Hard diffraction in ATLAS: Roman pots at 220 m

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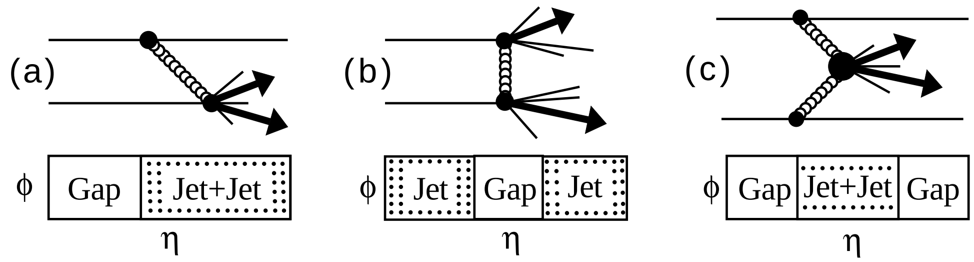
Contents:

- Diffractive Higgs production at the LHC: exclusive and inclusive production
- Existence of exclusive events: CDF rsesults
- Exclusive event production at the LHC
- Roman pot project at 220 in ATLAS at the LHC

Work done in collaboration with M. Boonekamp. J. Cammin, O. Kepka, A. Kupco, R. Peschanski, L. Schoeffel

