, Naruto UE, New Mexico, Nijmegen, BINP Novosibirsk, Ohio SU, Okayama, Oklahoma, LAL Orsay, Osaka, Oslo, Oxford, Paris VI and VII, Pavia, Pennsylvania, Pisa, Pittsburgh, CAS Prague, CU Prague, TU Prague, IHEP Protvino, Ritsumeikan, UFRJ Rio de Janeiro, Rochester, Rome I, Rome II, Rome III, Rutherford Appleton Laboratory, DAPNIA Saclay, Santa Cruz UC, Sheffield, Shinshu, Siegen, Simon Fraser Burnaby, Southern Methodist Dallas, NPI Petersburg, Stockholm, KTH Stockholm, Stony Brook, Sydney, AS Taipei, Tbilisi, Tel Aviv, Thessaloniki, Tokyo ICEPP, Tokyo MU, Toronto, TRIUMF, Tsukuba, Tufts, Udine, Uppsala, Urbana UI, Valencia, UBC Vancouver, Victoria, Washington, Weizmann Rehovot, Wisconsin, Wuppertal, Yale, Yerevan

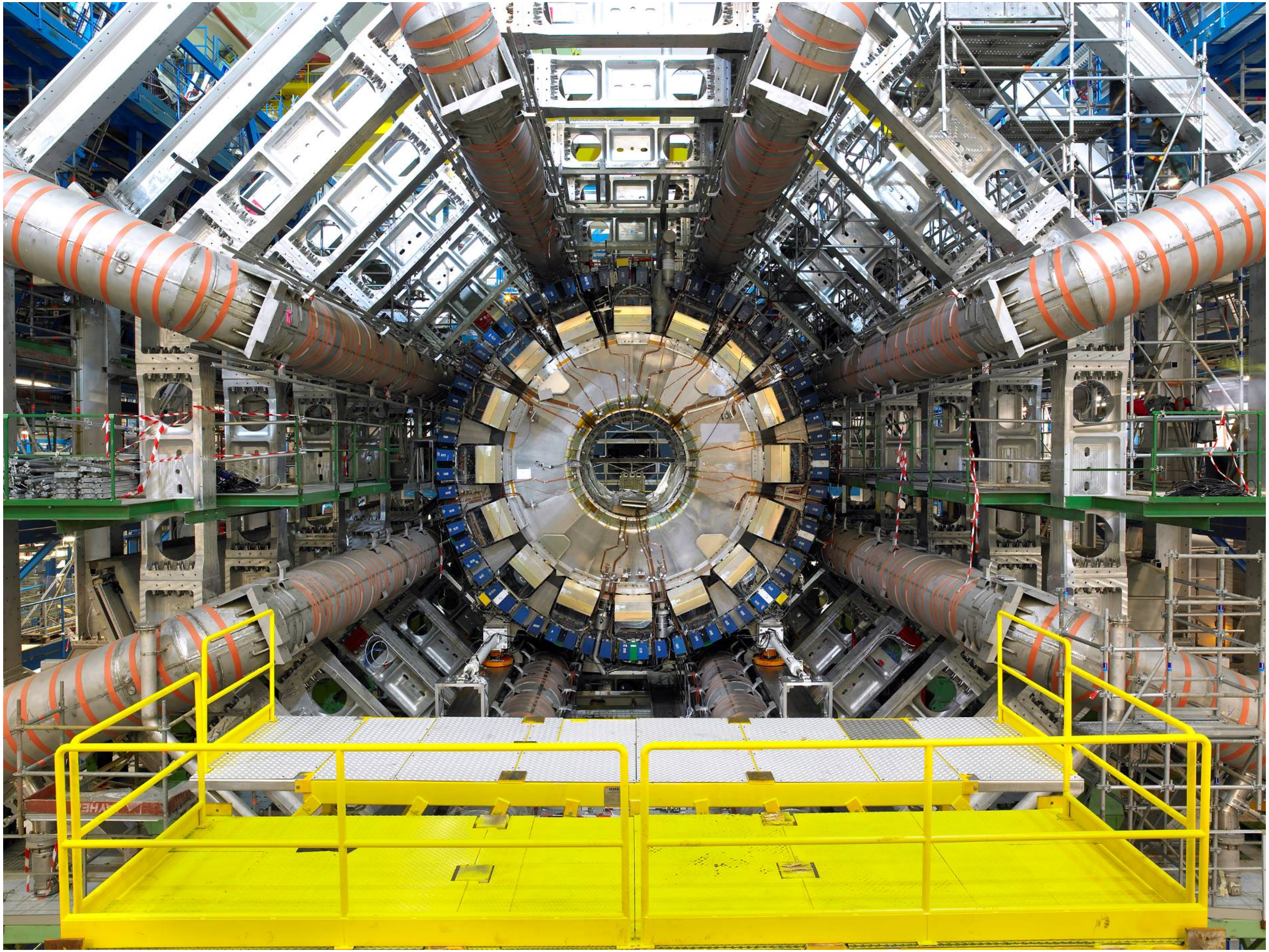


ATLAS

Length : ~ 46 m
Radius : ~ 12 m
Weight : ~ 7000 tons
~ 10^8 electronic channels
~ 3000 km of cables

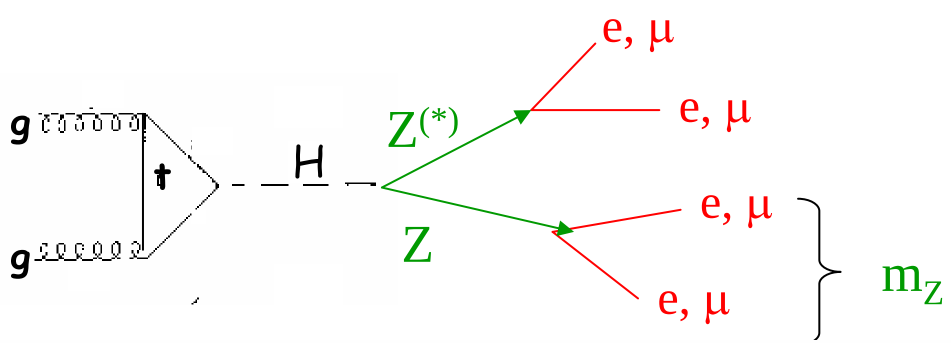
- **Tracking ($|\eta|<2.5$, B=2T) :**
  - -- Si pixels and strips
  - -- Transition Radiation Detector (e/π separation)
- **Calorimetry ($|\eta|<5$) :**
  - -- EM : Pb-LAr
  - -- HAD: Fe/scintillator (central), Cu/W-LAr (fwd)
- **Muon Spectrometer ($|\eta|<2.7$) :**
  air-core toroids with muon chambers





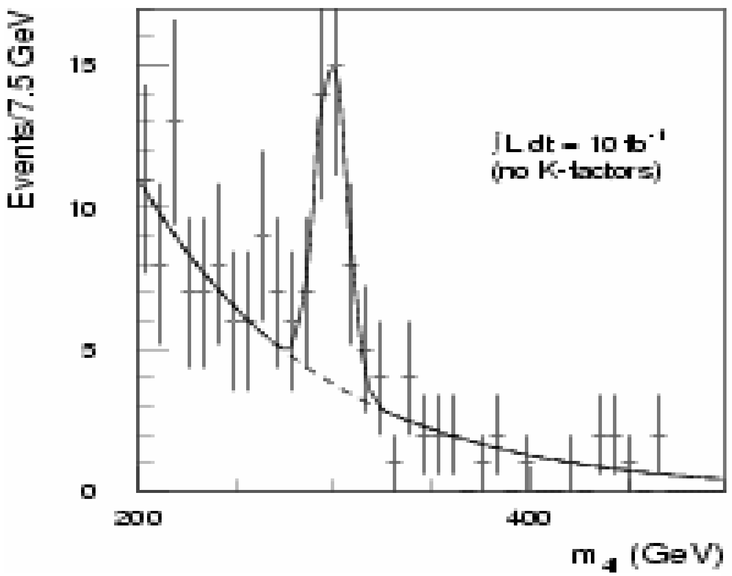
Physics example

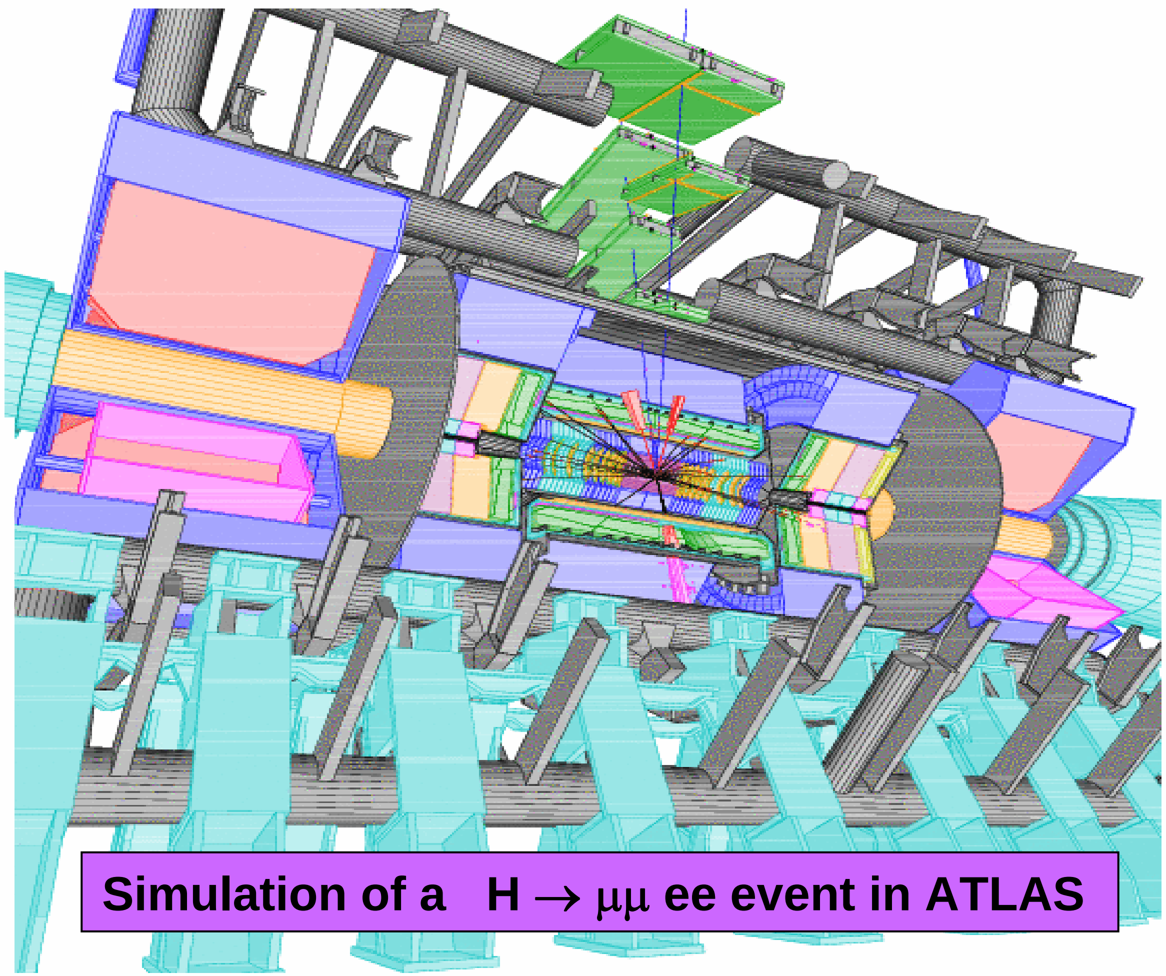
$H \to ZZ \to 4\ \ell$



“Gold-plated” channel for Higgs discovery at LHC

Signal expected in ATLAS after 1 year of LHC operation





Simulation of a $H \to \mu\mu\ ee$ event in ATLAS

Goals of Higgs Physics

Higgs Search = search for dynamics of $SU(2) \times U(1)$ breaking

- Discover the Higgs boson
- Measure its couplings and probe
  mass generation for gauge bosons and fermions

Fermion masses arise from Yukawa couplings via $\Phi^\dagger \to (0, \frac{v+H}{\sqrt{2}})$

$$\mathcal{L}_{\text{Yukawa}} = -\Gamma_d^{ij} \bar{Q}_L^{\prime i} \Phi d_R^{\prime j} - \Gamma_d^{ij*} \bar{d}_R^{\prime i} \Phi^\dagger Q_L^{\prime j} + \ldots \qquad = -\Gamma_d^{ij} \frac{v+H}{\sqrt{2}} \bar{d}_L^{\prime i} d_R^{\prime j} + \ldots$$

$$= -\sum_f m_f \bar{f} f \left(1 + \frac{H}{v}\right)$$

- Test SM prediction: $\bar{f} f H$ Higgs coupling strength $= m_f / v$
- Observation of $H f \bar{f}$ Yukawa coupling is no proof that v.e.v exists

Higgs coupling to gauge bosons

Kinetic energy term of Higgs doublet field:

$$(D^\mu \Phi)^\dagger (D_\mu \Phi) = \frac{1}{2}\partial^\mu H \partial_\mu H + \left[\left(\frac{gv}{2}\right)^2 W^{\mu +} W^-_\mu + \frac{1}{2}\frac{(g^2+g'^2)\, v^2}{4} Z^\mu Z_\mu \right] \left(1 + \frac{H}{v}\right)^2$$

- W, Z mass generation: $m_W^2 = \left(\frac{gv}{2}\right)^2$, $m_Z^2 = \frac{(g^2+g'^2)v^2}{4}$
- WWH and ZZH couplings are generated
- Higgs couples propotional to mass: coupling strength $= 2\, m_V^2/v \sim g^2\, v$ within SM

Measurement of WWH and ZZH couplings is essential for identification of H as agent of symmetry breaking: Without a v.e.v. such a trilinear coupling is impossible at tree level

Early measurements for Higgs physics

Discovery of Higgs boson may take 5–10 fb^{-1}, perhaps more ...
It certainly requires a well understood and calibrated detector

- optimistic case: $m_H \approx 160\,\mathrm{GeV}$, $H \to WW$
- challenging case: $m_H \approx 120\,\mathrm{GeV}$, $H\tau\tau$ and Hbb couplings substantially enhanced by large $\tan\beta$ effects

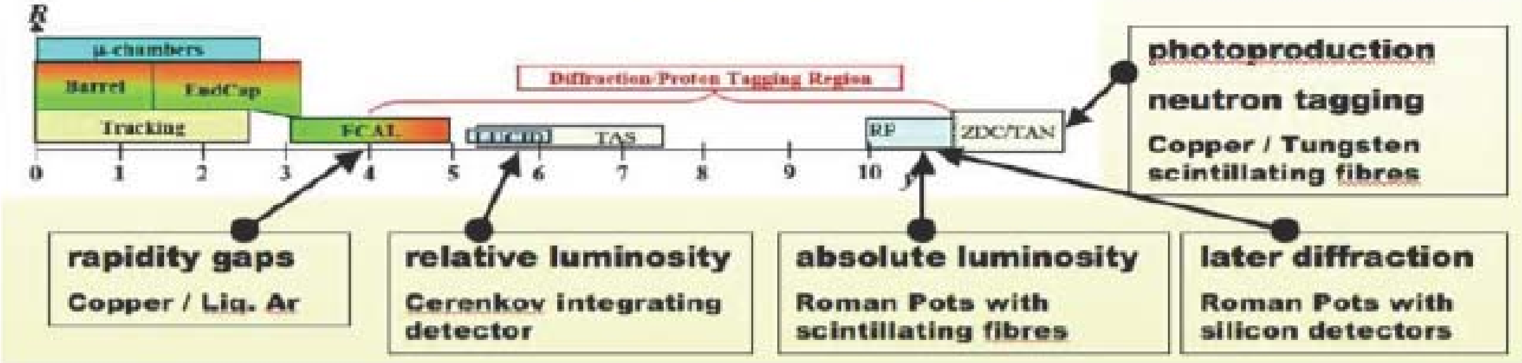
$\Longrightarrow$ no visible $H \to \gamma\gamma$, $H \to ZZ$ or $H \to WW$ signals

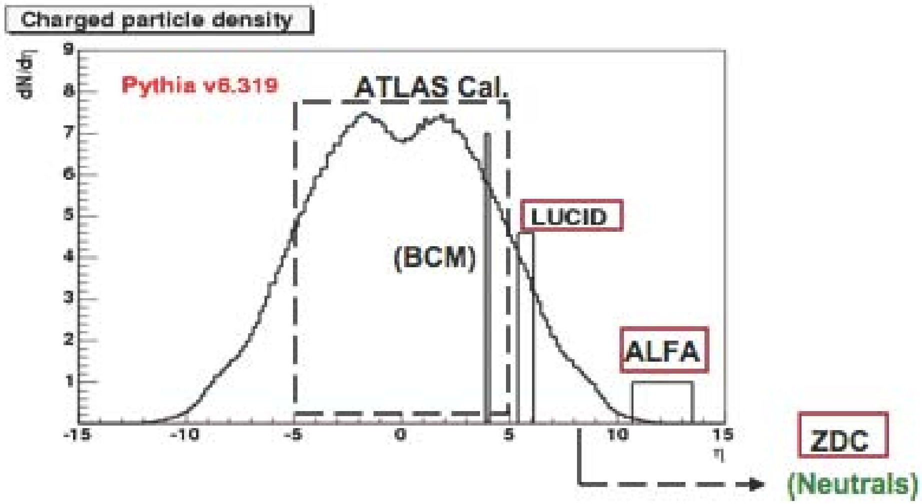
$\Longrightarrow$ must search in VBF channel $qq \to qqH$, $H \to \tau\tau$ or in $t\bar{t}H,\ H \to b\bar{b}$

Forward detectors for ATLAS/CMS

ATLAS rapidity coverage

ATLAS Forward Detectors





- LUCID
- ALFA RP
- ATLAS-ZDC

Absolute luminosity measurements-why?

- Cross sections for "Standard " processes
  - t-tbar production
  - W/Z production
  - …….

Theoretically known to better than 10% ……will improve in the future

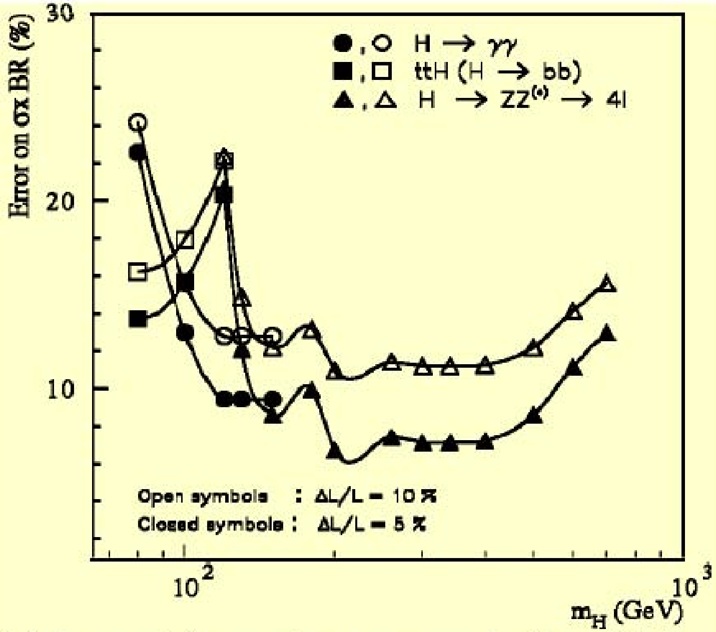
- New physics manifesting in deviation of $\sigma \times BR$ relative the Standard Model predictions

- Important precision measurements
  - Higgs production $\sigma \times BR$
  - tanβ measurement for MSSM Higgs
  - …….

Absolute Luminosity Measurement (cont.)

Examples

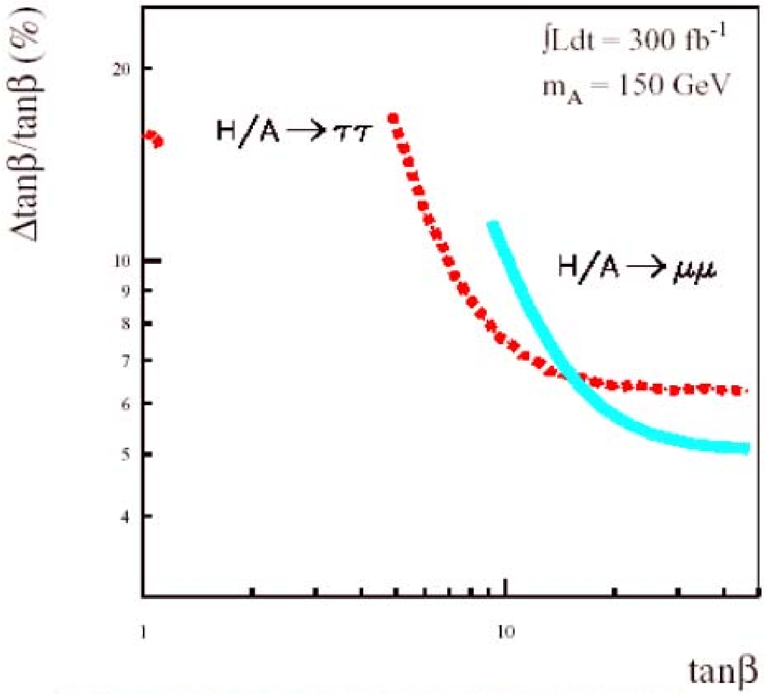
Higgs coupling



Relative precision on the measurement of $\sigma_H \times$BR for various channels, as function of m_H, at $\int Ldt = 300\ fb^{-1}$. The dominant uncertainty is from Luminosity: 10% (open symbols), 5% (solid symbols).

(ATLAS-TDR-15, May 1999)

tanβ measurement



Systematic error dominated by luminosity (ATLAS Physics TDR)

ALFA = Absolute Luminosity For ATLAS

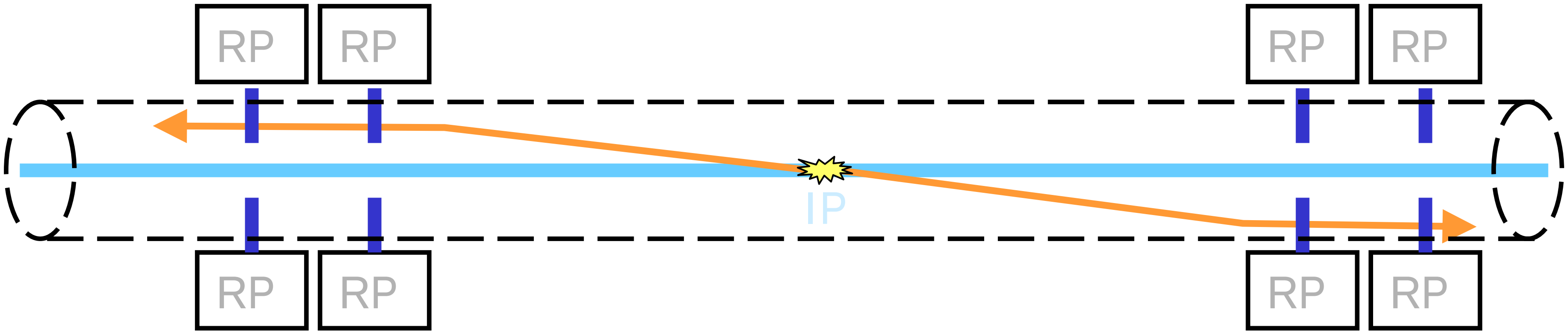
The Roman Pot mechanics.

The detectors

The electronics

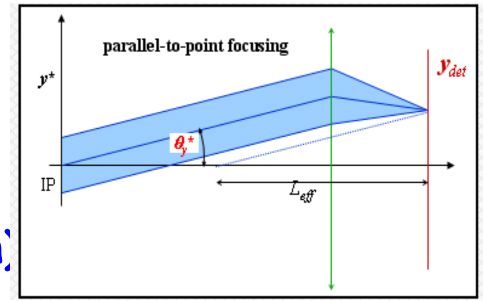
ALFA - ATLAS Roman Pots

- Goal: Determine absolute luminosity at IP1 (2-3% precision)
- Measure elastic rate dN/dt in the Coulomb interference region (à la UA4). $|t|$~0.00065 GeV^2 or Θ ~ 3.5 microrad.

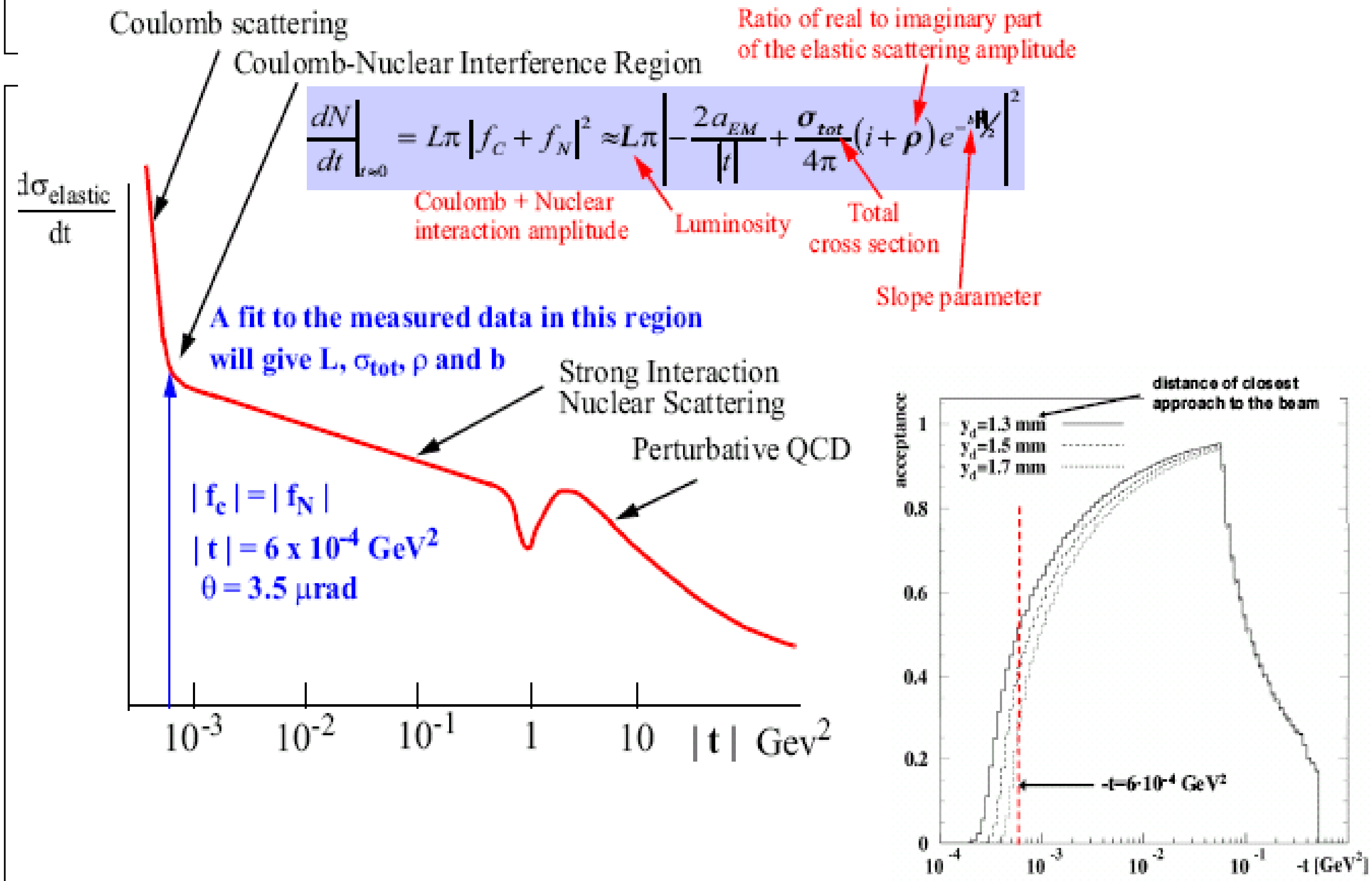


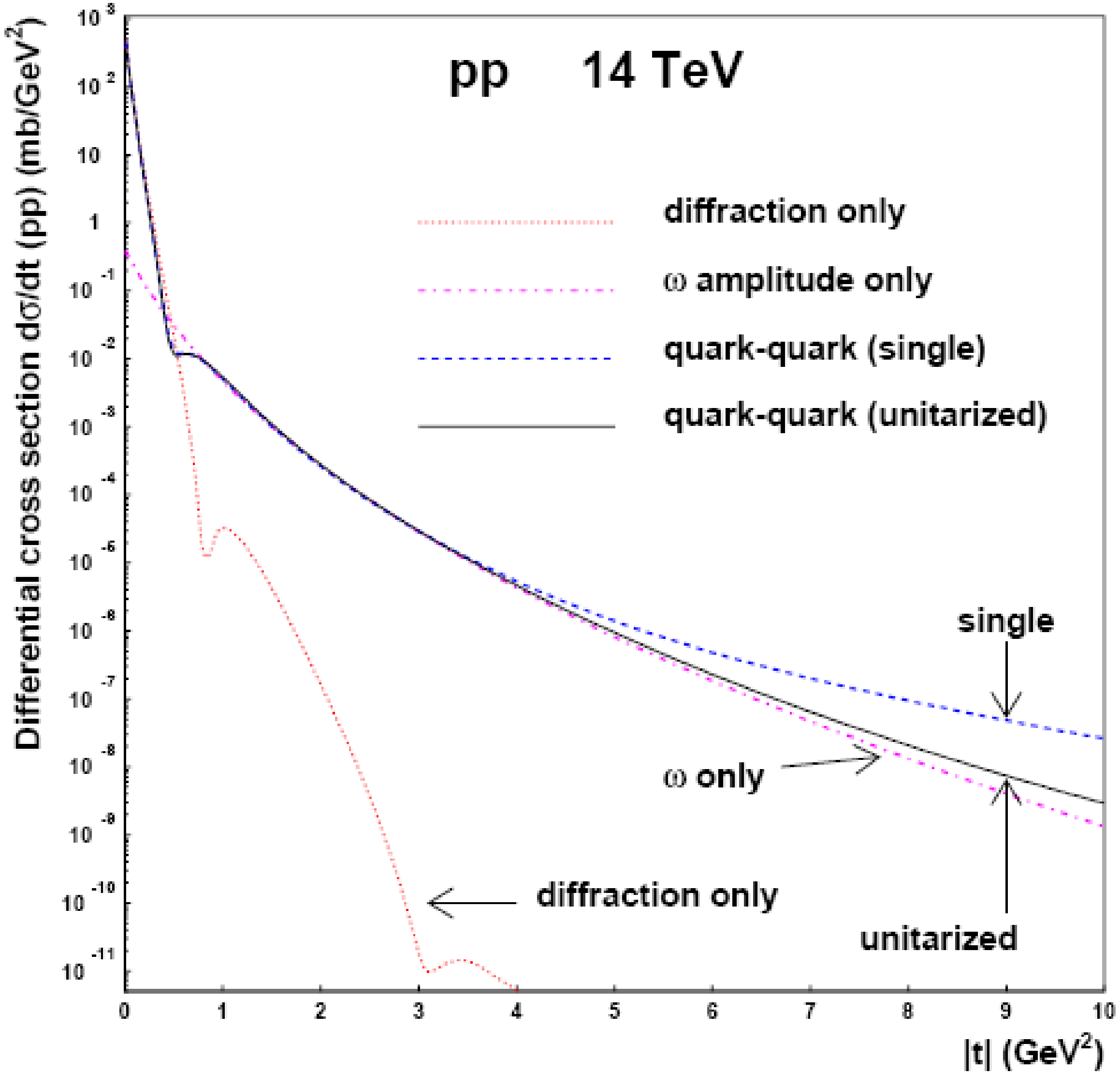
This requires (apart from special beam optics)

- to place detectors ~1.5 mm from LHC beam axis
- to operate detectors in the secondary vacuum of a Roman Pot
- spatial resolution $s_x = s_y$ well below 100 micron (goal 30 micron)
- no significant inactive edge (< 100 micron)

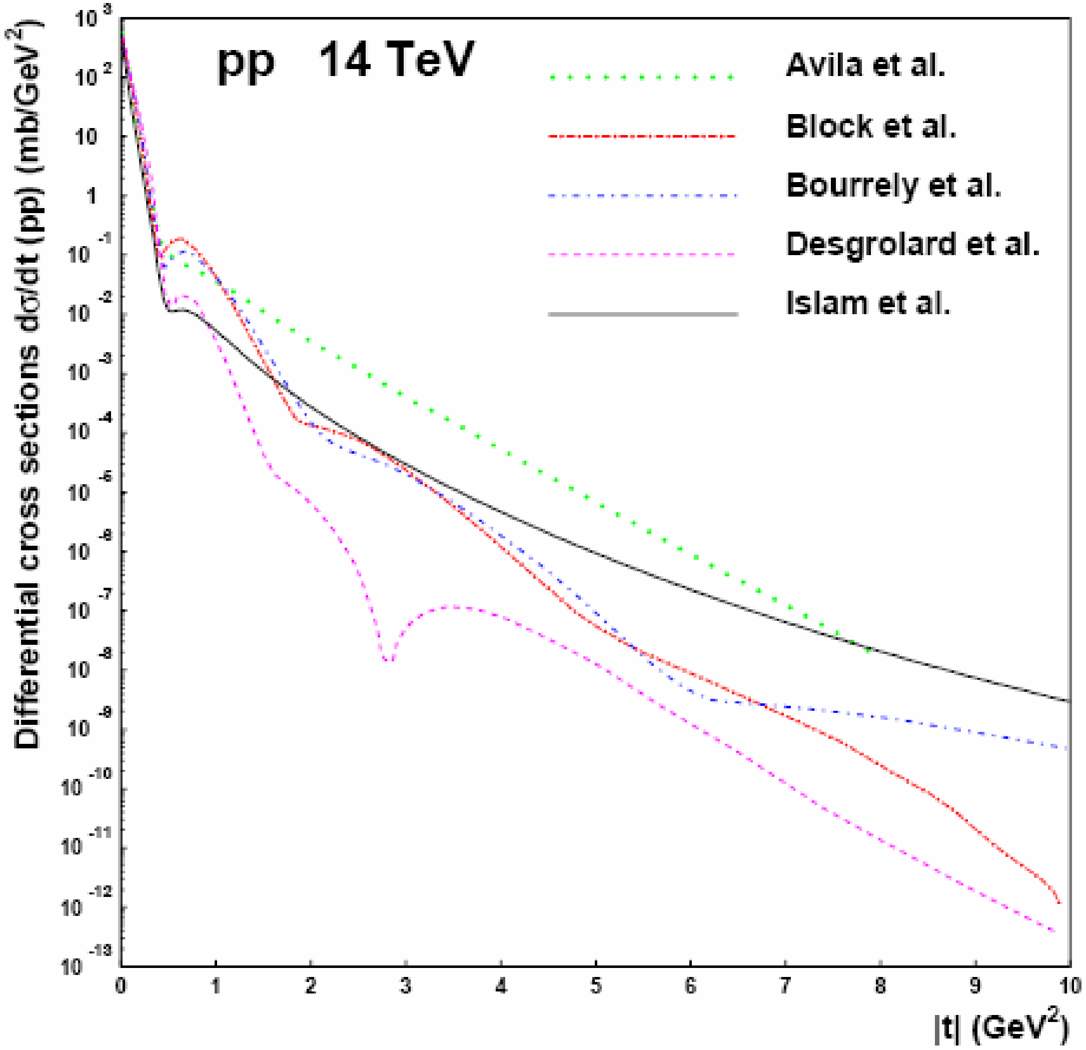


Elastic scattering





pp 14 TeV
diffraction only
ω amplitude only
quark-quark (single)
quark-quark (unitarized)
single
ω only
unitarized
diffraction only
Differential cross section dσ/dt (pp) (mb/GeV²)
|t| (GeV²)



Avila et al.: Phenomenological analysis based on parametrization of $\operatorname{Im} T(s,t)$ using entire functions of $\ln s$.

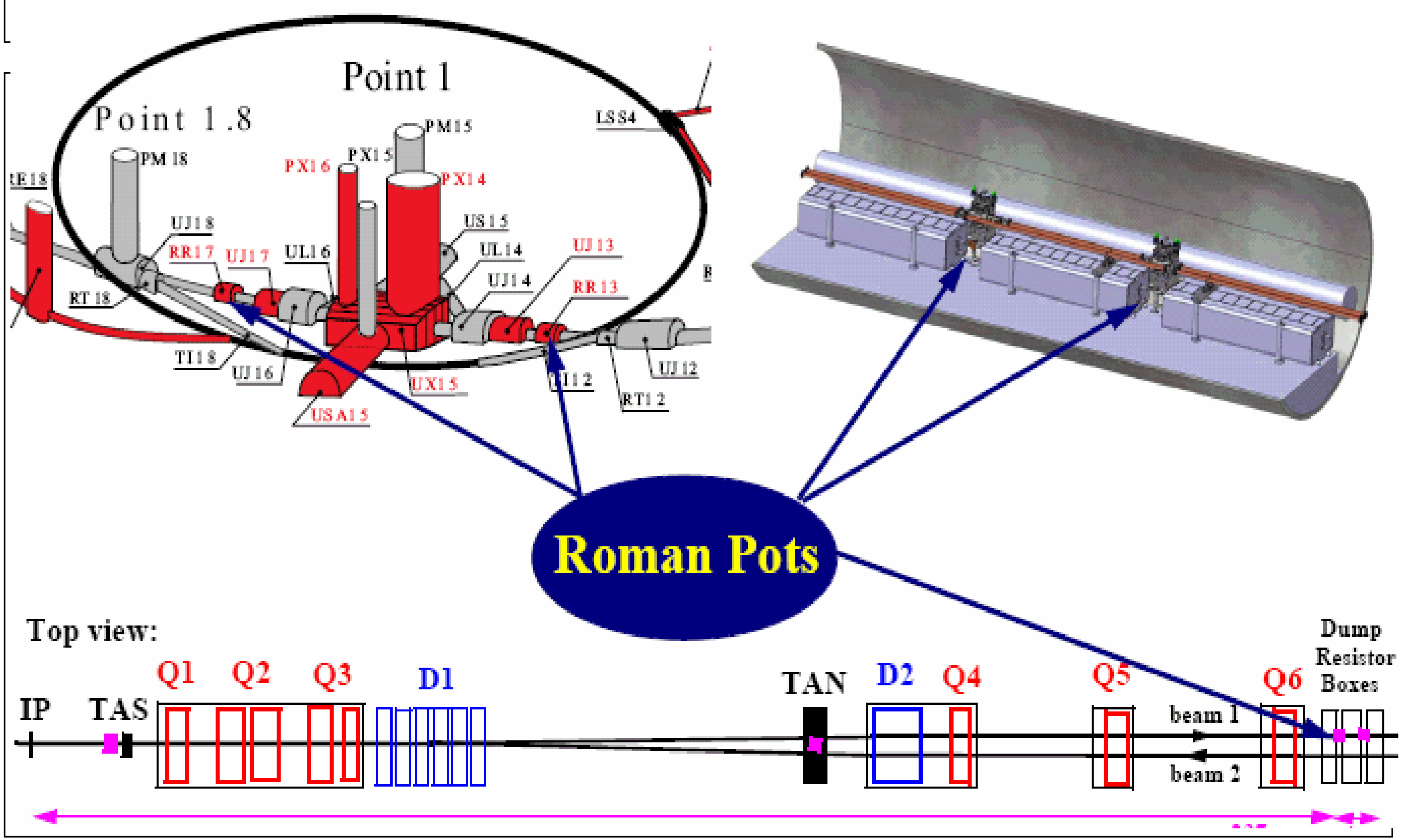
Block et al.: QCD-inspired eikonal model with quark-quark, quark-gluon, and gluon-gluon interactions.

Bourrely et al.: Eikonal model based on QED tower diagrams and impact picture.

Desgrolard et al.: Generalized pomeron-reggeon eikonal model that includes the odderon.

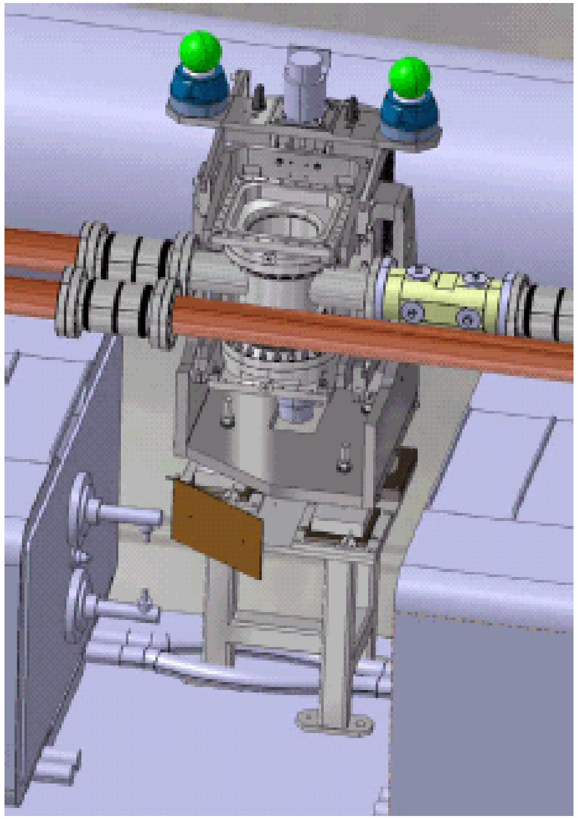
Islam et al.: Nucleon-structure model with soft hadronic diffraction, hard pomeron, and confined valence quarks.