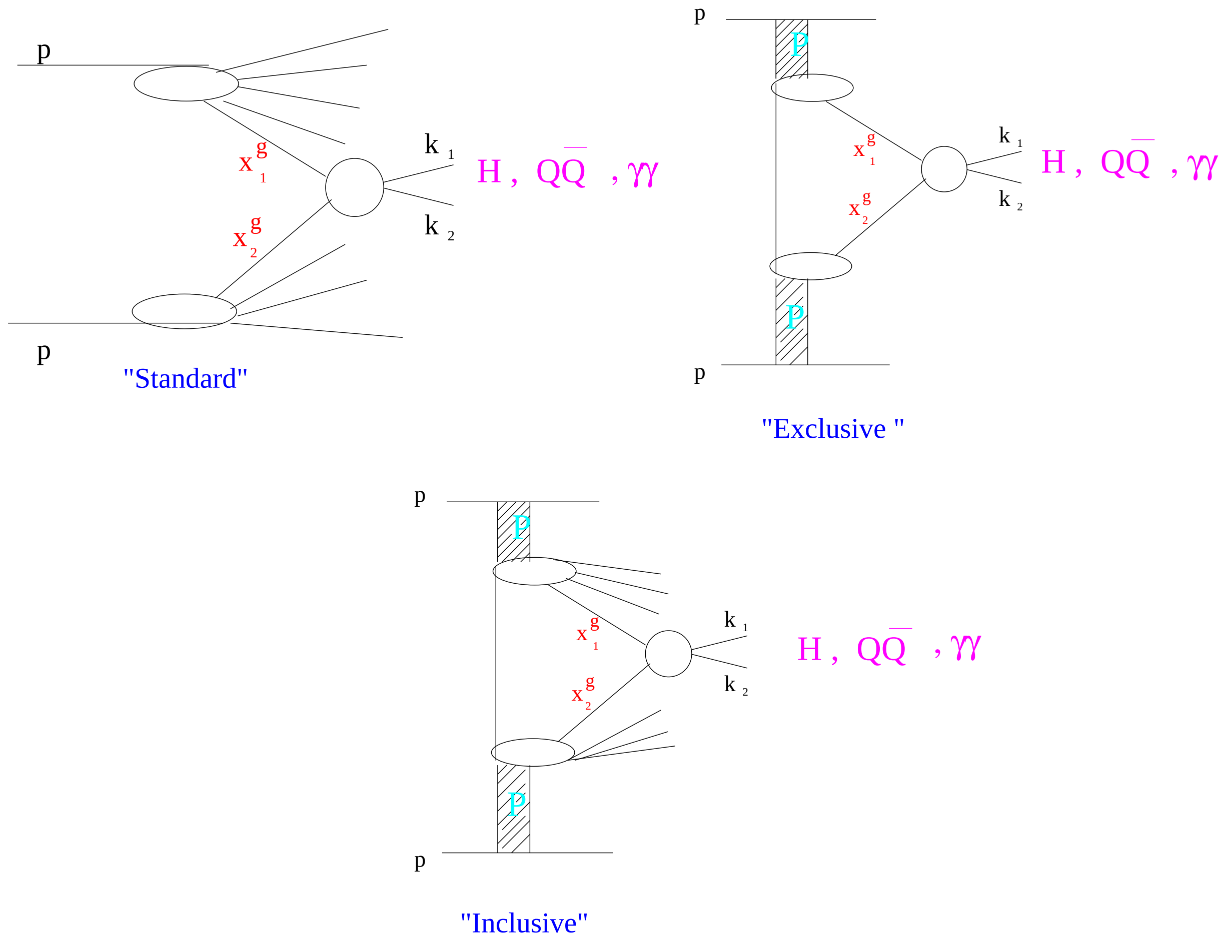
Diffraction at Tevatron/LHC



Kinematic variables

- t: 4-momentum transfer squared
- ξ_1, ξ_2: proton fractional momentum loss (momentum fraction of the proton carried by the pomeron)
- $\beta_{1,2} = x_{Bj,1,2}/\xi_{1,2}$: Bjorken-x of parton inside the pomeron
- $M^2 = s\xi_1\xi_2$: diffractive mass produced
- $\Delta y_{1,2} \sim \Delta\eta \sim \log 1/\xi_{1,2}$: rapidity gap

Diffractive "Exclusive" production



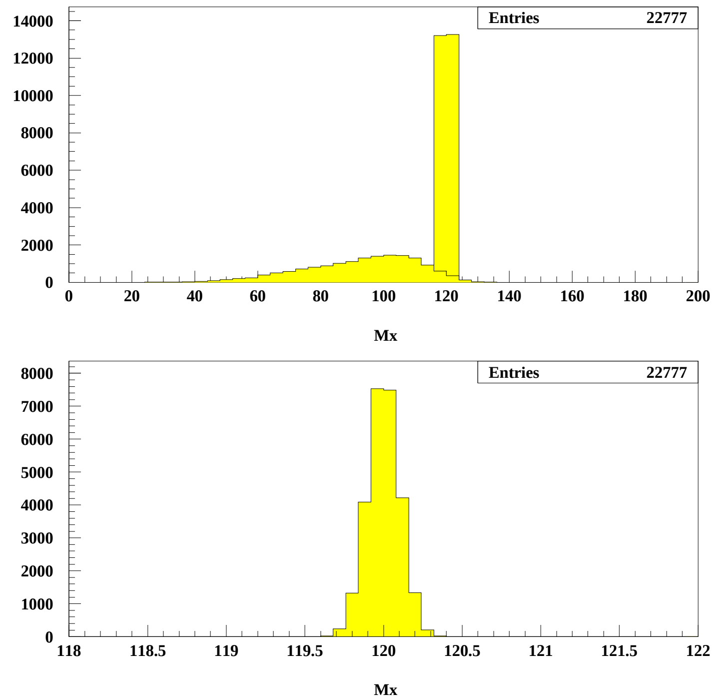
All the energy is used to produce the Higgs (or the dijets), namely $xG \sim \delta$ (See in particular "Saclay model (R. Peschanski, M. Boonekamp, J. Cammin, A. Kupco, O. Kepka, C. R.) (coupling via a pomeron), and Durham model (A. Martin, V. Khoze, M. Ryskin) (direct coupling to the proton)