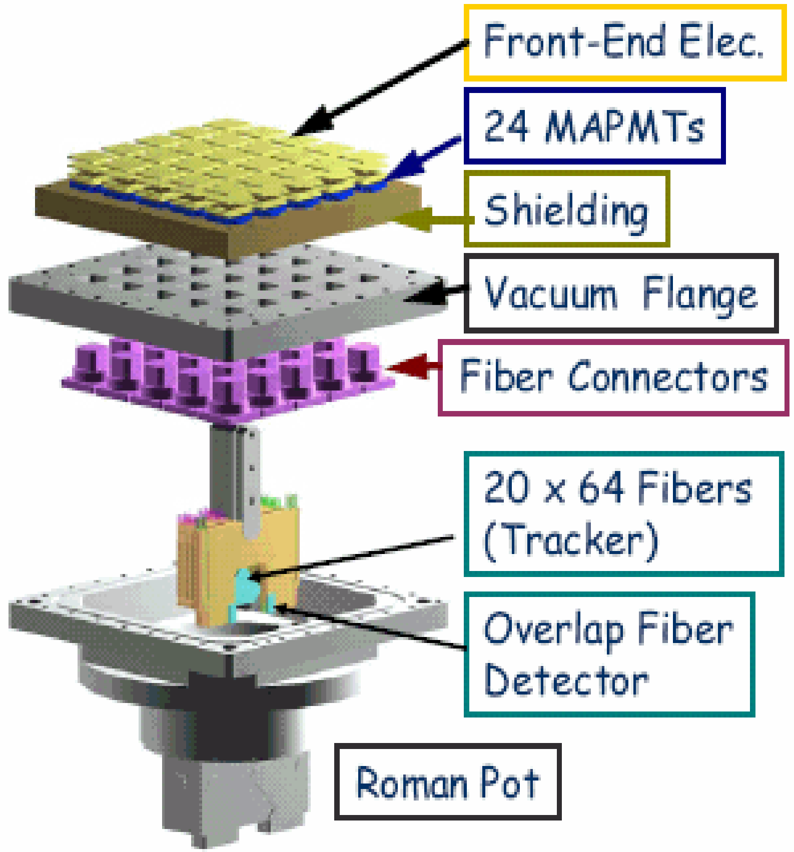
Roman Pot locations



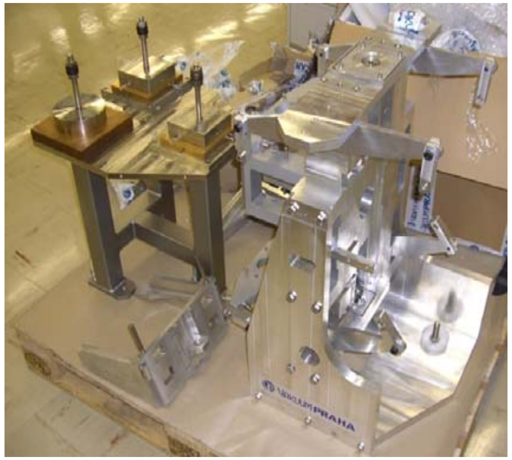
The Roman Pot mechanics

The Roman Pot Unit

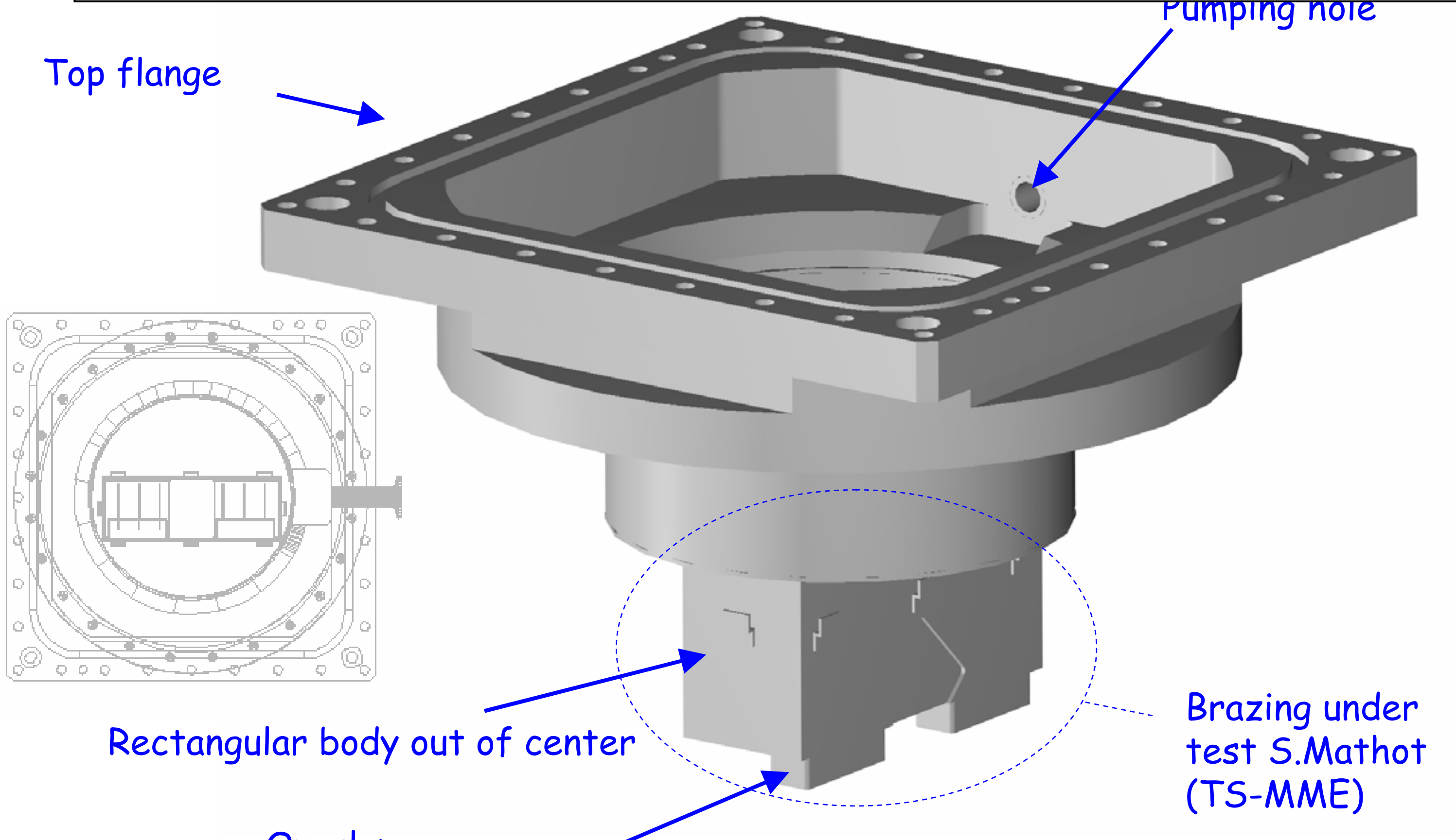




Received recenly prototype Roman Pot Unit (i.e without pot)
Now being assembled by PH/DT1 team.
Will be used to set up the control system and organize cable routing and patch panels



The Pot



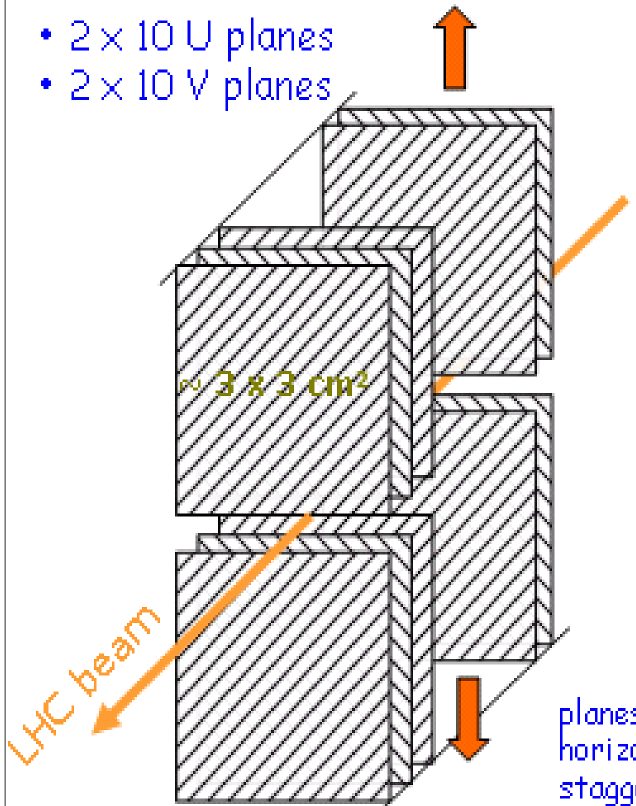
First prototype being prepared

- Will soon be vacuum tested
- Simulation of contribution to the impedanc budget ongoing

The detectors-fiber trackers

Concept

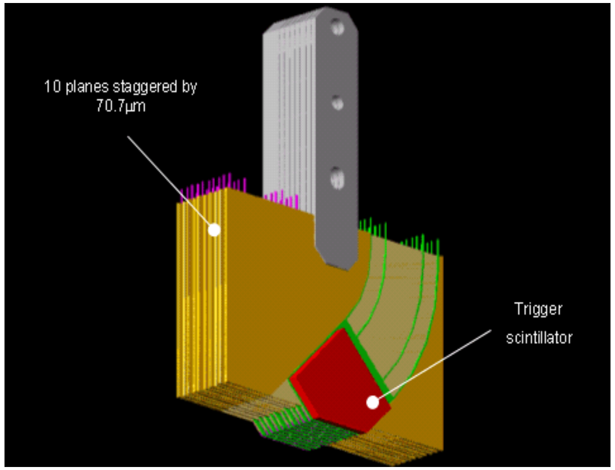
- 2 × 10 U planes
- 2 × 10 V planes

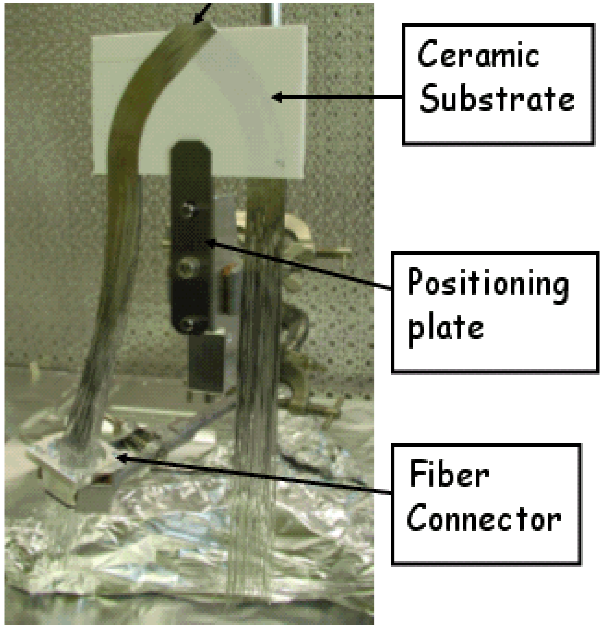


- scintillating fibres
- 0.5 mm² square

planes are horizontally staggered by multiples of 70.7 micrometer

The fibres are read out by MAPMT



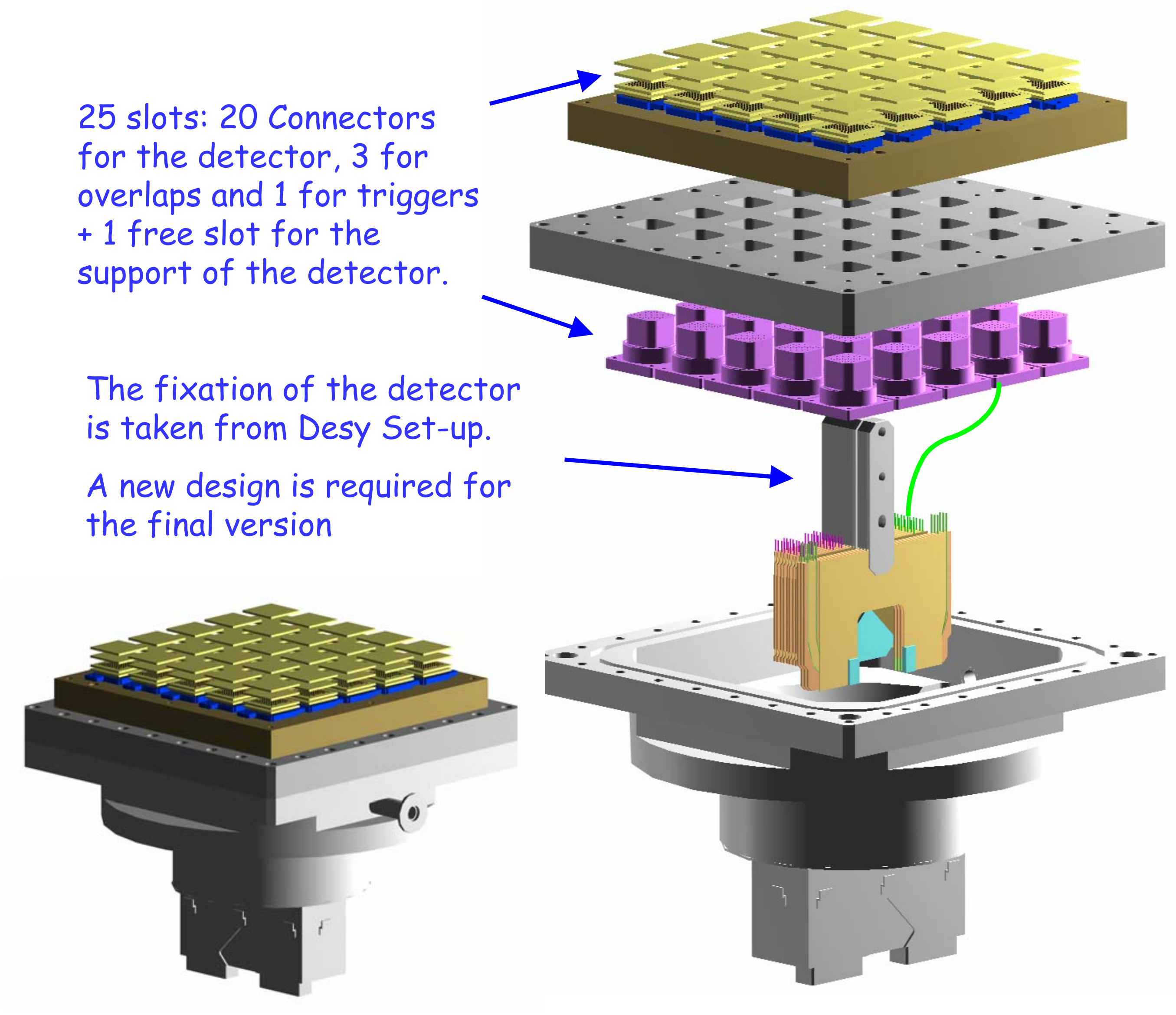


Design of ALFA detector

25 slots: 20 Connectors for the detector, 3 for overlaps and 1 for triggers + 1 free slot for the support of the detector.

The fixation of the detector is taken from Desy Set-up.

A new design is required for the final version



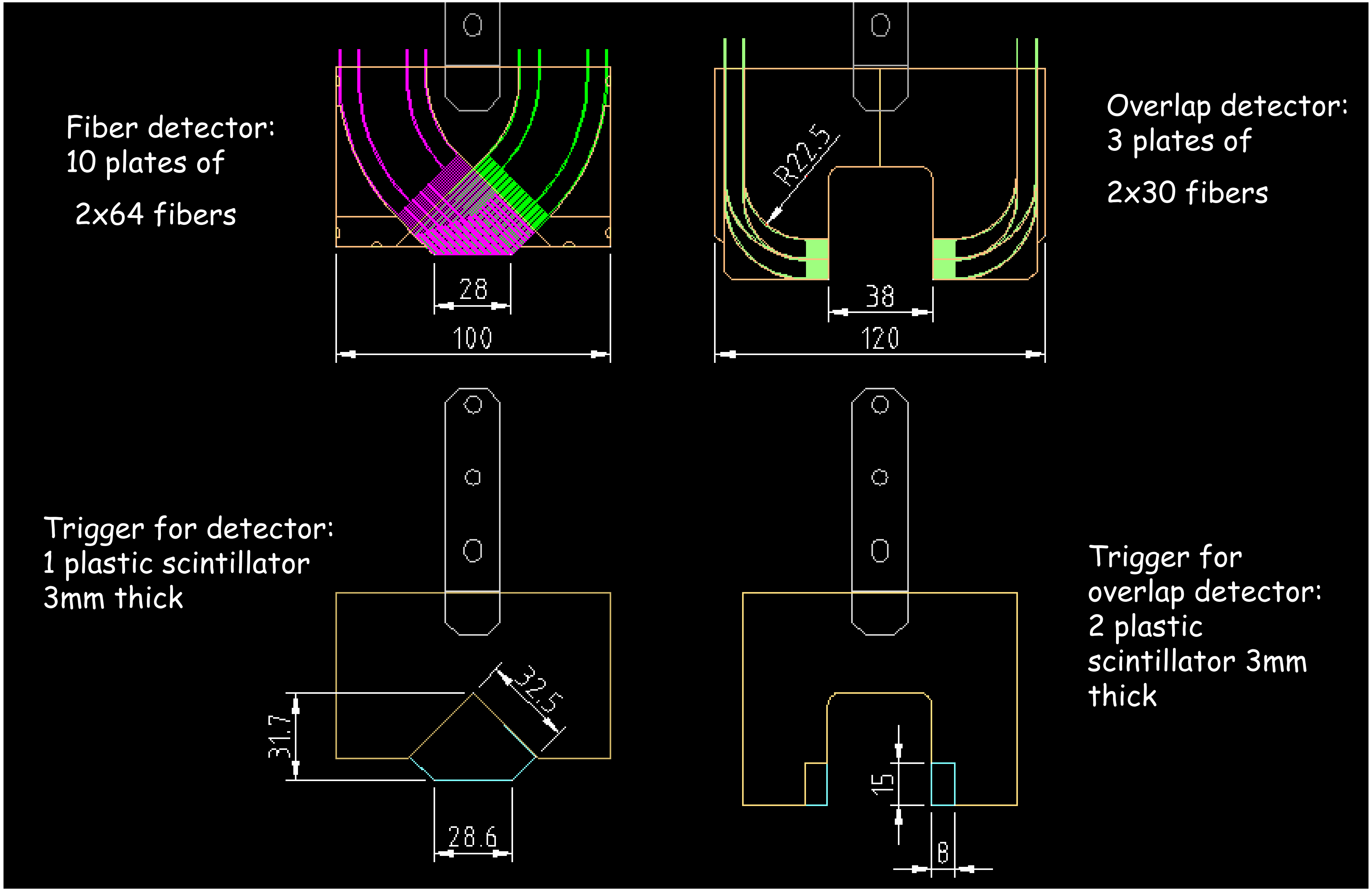
MAPMTs + PMFs + mu-metal shielding

PM baseplate

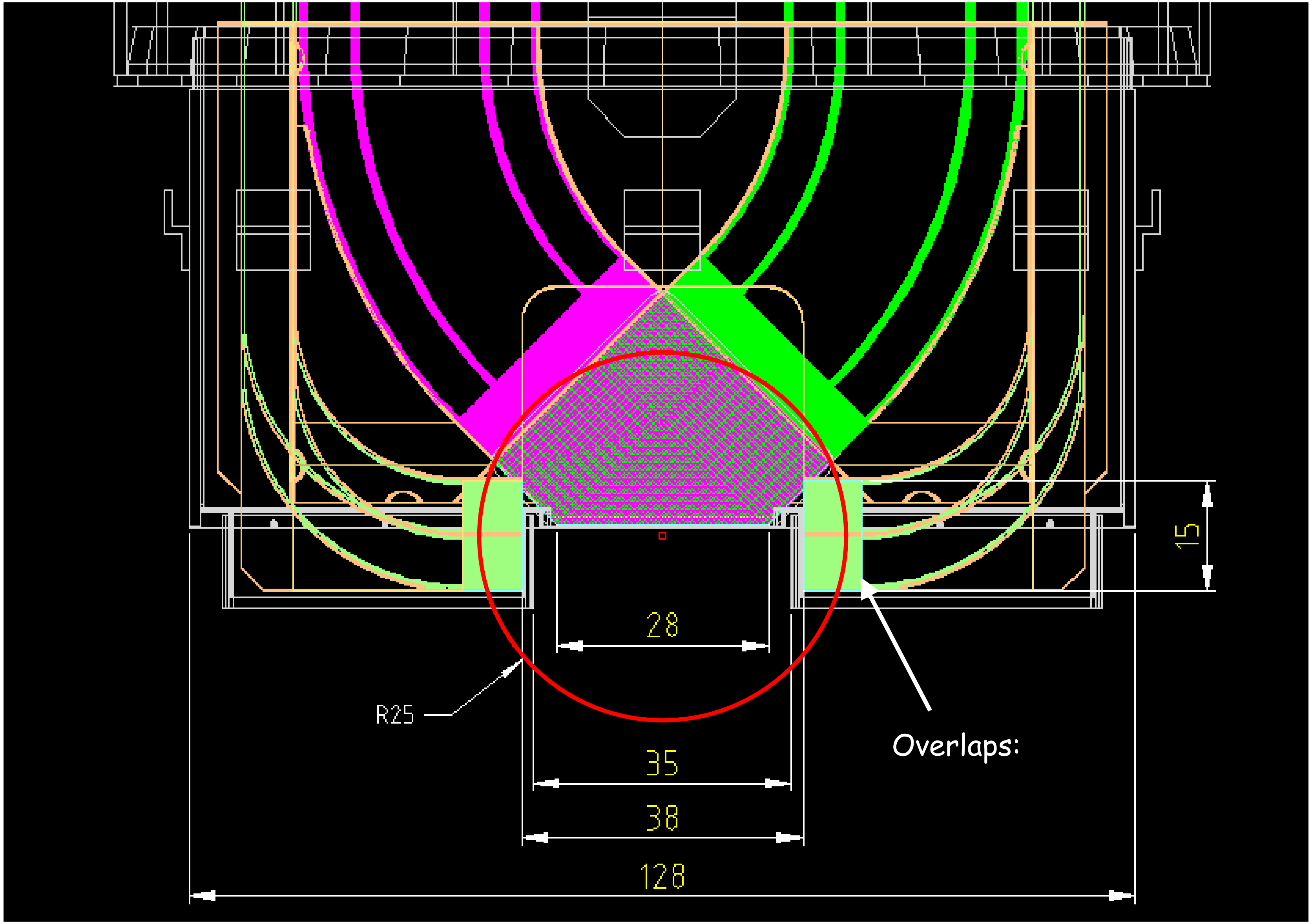
Connectors
Fiber detector
overlaps
trigger scint.

Pot

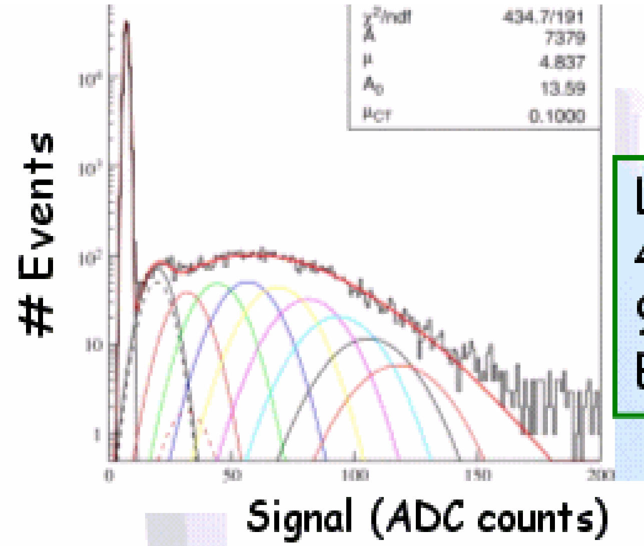
4 types of plates designed



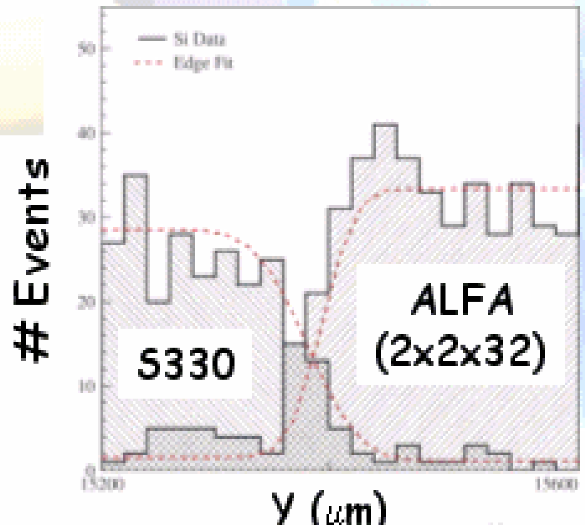
Front view of detector in pot



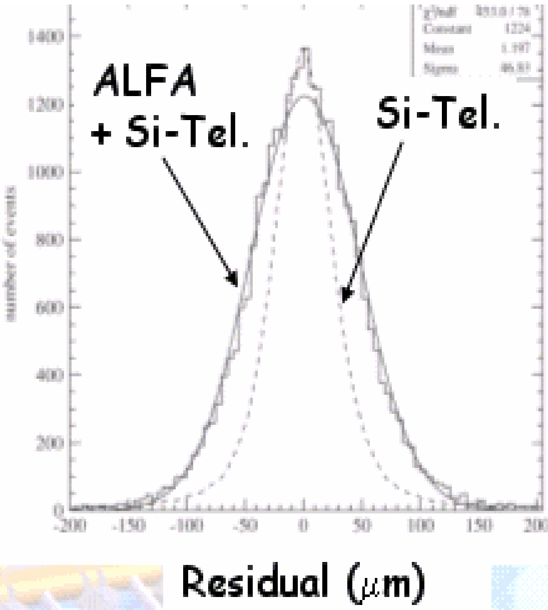
DESY test beam results



Light yield:
45° cut → 3.9 p.e.
90° cut → 4.5 p.e.
Efficiency ~ 95%

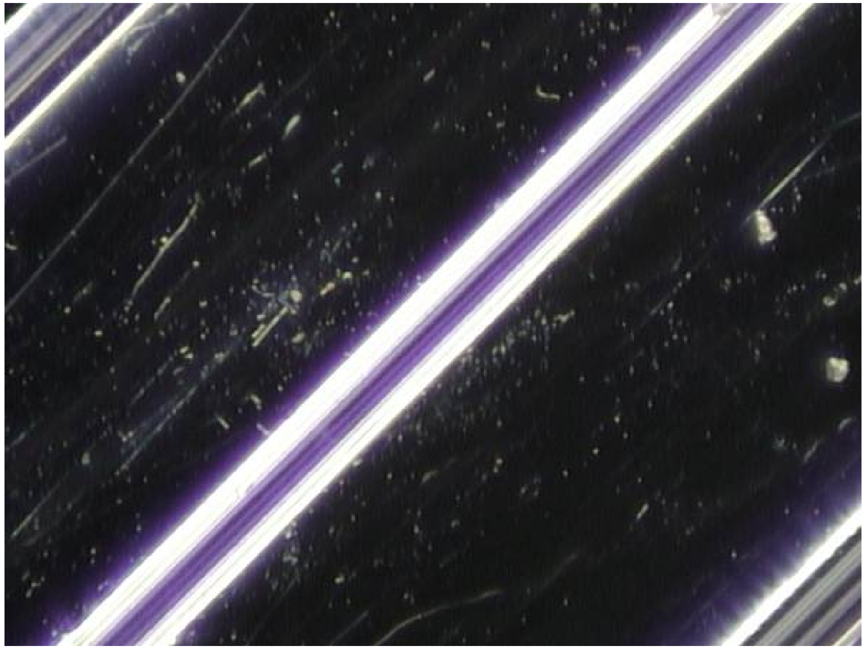


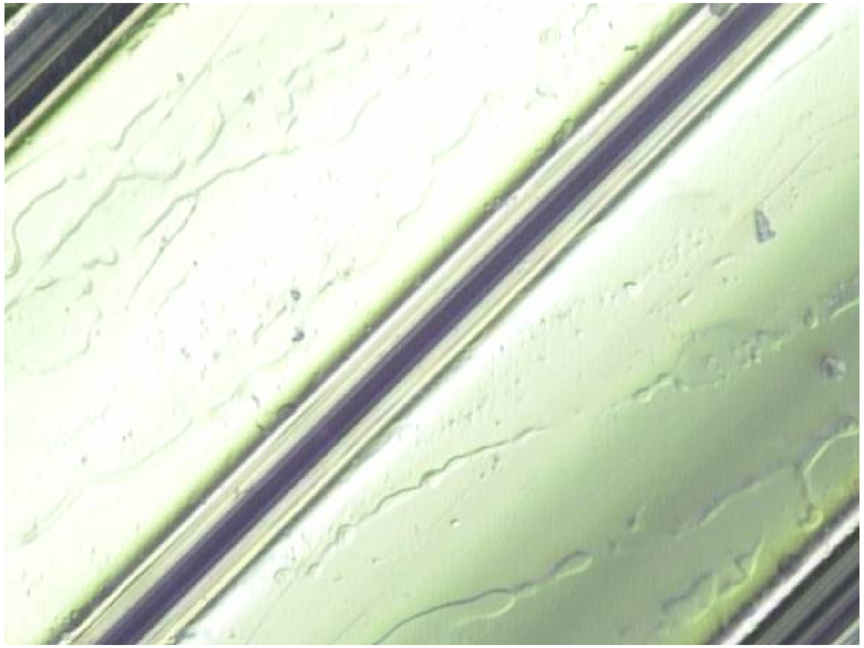
Non-Active Edge
Region << 100μm

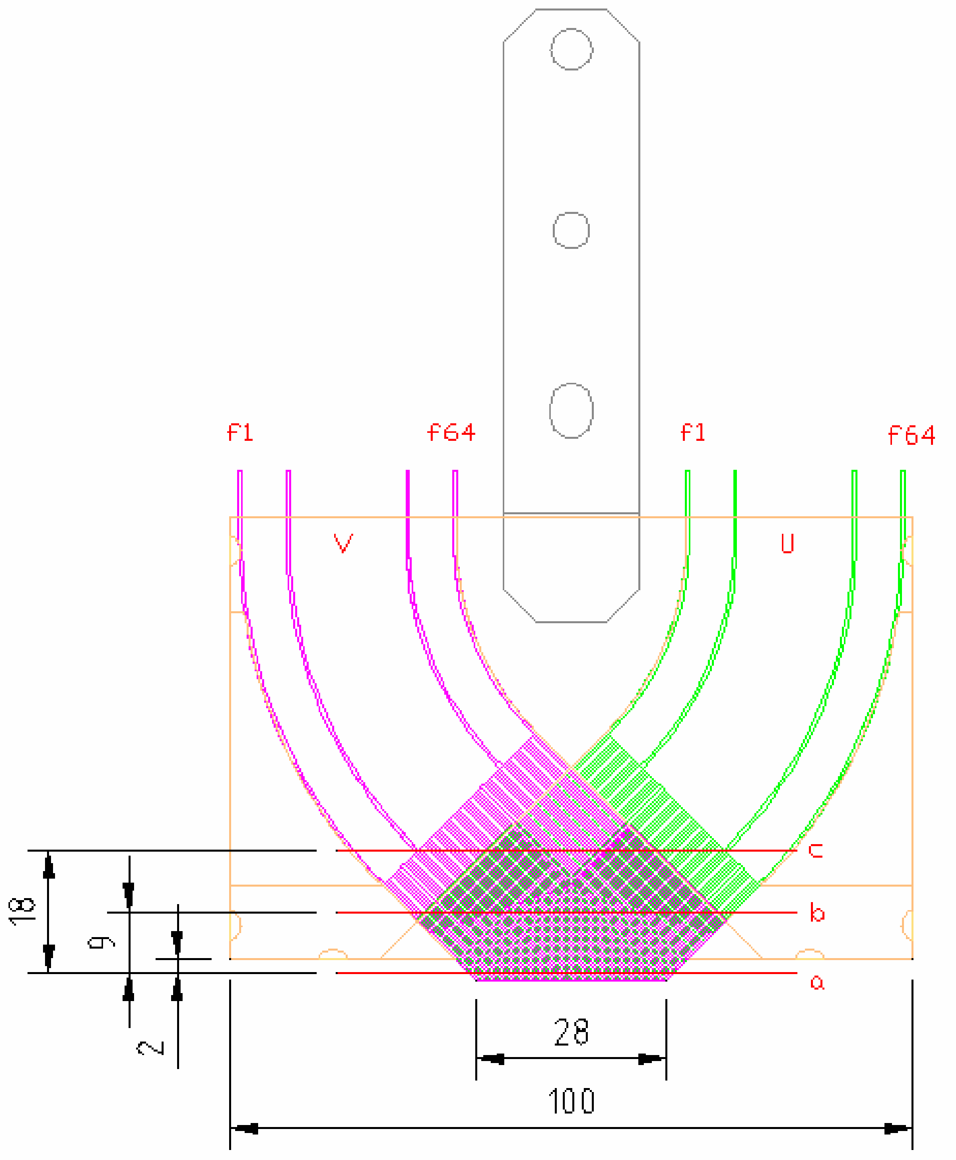


ALFA Resolution:
$\sigma_{x,y}$ ~ 36 μm

Potentially increased by multiple scattering of the relatively low energy electrons





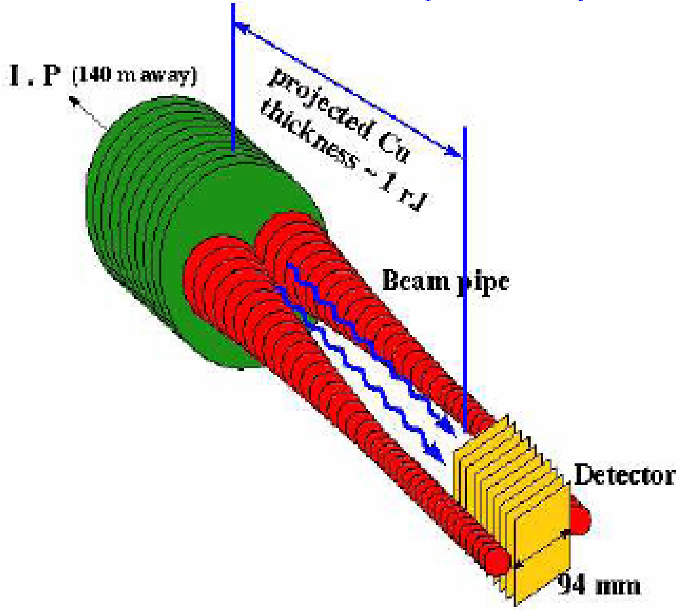


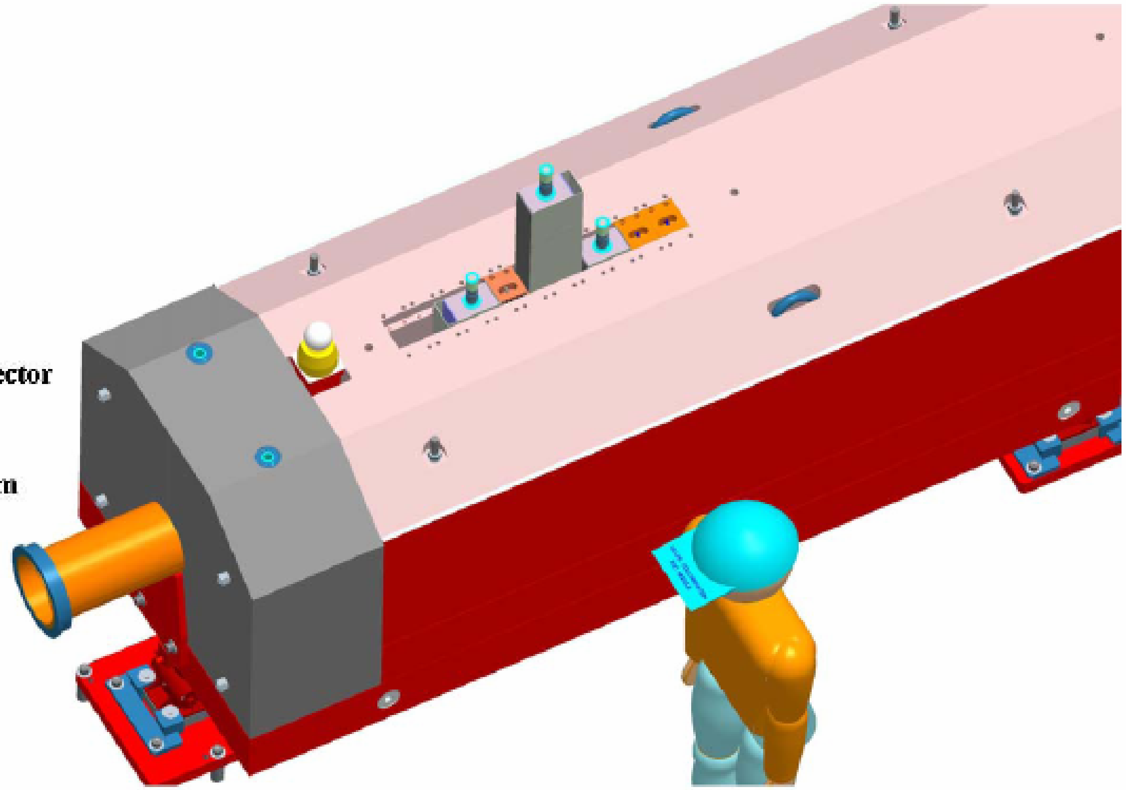
staggering

plane	s (mm)
1	0.0000
2	0.2828
3	-0.1414
4	0.1414
5	-0.2828
6	0.3536
7	-0.0707
8	0.2121
9	-0.2121
10	0.0707

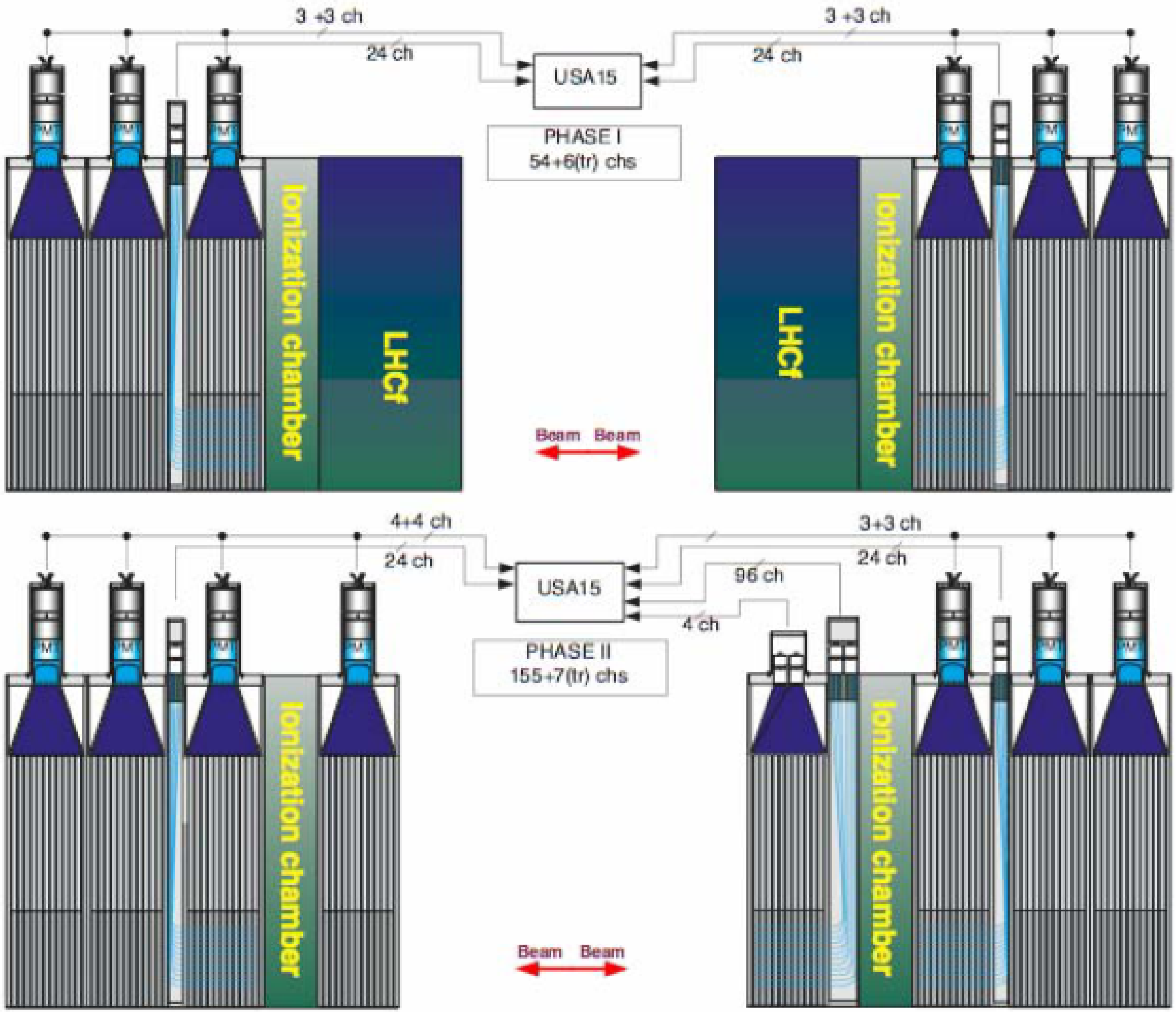
ZDC in ATLAS

A Zero Degree Calorimeter (ZDC) is a calorimeter that resides at the junction where the two beam pipes of the LHC become one – at 0° from the pp collisions. It is housed in the shielding unit that protects the S.C magnets from radiation, and measures neutral particle production at 0°. It can play many roles.



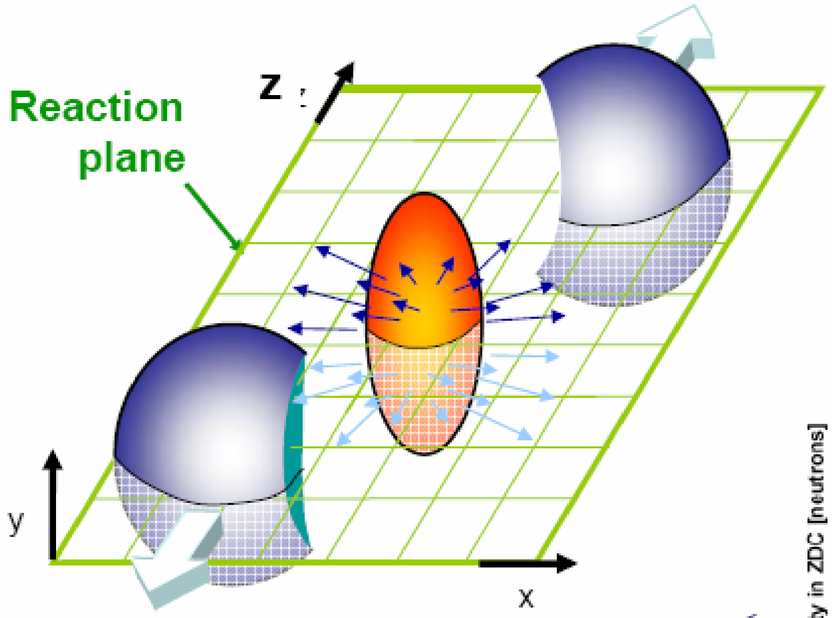


ZDC scenarios and cabling



Event characterization using forward detectors

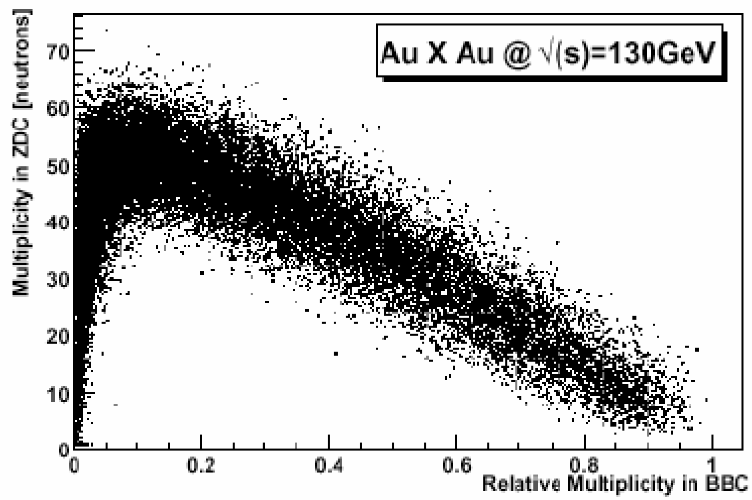
>>Direction and magnitude of impact parameter, b



Spectator neutrons
•measure centrality,
•Min_min_bias trigger

Magnitude from complementary parameters

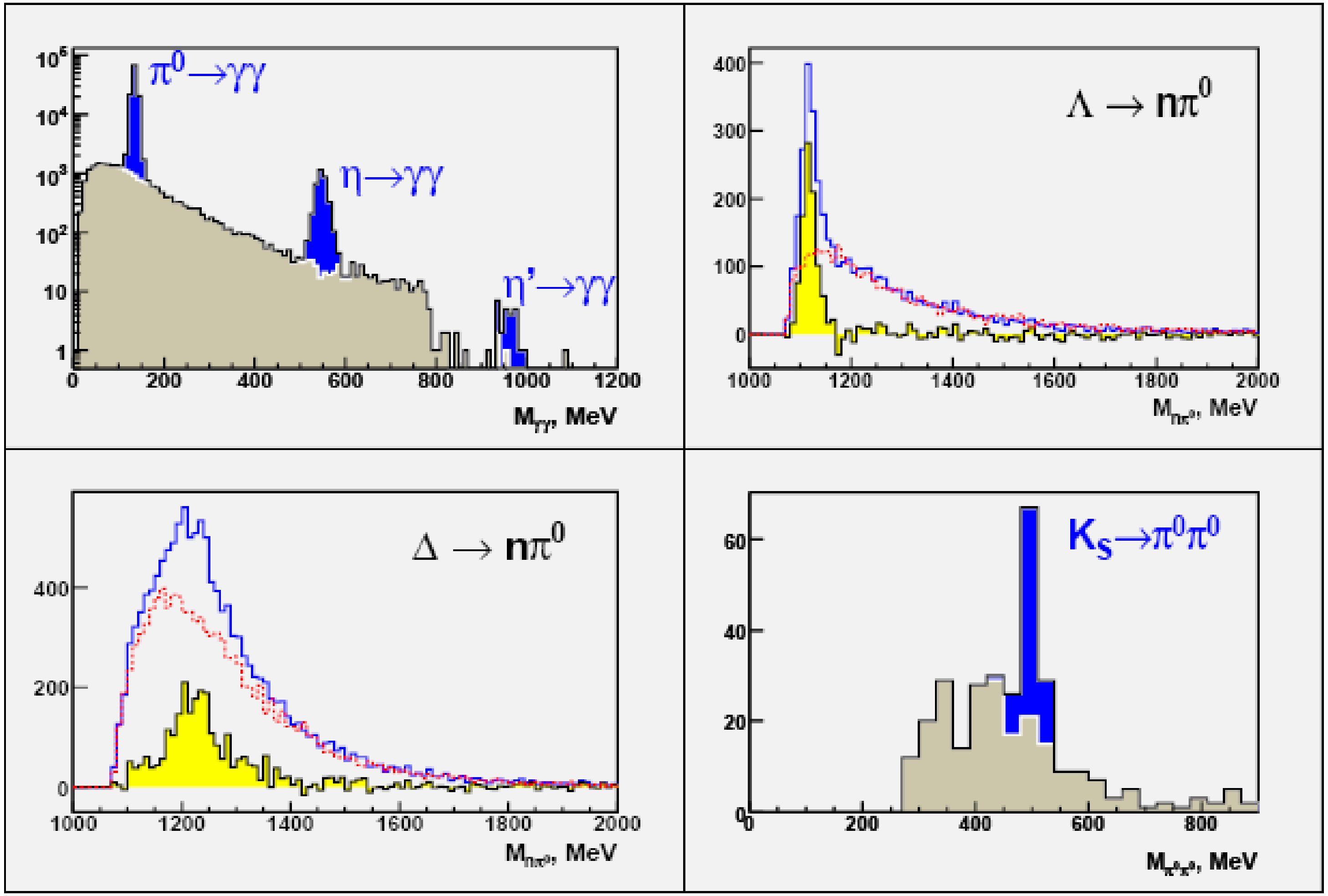
$N_{participant}=2*A-N_{spectator}$



Beam-Beam Counter Mult/1000

ZDC in pp(Phase II configuration)

In pp, the ZDC can measure forward production cross sections for several types of particles at very high energies. This will be useful for adjusting parameters for simulations and models, and for cosmic ray physics where the energy in one proton's rest frame is 10^{17} eV – a very interesting energy for extended air showers.

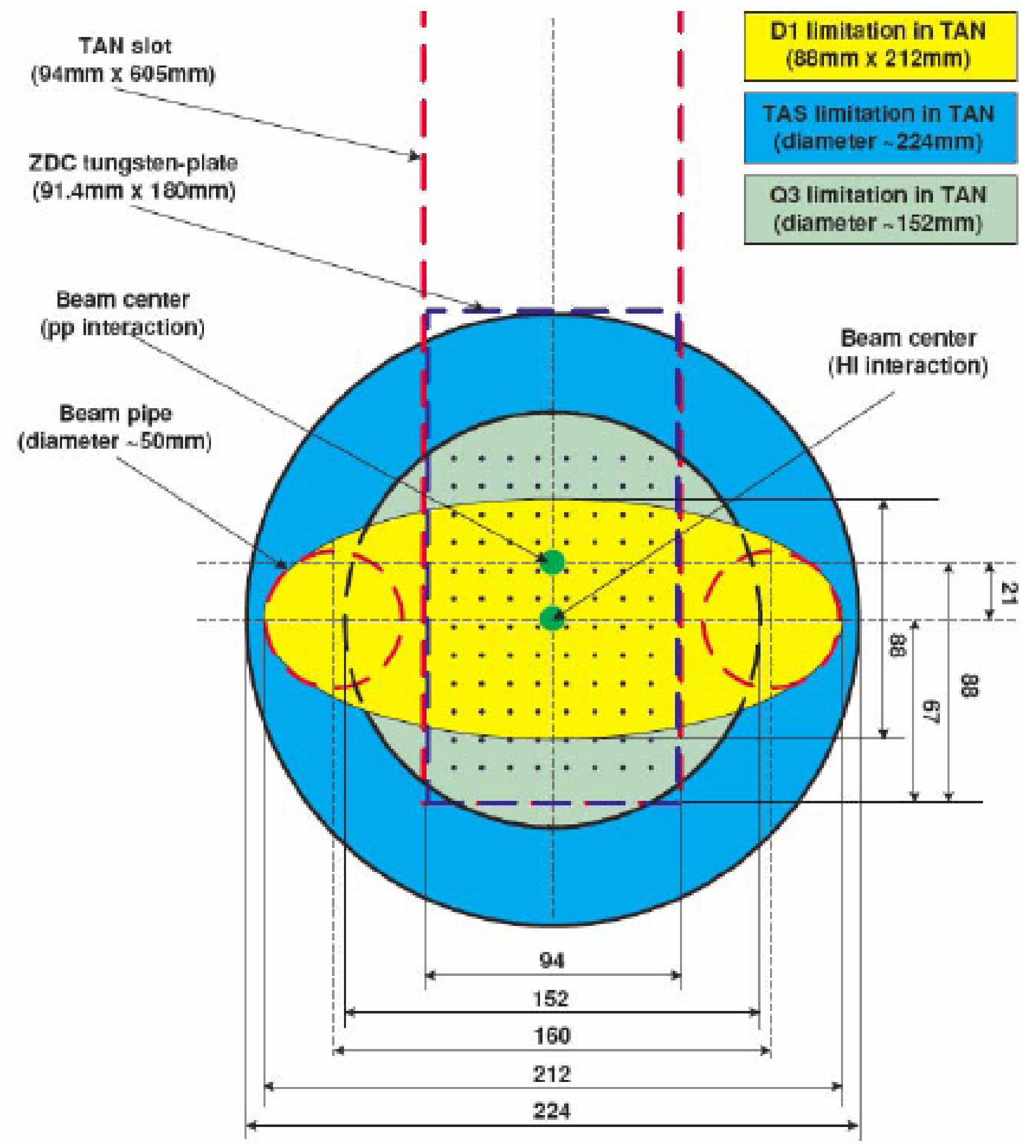


What happens when a high energy proton hits the upper atmosphere?

The ZDC can find a pi0 in the midst of several neutrons.

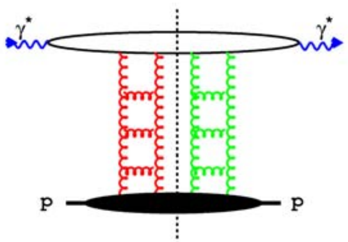
(1M Pythia events analyzed by a ZDC)

Aperture limitations from upstream components of the machine

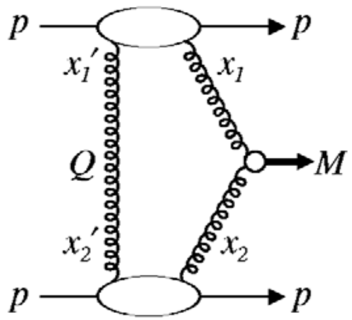


Short review of Diffraction at HERA at small x

HERA

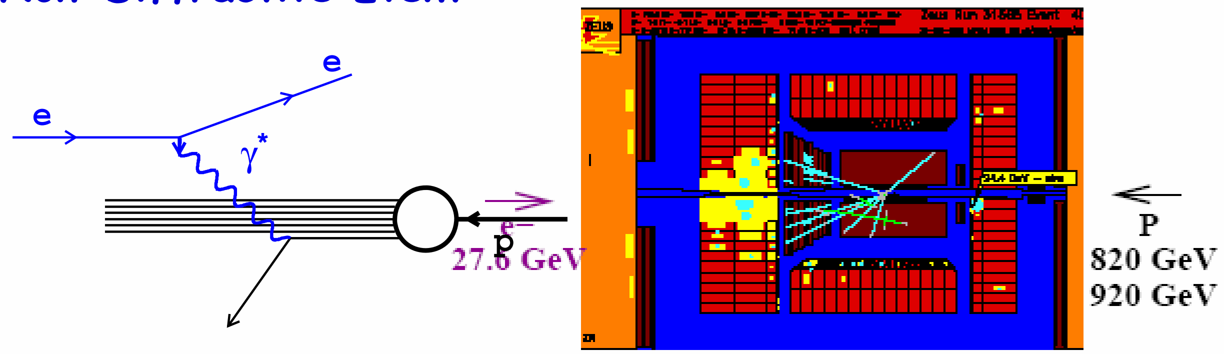


LHC

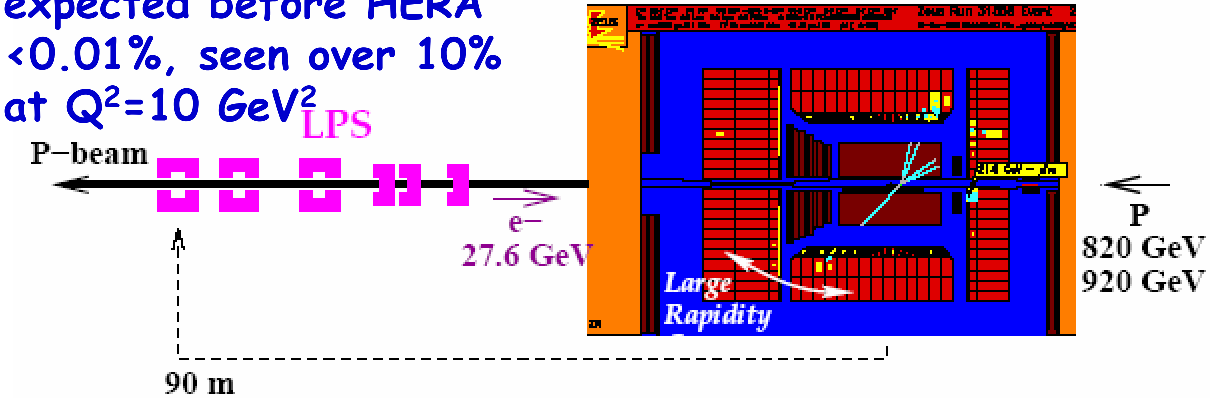


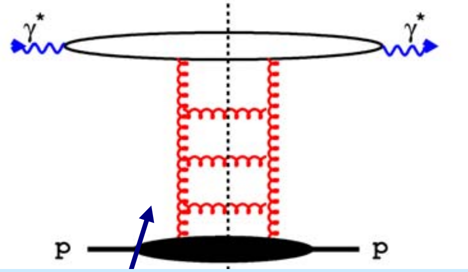
Hard Diffraction – the HERA surprise

Non-Diffractive Event

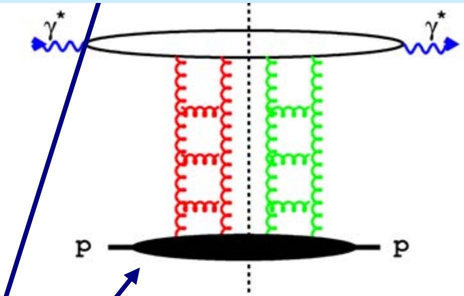


Diffractive Event
expected before HERA
<0.01%, seen over 10%
at Q^2=10 GeV^2





$$\tau_{qq} \approx \frac{1}{\Delta E} \approx \frac{1}{m_p x} \approx 10 - 1000 \ \ \text{fm}$$



Diffraction at HERA is so large because it is a shadow of DIS (i.e. inelastic processes) ➔ dipole picture

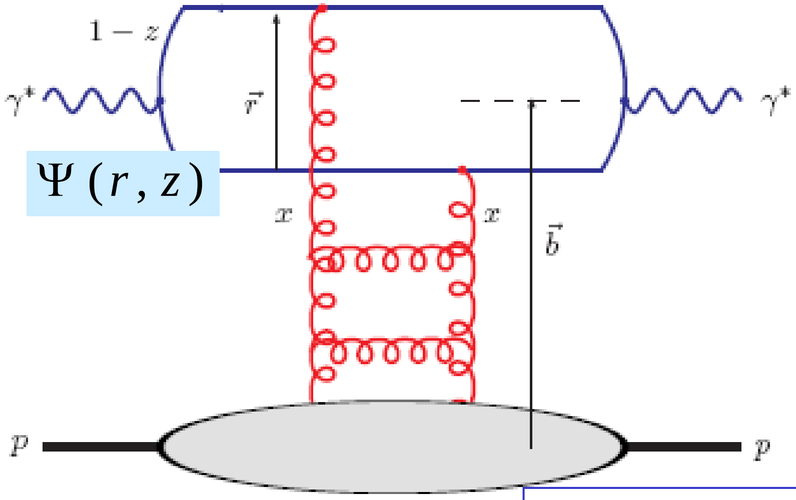
$$\sigma_{tot}^{\gamma^* p} = \frac{1}{W^2} ImA_{el}(W^2, t=0)$$

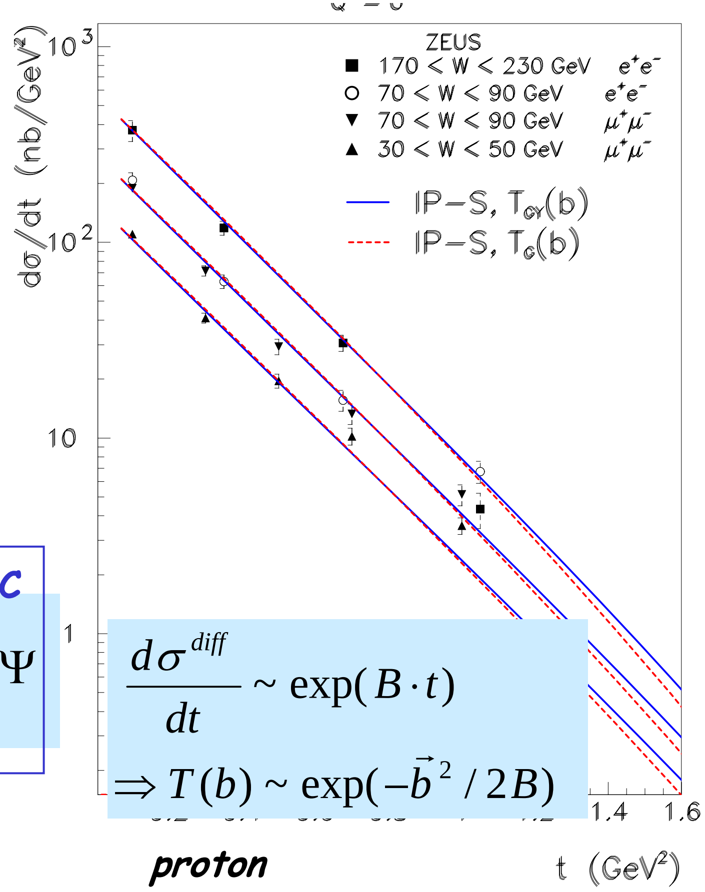
$$\sigma_{tot}^{\gamma p} = \frac{1}{W^2} ImA_{el}(W^2, t=0)$$

Dipole Models

equivalent to LO perturbative QCD for small dipoles

NNPZ, GLM, FKS, GBW, MMS
DGKP, BGBK, IIM, FSS……
KT - Kowalski, Teaney
KMW - Kowalski, Motyka, Watt





G-M or classical CGC

$$\sigma_{tot}^{\gamma^* p} = \int d^2\vec{r} \int_0^1 dz \int d^2 b \Psi^* \cdot 2\left\{1 - \exp\left(-\frac{\Omega}{2}\right)\right\}\Psi$$

$$\frac{d\sigma^{diff}}{dt} \sim \exp(B \cdot t)$$

$$\Rightarrow T(b) \sim \exp(-\vec{b}^2 / 2B)$$

Optical Theorem

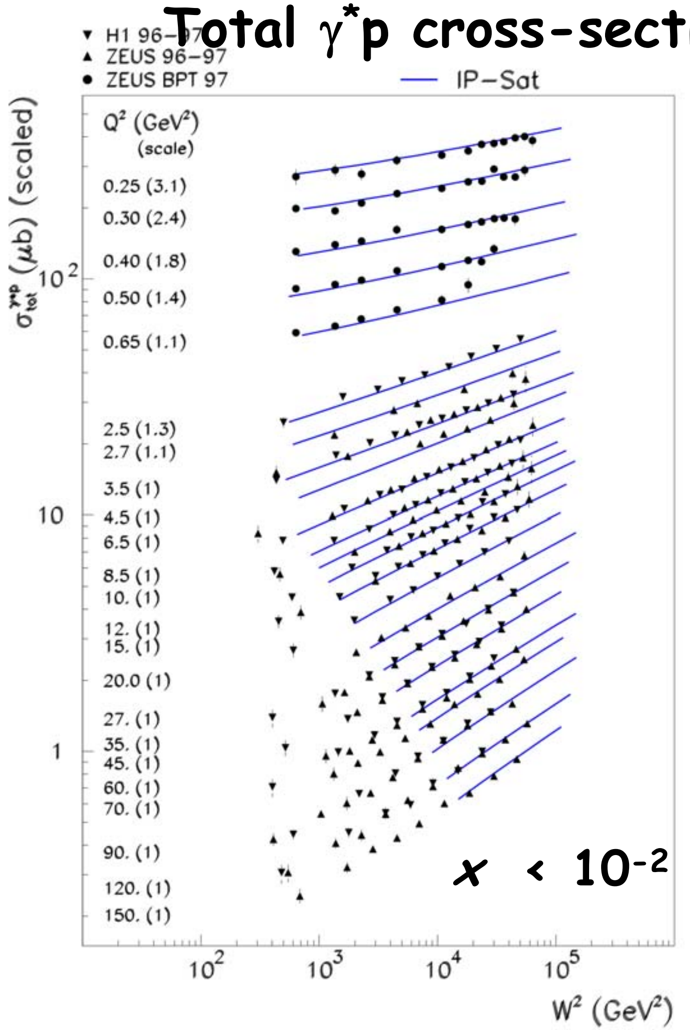
$$\Omega = \frac{\pi^2}{N_C} r^2 \alpha_s(\mu^2) xg(x,\mu^2) T(b)$$

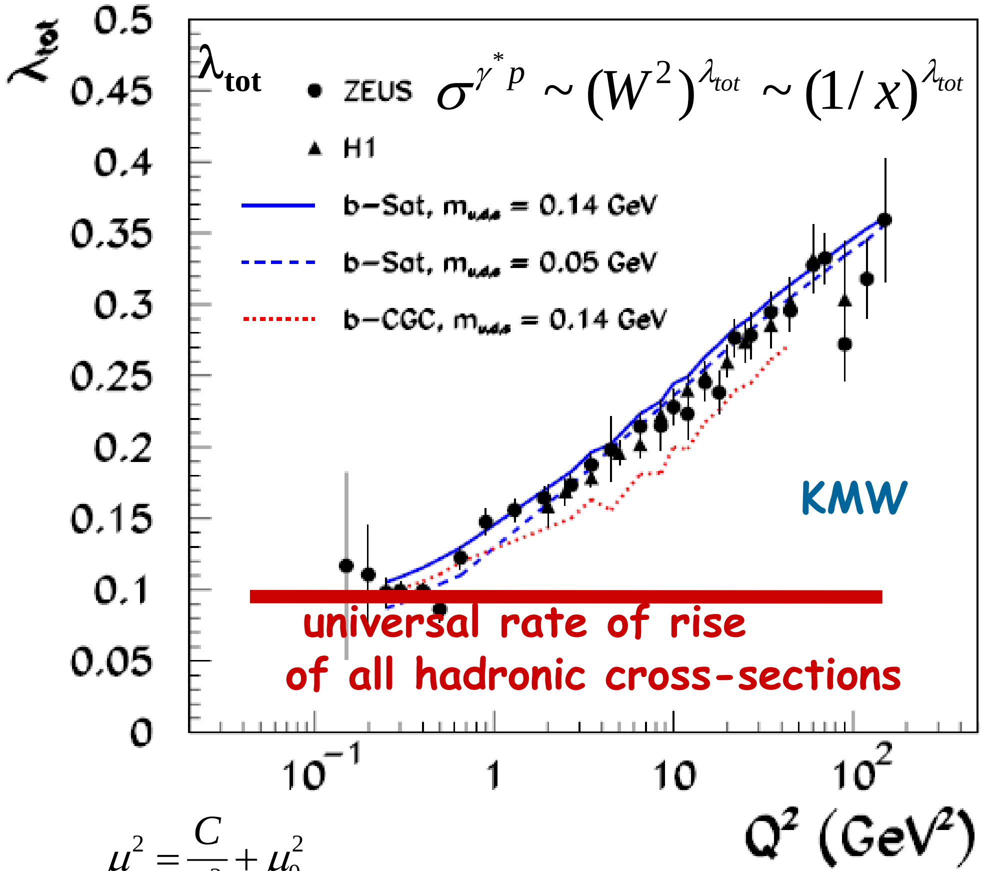
proton shape

$$\frac{d\sigma_{VM}^{\gamma^* p}}{dt} = \frac{1}{16\pi} \left| \int d^2\vec{r} \int d^2 b e^{-i\vec{b}\cdot\vec{\Delta}} \int_0^1 dz \Psi_{VM}^* \; 2\left\{1 - \exp\left(-\frac{\Omega}{2}\right)\right\}\Psi \right|^2$$

KT

Total $\gamma^* p$ cross-section





$$\sigma^{\gamma^* p} \sim (W^2)^{\lambda_{tot}} \sim (1/x)^{\lambda_{tot}}$$

$$\mu^2 = \frac{C}{r^2} + \mu_0^2$$

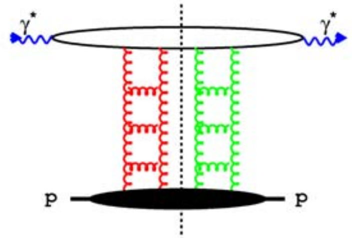
$$\frac{d\sigma_{q\bar{q}}}{d^2 \boldsymbol{b}} = 2\left[1 - \exp\left(-\frac{\pi^2}{2N_c} r^2 \alpha_S(\mu^2) x g(x,\mu^2) T(b)\right)\right] \quad xg(x,\mu_0^2) = A_g \left(\frac{1}{x}\right)^{\lambda_g} (1-x)^{5.6}$$

b-Sat

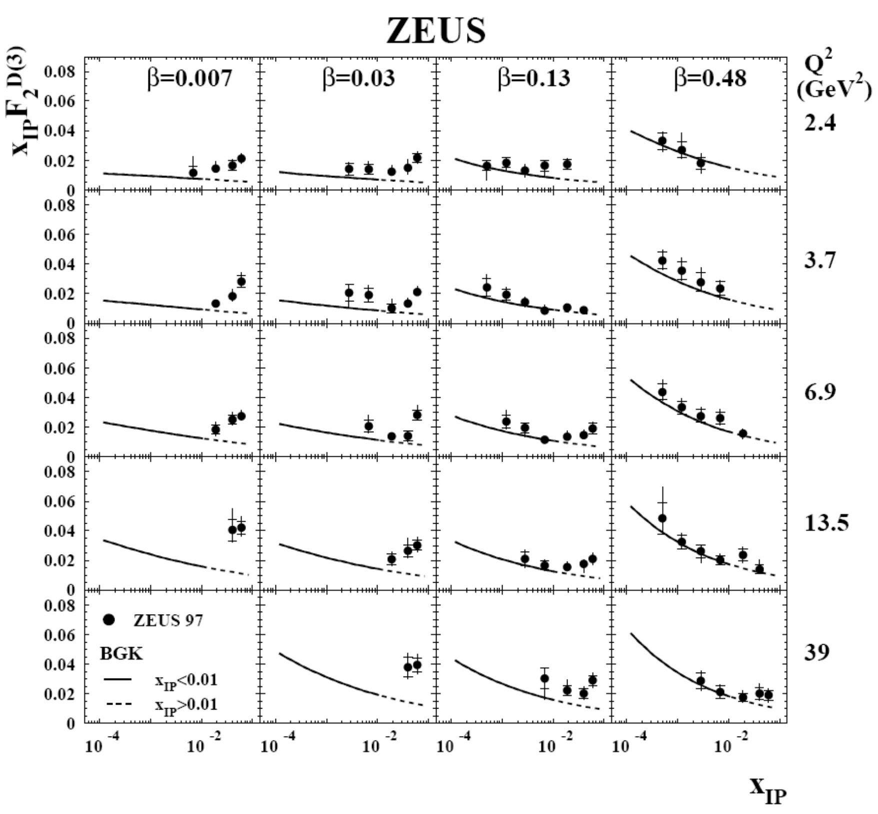
$$\frac{d\sigma_{q\bar{q}}}{d^2 \boldsymbol{b}} \equiv 2\mathcal{N}(x,r,b) = 2 \times \begin{cases} \mathcal{N}_0 \left(\frac{rQ_s}{2}\right)^{2\left(\gamma_s + \frac{1}{\kappa\lambda Y}\ln\frac{2}{rQ_s}\right)} & : \quad rQ_s \le 2 \\ 1 - e^{-A\ln^2(BrQ_s)} & : \quad rQ_s > 2 \end{cases}$$

b- CGC or quantum-CGC

Dipole Model - gluon density convoluted with dipole wave functions
simultaneous prediction/description of many reactions

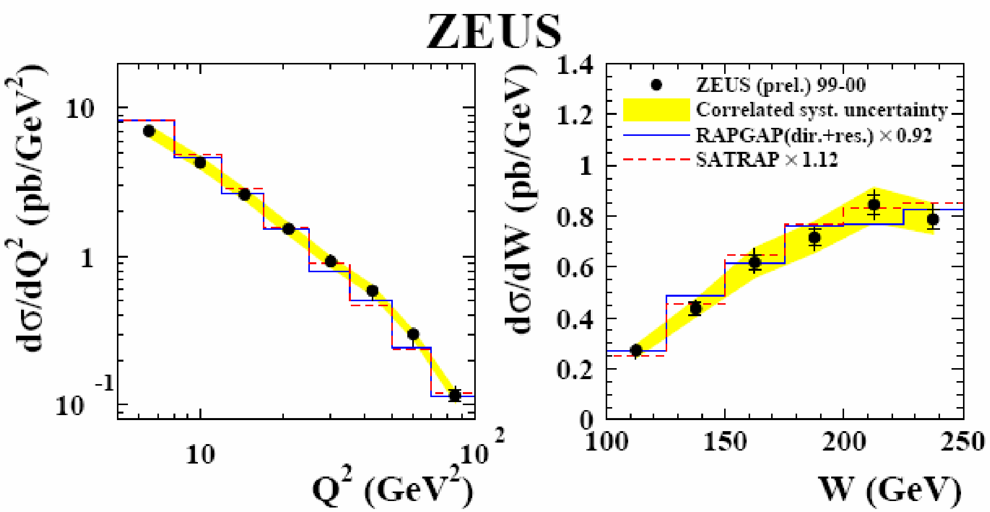


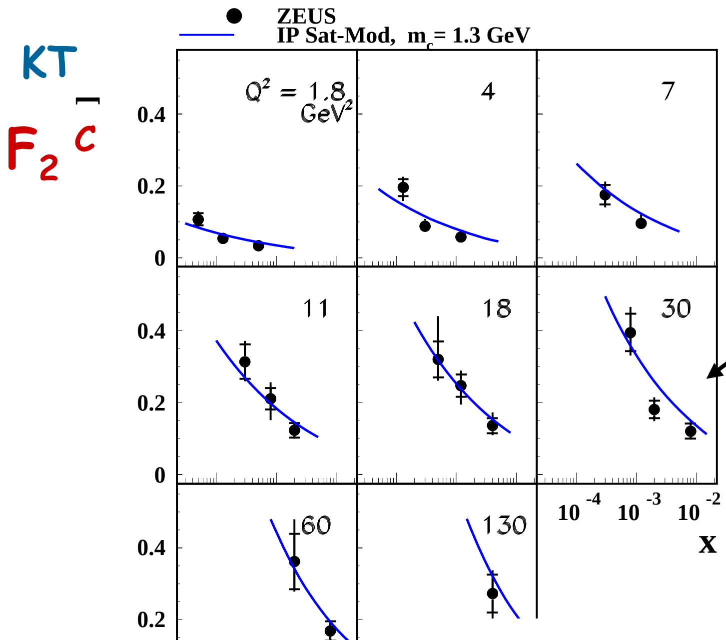
Inclusive Diffractive Cross Section



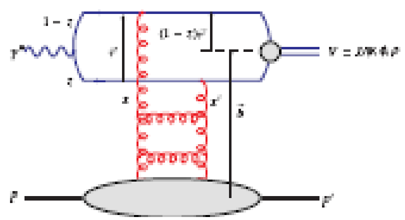
Diffractive Di-jets

Q^2 > 5 GeV^2

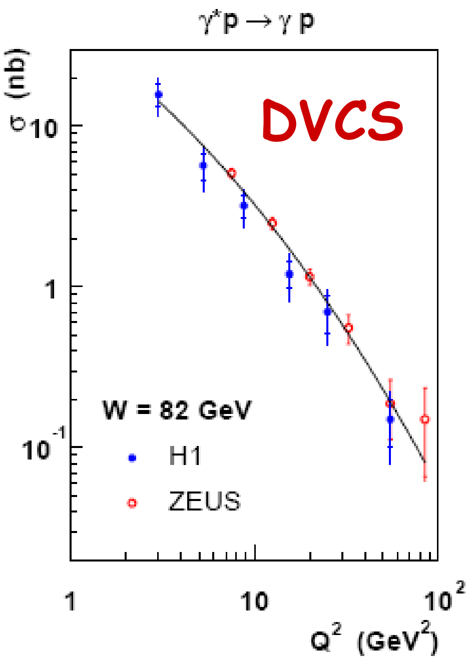


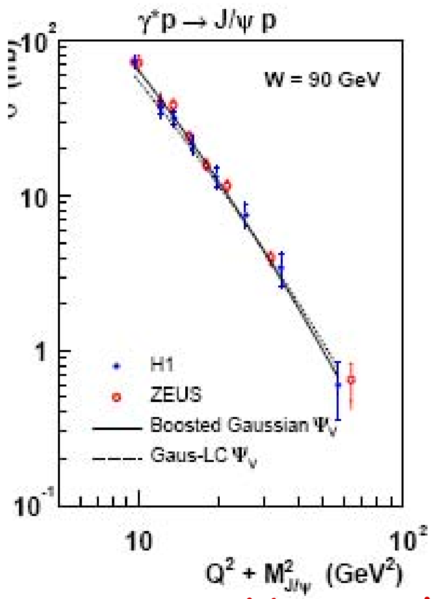


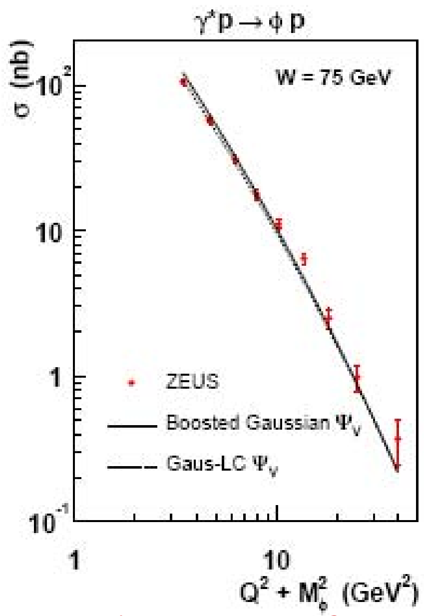
from gluon density convoluted with dipole wave functions we obtain simultaneous prediction/description of many reactions

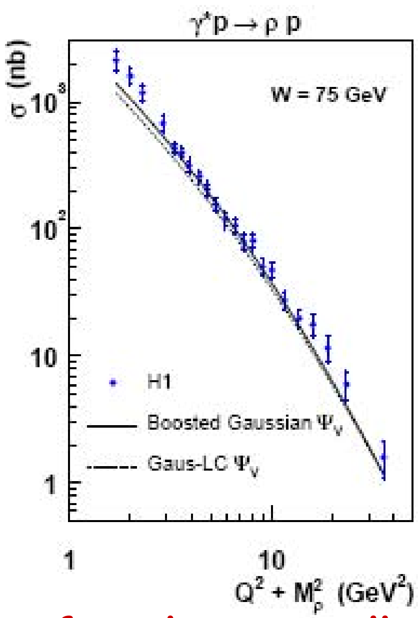


Vector Mesons





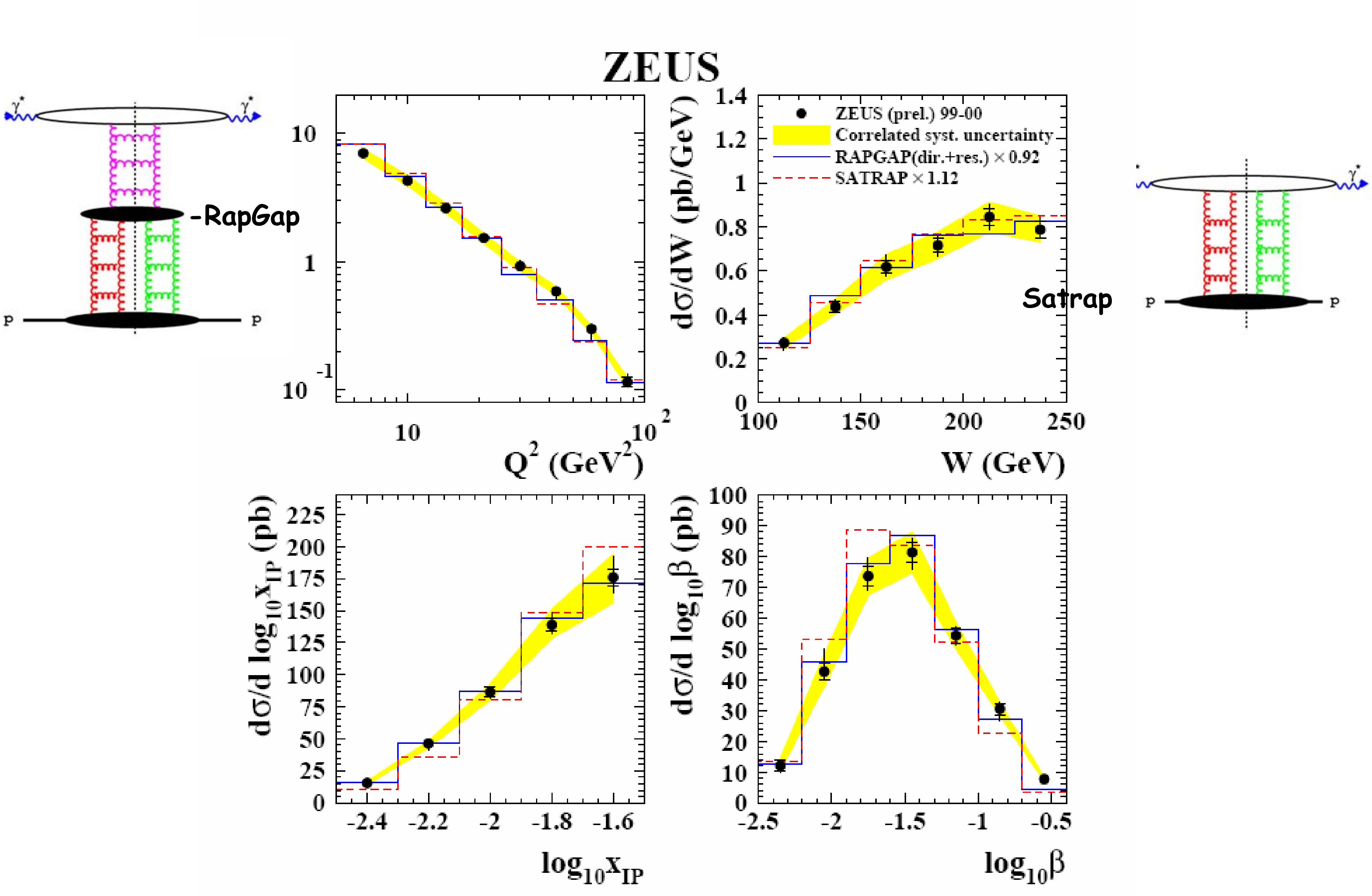




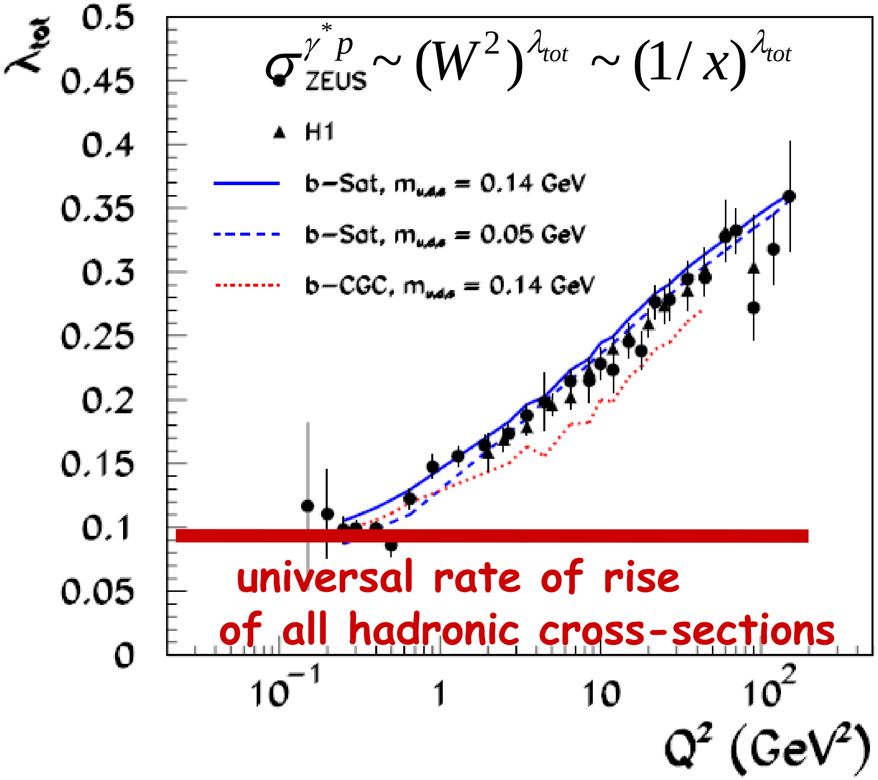
Note: educated guesses for VM wf work very well

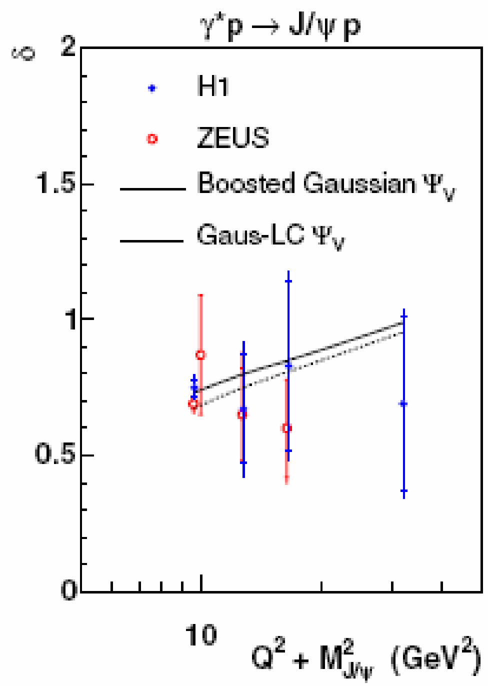
Diffractive Di-jets

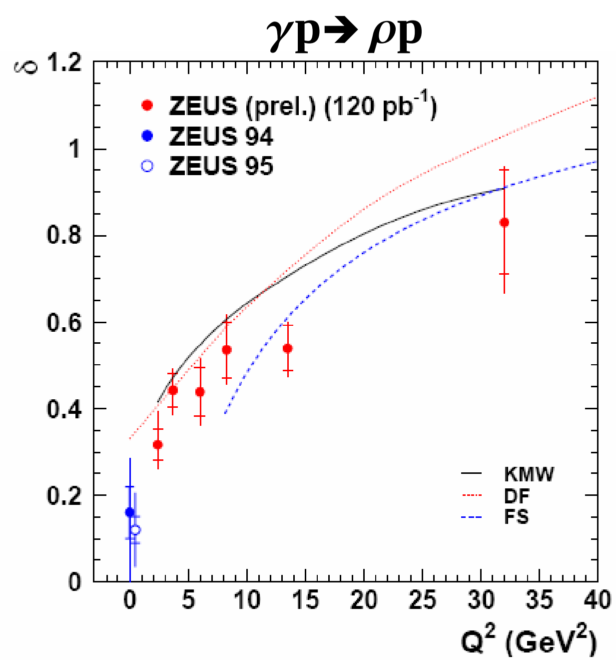
$Q^2 > 5\ GeV^2$



Discovery of HERA







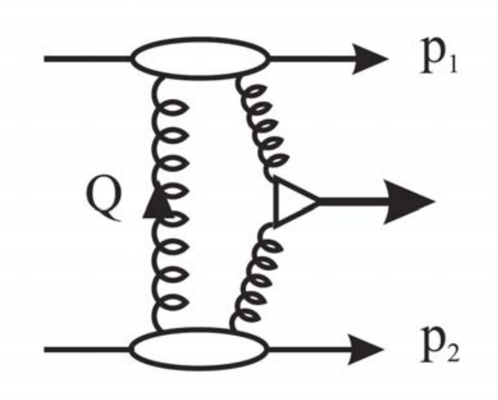
Pomeron is a fundamental QCD object

intercept - $\alpha(Q^2) = 1 + \lambda_{tot} = 1 + \delta/2$

soft and hard Pomeron join together

Computation of Diffractive Processes at LHC

Khoze – Martin - Ryskin Approach



$$\sigma = L \cdot \hat{\sigma}$$

$$M^2 \frac{\partial L}{\partial y \partial M^2} = S^2 L^{exclusive}$$ **Gluon Luminosity**

$$L^{exclusive} = \left(\frac{\pi}{(N_c^2 - 1)b} \int \frac{dQ_t^2}{Q_t^4} f_g(x_1, x_1', t, Q_t, \mu) f_g(x_2, x_2', t, Q_t, \mu) \right)^2$$

f_g unintegrated (skewed) gluon densities

obtained from low-x data of HERA

gg ->Jet+Jet

$$\frac{d\hat{\sigma}}{dt} \approx \frac{9}{4} \frac{\pi \alpha_s^2}{E_T^4}$$

gg -> Higgs

$$\hat{\sigma}_{Higgs} \propto \Gamma_{Higgs}$$

$$f_g(x, x', t, Q_t, \mu) = \beta(t) \cdot R_g \cdot \frac{\partial}{\partial \ln Q_t^2} [\sqrt{T(Q_t, \mu)} \cdot xg(x, Q_t^2)]$$

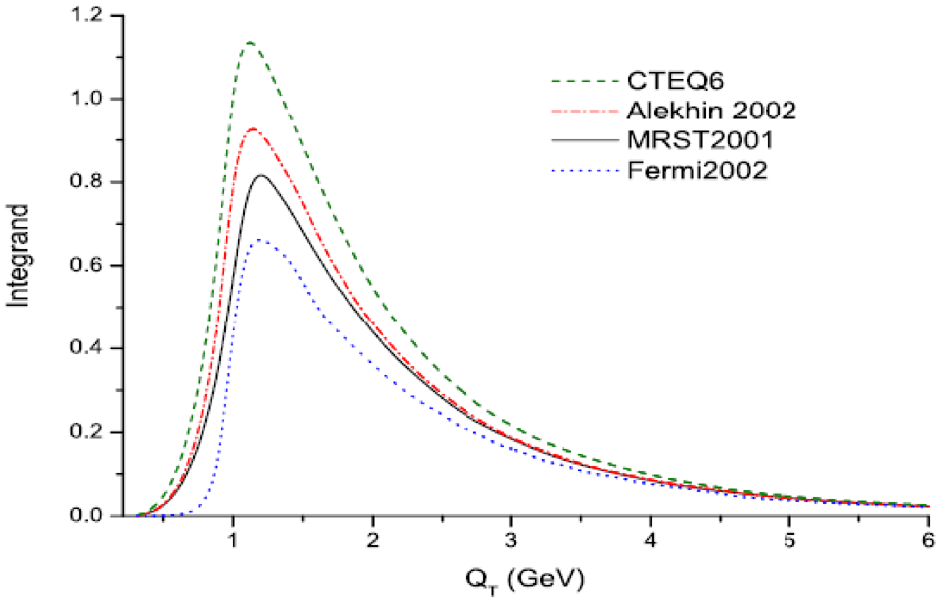
$$T(Q_t, \mu) = \exp\left(-\int_{Q_t^2}^{\mu^2} \frac{\alpha_S(k_t^2)}{2\pi} \frac{dk_t^2}{k_t^2} \int_0^{k_t/(\mu + k_t)} z P_{gg}(z) dz \right)$$

$$f_g(x_1, x_1', t, Q_t, \mu) = \beta(t) f_g(x_1, x_1', t = 0, Q_t, \mu) \qquad b(t) = \exp(Bt/2)$$

Note: *xg(x,.)* drive the rise of *F_2* at HERA and Gluon Luminosity decrease at LHC

Behaviour of the integrand:

$$\text{Im } M_0(y) \sim \int \frac{kdk}{k^4} f_g^{\text{off}}(x_1, k^2; \mu)\, f_g^{\text{off}}(x_2, k^2; \mu)$$ [J. Forshaw]



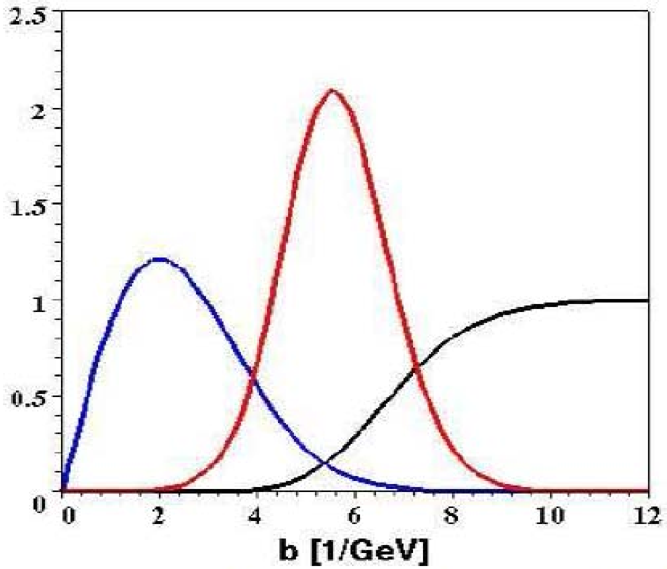
The integrand is dominated by momenta $Q_T \sim 1 - 2$ GeV

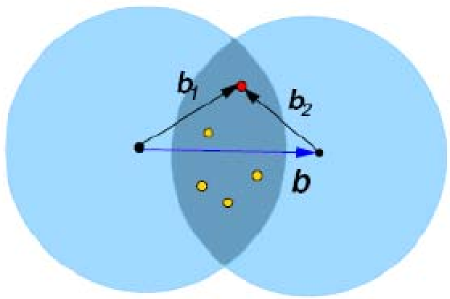
Impact parameter profile of exclusive process

Gap survival factor: $$S^2 = \frac{\int b\,db\ \exp(-\Omega(b))\ |M_{\rm hard}(b)|^2}{\int b\,db\ |M_{\rm hard}(b)|^2}$$

Exclusive Production = Hard matrix element × Amplitude of no rescattering

Production profile (red) for LHC is magnified by factor of 100

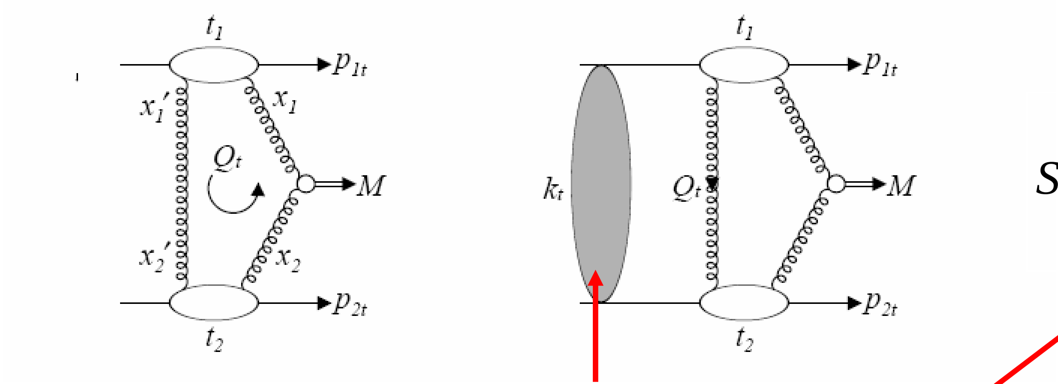




Production dominated by $b \simeq 1$ fm and $b_1 \simeq 0.5$ fm

Two-channel eikonal model of gap survival is used that incorporates low-mass diffractive intermediate states. Typically: $S^2 \simeq 0.03$ for exclusive processes at the LHC

Survival Probability S^2



Soft Elastic Opacity

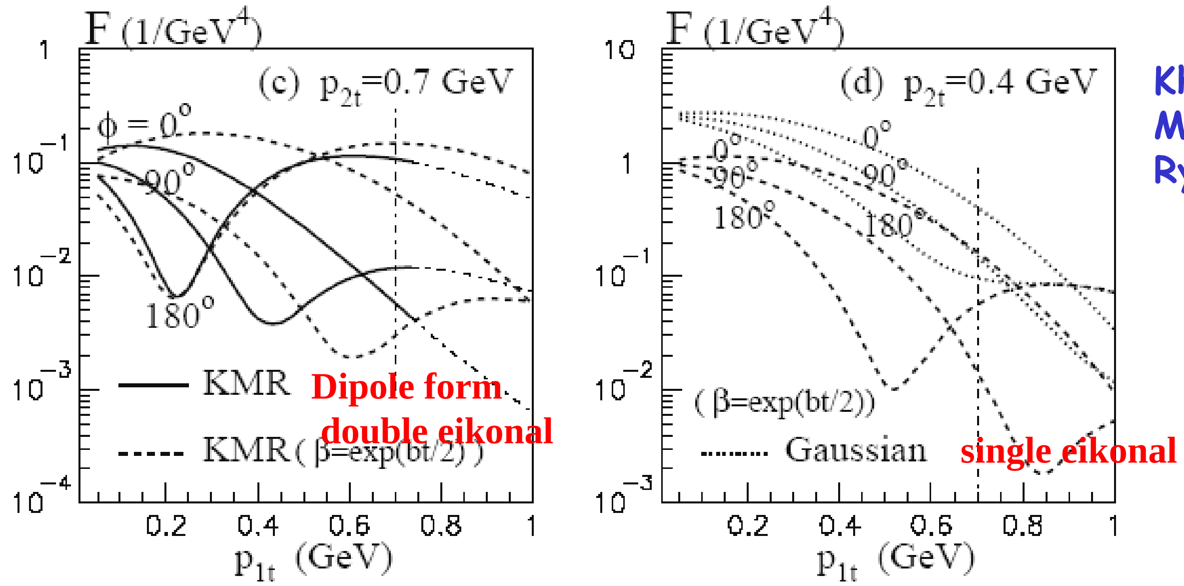
$$S^2 = \frac{\int M^2(s,b)\, e^{-\Omega(s,b)}\, d^2b}{\int M^2(s,b)\, d^2b}$$

$$F(\vec{p}_{1t}, \vec{p}_{2t}) = \frac{\beta^2(t_1)\beta^2(t_2)}{< S^2 > \pi^2 / b_0^2} S^2(\vec{p}_{1t}, \vec{p}_{2t})$$

t – distributions at LHC

Effects of soft proton absorption modulate the hard t- distributions

t-measurement will allow to disentangle the effects of soft absorption from hard behavior



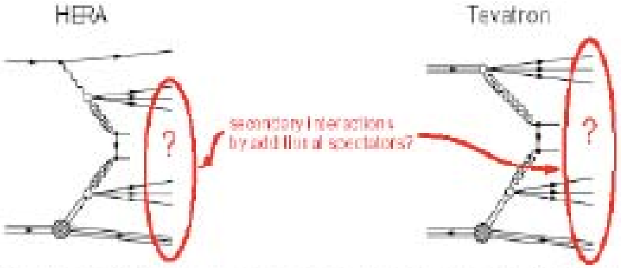
Khoze
Martin
Ryskin

HERA results

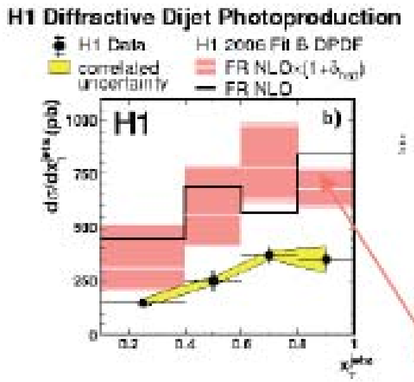
Uniform suppression ?

Summary of EDS07
Halina Abramowicz

- Suppression seems independent of final state



- Possibly dependent on the diffracted particle



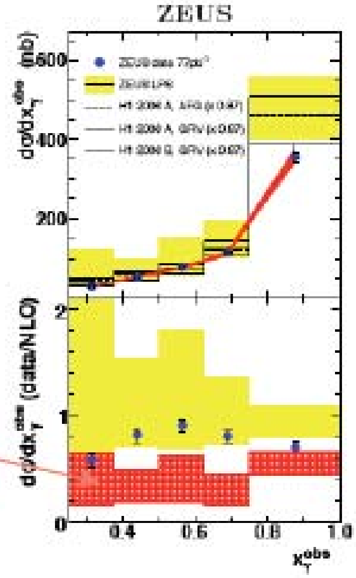
ZEUS and H1 measurements cover **different kinematic ranges**

H1: $E_T > 5$ GeV , $x_{IP} < 0.030$

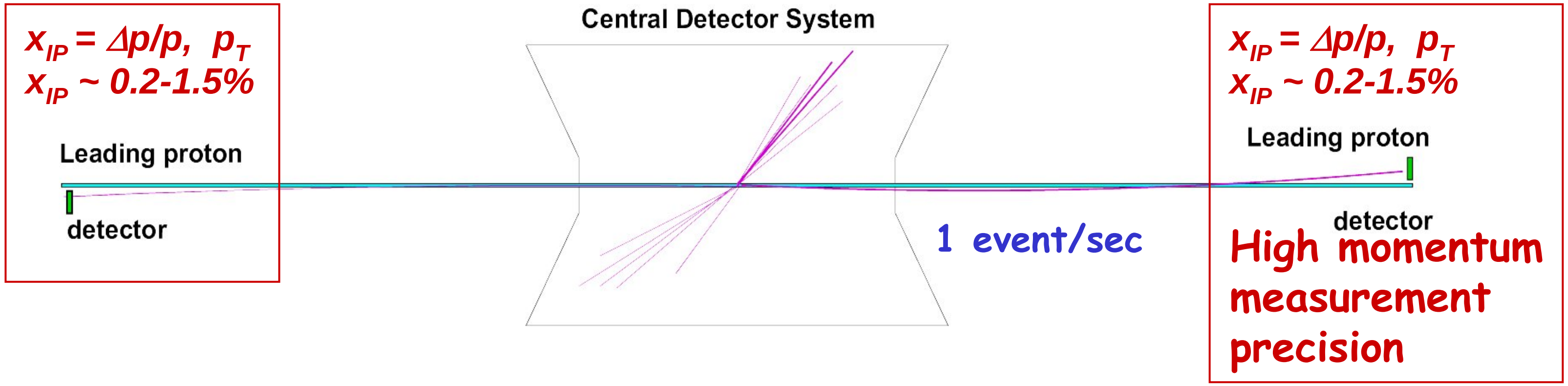
ZEUS: $E_T > 7.5$ GeV, $x_{IP} < 0.025$

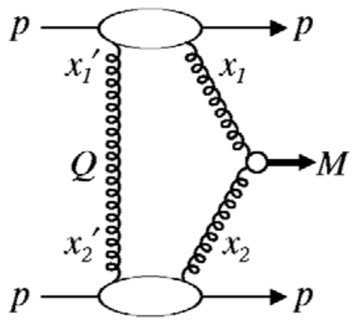
x2 too high

res. γ x 0.34



Exclusive Double Diffractive Reactions at LHC





low x QCD reactions (KMR)

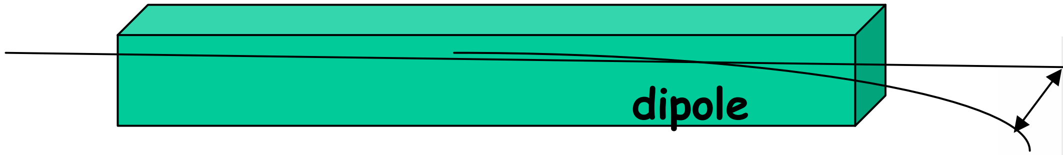
pp => pp + $g_{Jet}\, g_{Jet}$ $\sigma \sim$ 1 nb for M(jj) ~ 50 GeV

$\sigma \sim 0.5$ pb for M(jj) ~ 200 GeV

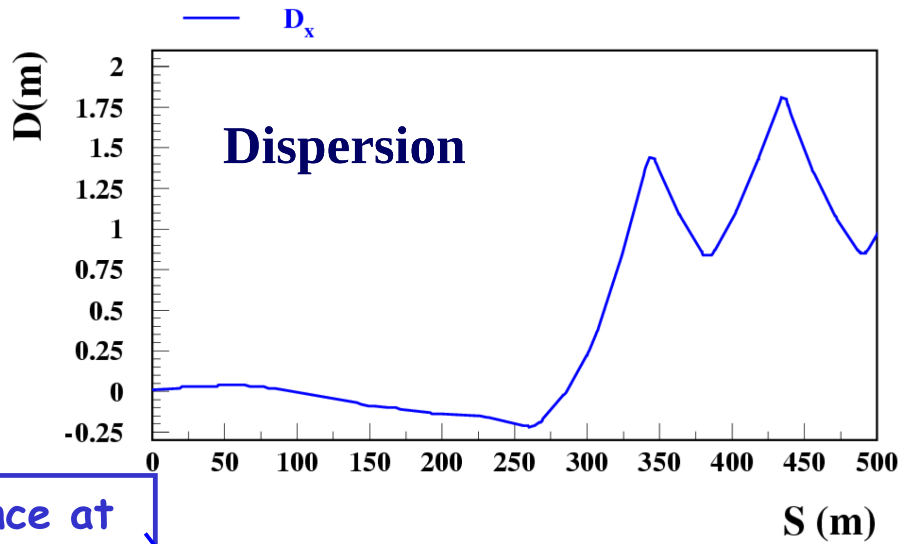
$\eta_{JET}| < 1$

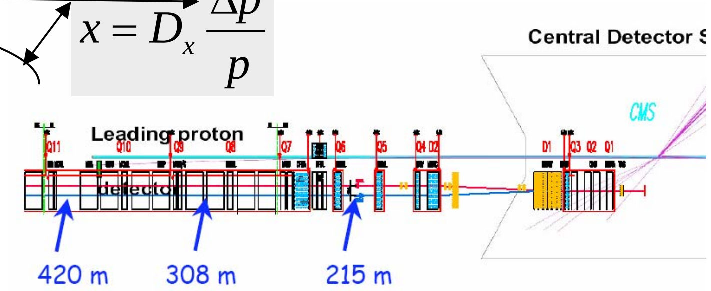
pp => pp + Higgs $\sigma \sim$ O(3) fb SM (inclusive ~ 20 pb)

~ O(100) fb *MSSM*



$$x = D_x \frac{\Delta p}{p}$$



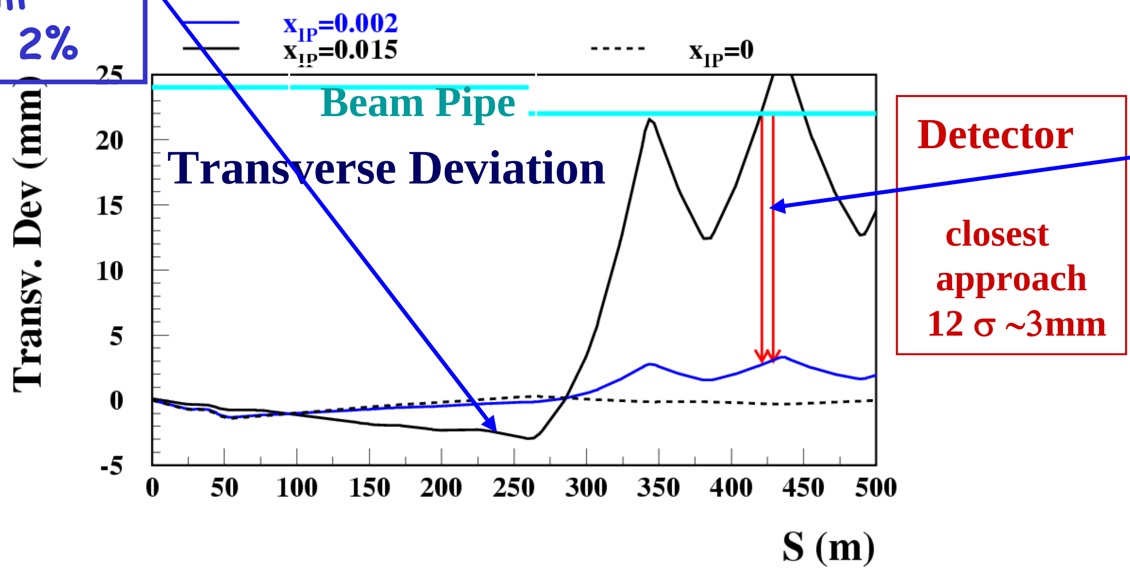


At 420 m

$$\frac{\Delta p}{p} = 0.01 \quad \Rightarrow \quad x = 1.5\,\text{cm}$$

$$\frac{\Delta p}{p} = 0.001 \quad \Rightarrow \quad x = 1.5\,\text{mm}$$

acceptance at 220/240m
x_{IP} ~ 1 - 2%

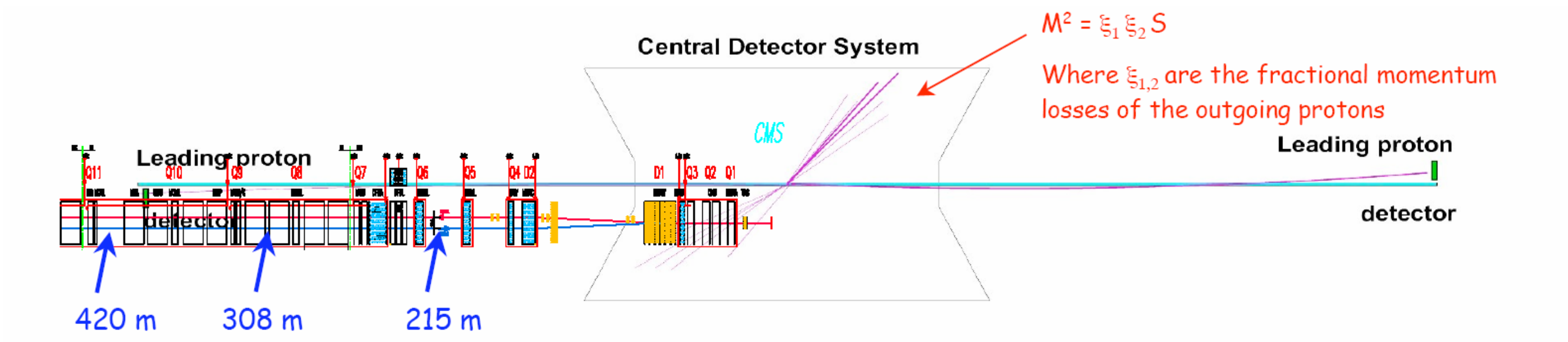


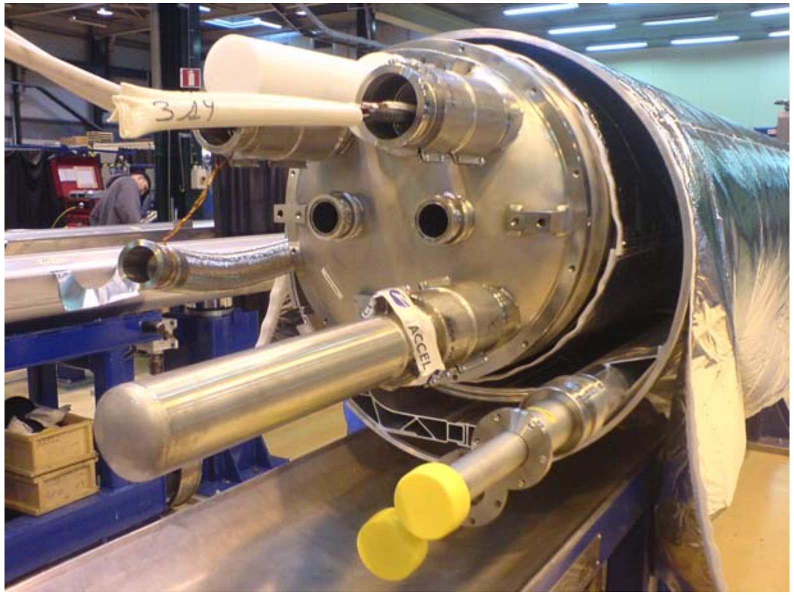
acceptance at 420m
x_{IP} ~ 0.2 - 1.5 %
t from 0 to ~10 GeV^2

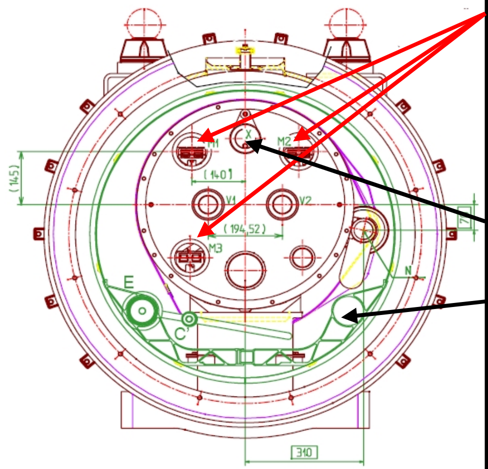
deflection of protons due to main magnets

→ stability against beam tuning effects

The 420m region at the LHC

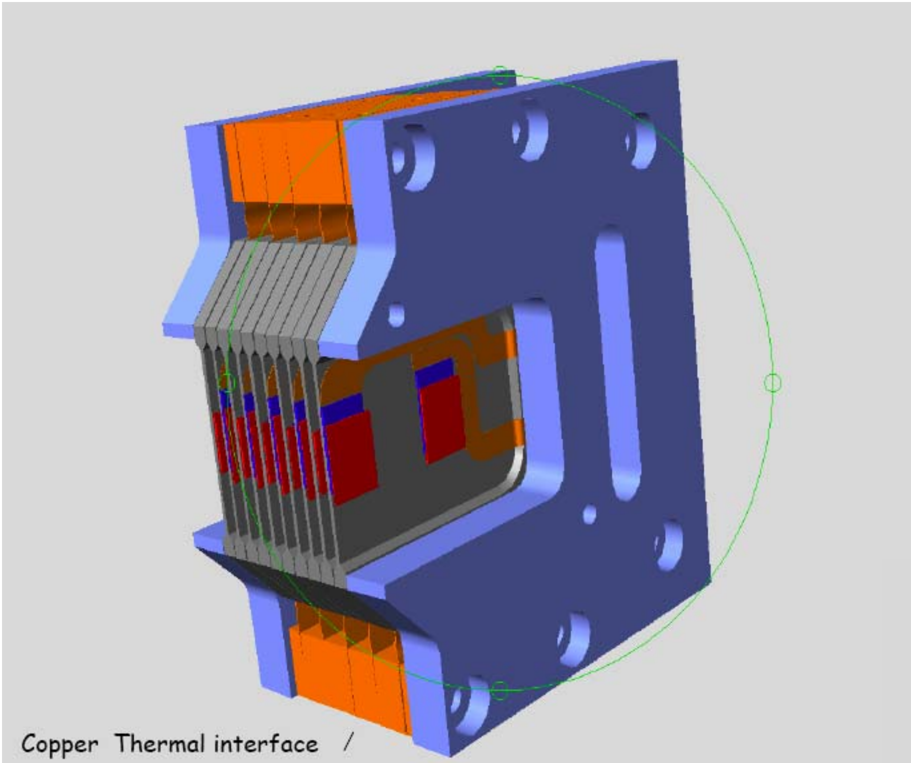






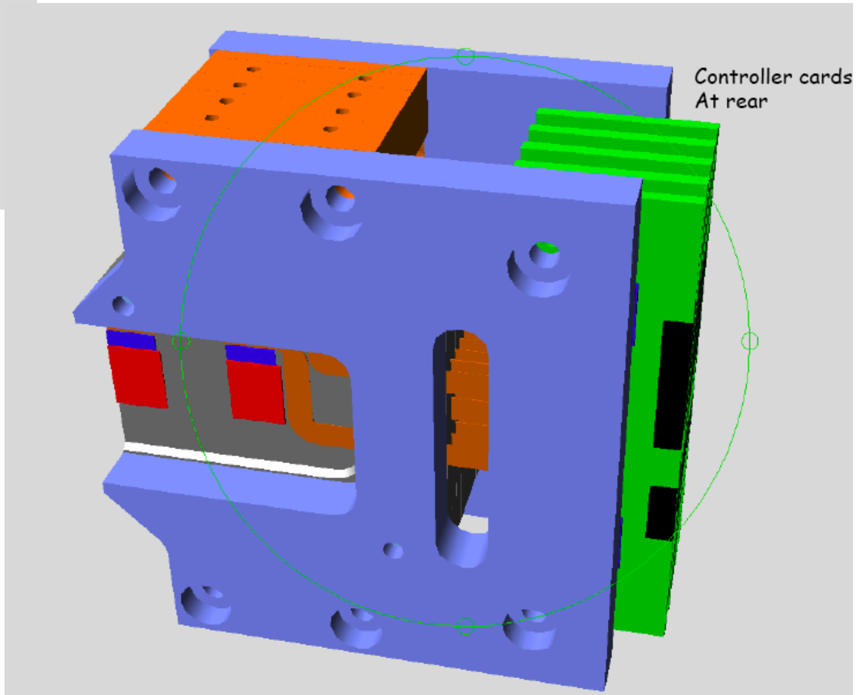
Line	T(K)	$Ø_i$ - $Ø_e$(mm)
M1,M2,M3 Bus-bars	1.9	80-84
N Auxiliary bus-bars	1.9	50-53
X Heat exchanger	1.8	54-58
E Thermal shield	50-65	79-86
C' Supports posts and beam screens	4.6	15-17.2
V1,V2 He jackets	1.9	50-53 66-70

FP420 Silicon Detector Stations



Brunell

Manchester / Mullard Space Sci. Lab



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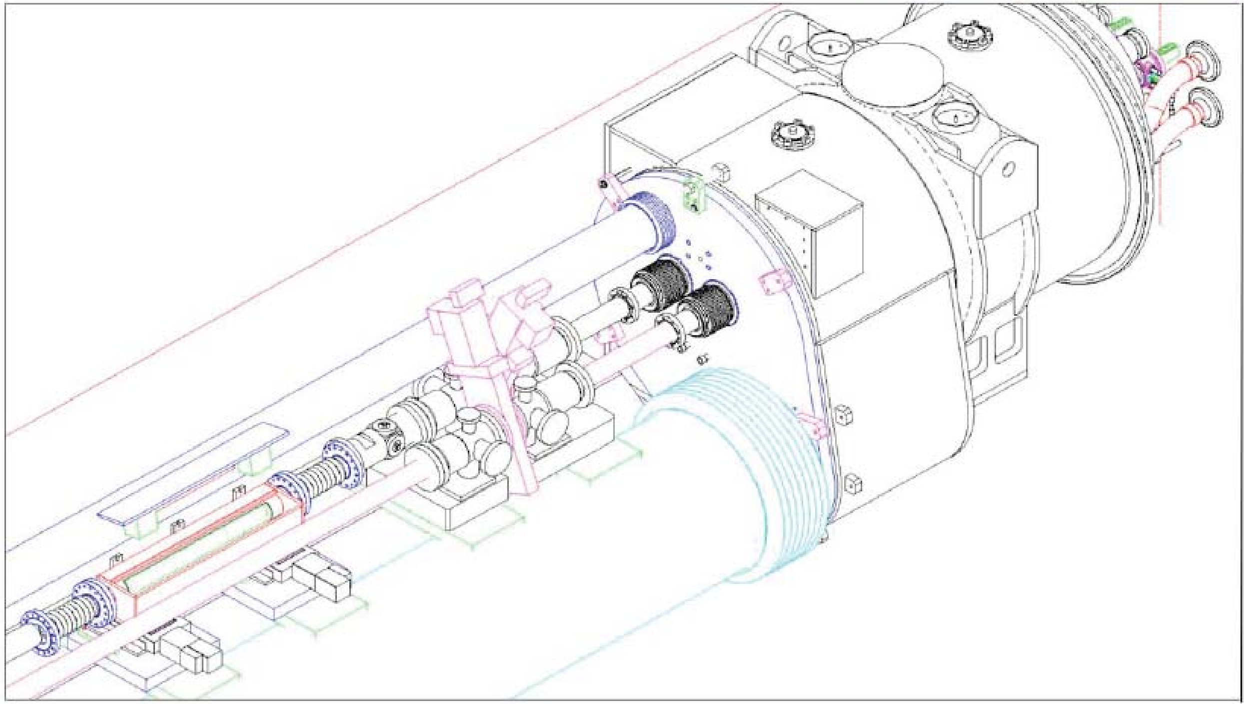
1824

The University
of Manchester

FP420 ATMs



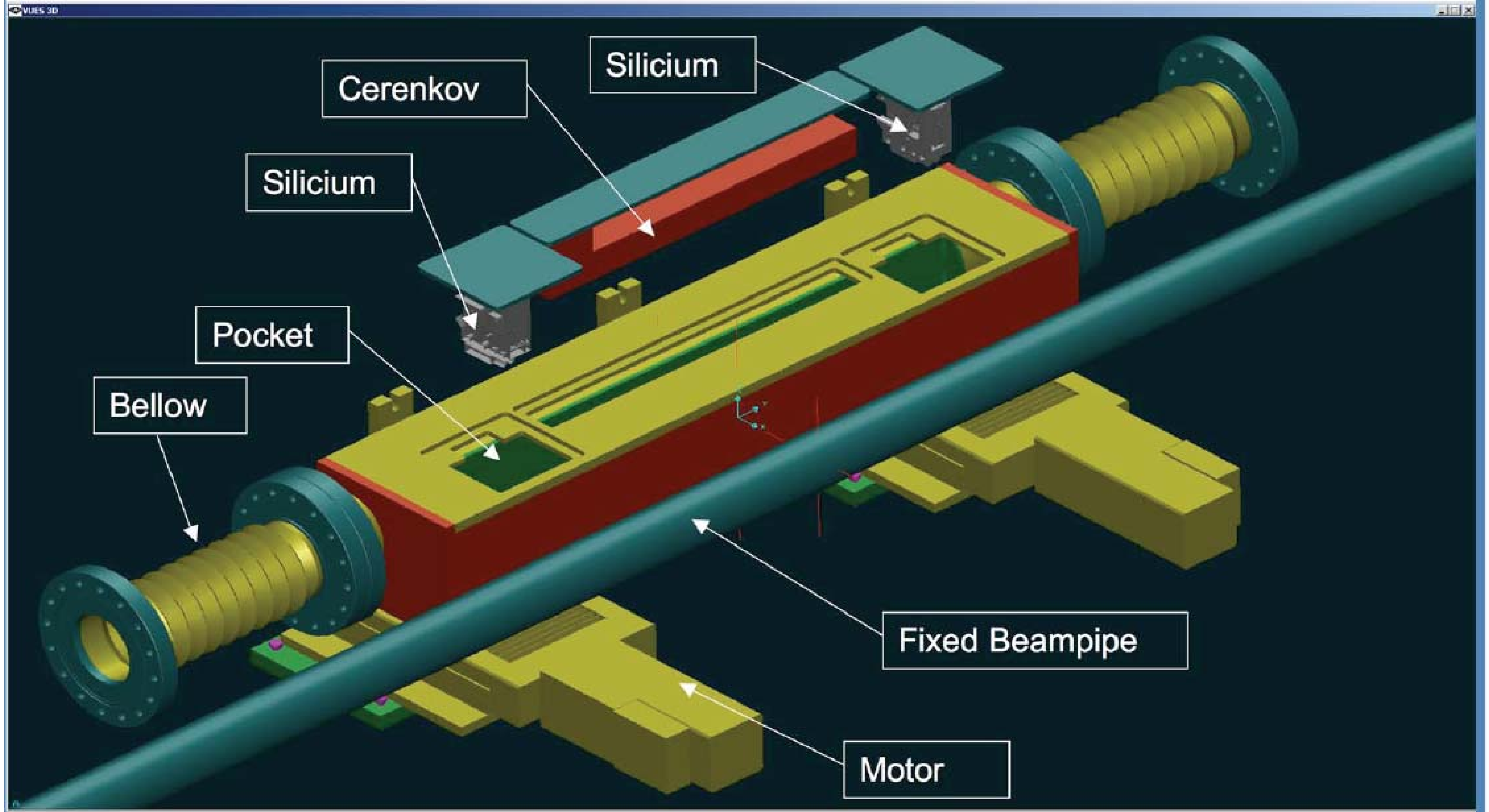
T. Colombet,

T. Renaglia,

R. Folch

TECHNICAL SUPPORT DEPARTMENT
TS

Integration of the moving beampipe and detectors



Measuring Higgs couplings at LHC

LHC rates for partonic process $pp \to H \to xx$ given by $\sigma(pp \to H) \cdot BR(H \to xx)$

$$\sigma(H) \times \mathrm{BR}(H \to xx) = \frac{\sigma(H)^{\mathrm{SM}}}{\Gamma_p^{\mathrm{SM}}} \cdot \frac{\Gamma_p \Gamma_x}{\Gamma} ,$$

Measure products $\Gamma_p \Gamma_x / \Gamma$ for combination of processes ($\Gamma_p = \Gamma(H \to pp)$)

Problem: rescaling fit results by common factor f

$$\Gamma_i \to f \cdot \Gamma_i , \qquad \Gamma \to f^2 \Gamma = \sum_{obs} f \Gamma_i + \Gamma_{rest}$$

leaves observable rate invariant $\Longrightarrow$ no model independent results at LHC

Loose bounds on scaling factor:

$$f^2 \Gamma > \sum_{obs.} f \Gamma_x \qquad \Longrightarrow \qquad f > \sum_{obs.} \frac{\Gamma_x}{\Gamma} = \sum_{obs.} BR(H \to xx) (= \mathcal{O}(1))$$

Total width below experimental resolution of Higgs mass peak ($\Delta m = 1 \ldots 20$ GeV)

$$f^2 \Gamma < \Delta m \qquad \Longrightarrow \qquad f < \sqrt{\frac{\Delta m}{\Gamma}} < \mathcal{O}(10 - 40)$$

Absolute branching ratio measurement from $pp \to ppH$?

- Observe inclusive Higgs mass peak in recoil invariant mass spectrum
- For these events measure fraction with two b jets in central detector or other high branching ratio Higgs signal

Alternative if trigger on central event is required:

- Observe Higgs mass peak in recoil invariant mass spectrum for e.g. bb and WW signatures in central detector
- Ratio of rates gives ratio of partial widths, e.g. Γ_b/Γ_W

Obtain information on $\Gamma_b = \Gamma(H \to bb)$

$\Longrightarrow$ improved bound on

$$f > \sum_{obs.} \frac{\Gamma_x}{\Gamma} = \sum_{obs.} BR(H \to xx)$$

Note: need ≥ 100 events for competitive statistical errors

Tri-mixing CPX SUSY scenario

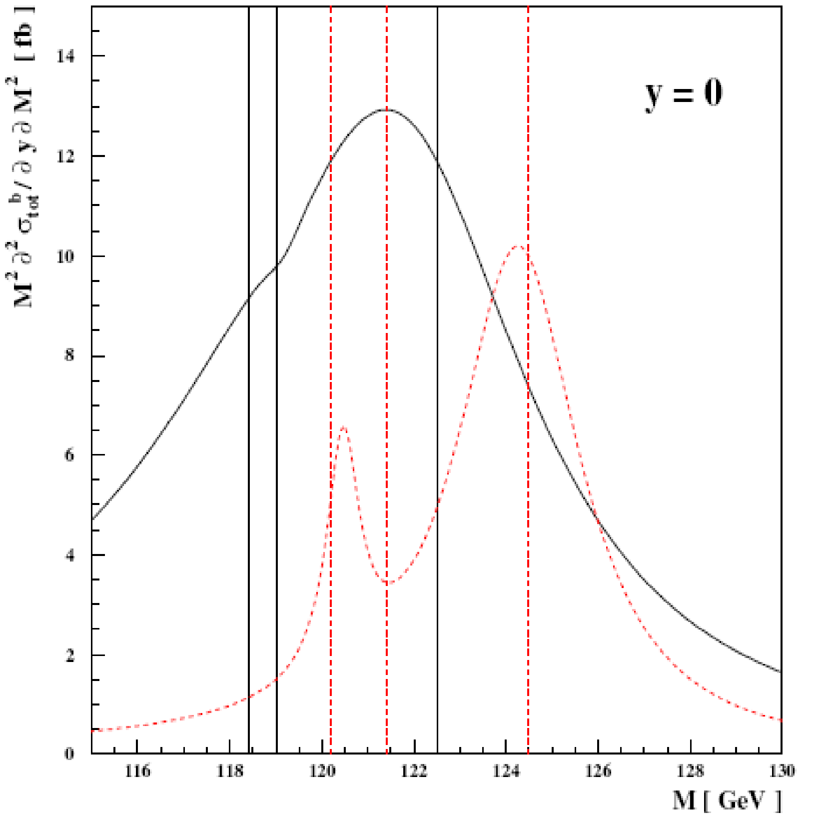
[Ellis, Lee, Pilaftsis]

Tri-mixing scenario: with $\tan\beta \simeq 50$, $M_{\rm SUSY} = 0.5$ TeV, $M_{H^\pm} \simeq 155$ GeV

H_i are nearly degenerate, $M_{H_i} \simeq 120$ GeV

CPX phase -90^o (-10^o)

$$M^2 \frac{d\sigma}{dy\, dM^2}(pp \to pp + H \to pp + b\bar{b})$$



Explicit CP violation measurement should be possible in $\tau\bar{\tau}$ decay channels