DPEMC Monte Carlo

- DPEMC (Double Pomeron Exchange Monte Carlo): New generator to produce events with double pomeron exchange (contains POMWIG, Bialas Landshoff model for inclusive diffraction and both "Durham" and "Saclay" models for exclusive diffraction) http://boonekam.home.cern.ch/boonekam/dpemc.htm, paper to be submitted to Comp. Phys. Com.
- Interface with Herwig: for hadronisation
- Exclusive and inclusive processes included: Higgs, dijets, diphotons, dileptons, SUSY, QED, Z, W...
- DPEMC generator interfaced with a fast simulation of LHC detector (as an example CMS, same for ATLAS), and a detailled simulation of roman pot acceptance
- Gap survival probability of 0.03 put for the LHC
- Another available MC: "Exhume" for Durham model, POMWIG for inclusive diffractin
- See the talk by Oldřich Kepka on Wednesday morning in the MC session for more information about the MC

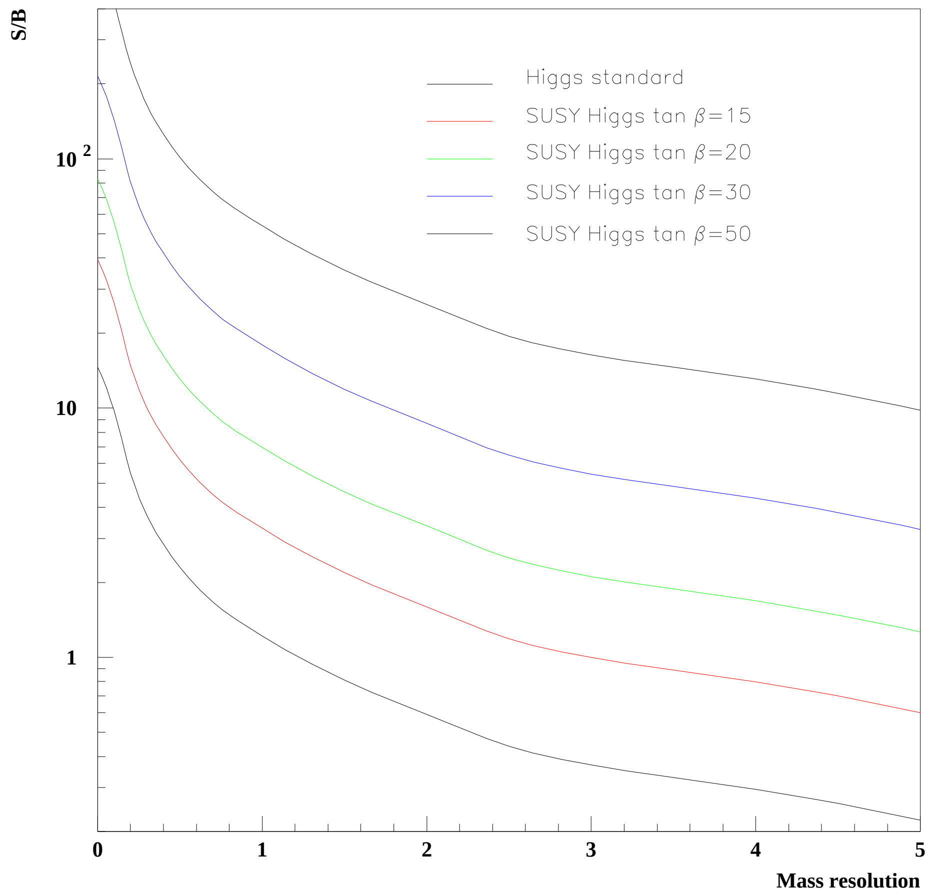
Advantage of exclusive Higgs production?

- Good Higgs mass reconstruction: fully constrained system, Higgs mass reconstructed using both tagged protons in the final state ($pp \to pHp$)
- $M_H = \sqrt{\xi_p \xi_{\bar{p}} S}$
- No energy loss in pomeron "remnants"



An example: Diffractive SUSY Higgs production

At high $\tan\beta$, possibility to get a S/B over 50 (resp. 5.) for 100 (resp.10) fb^{-1}! (Phys.Rev.D73 (2006) 115011)

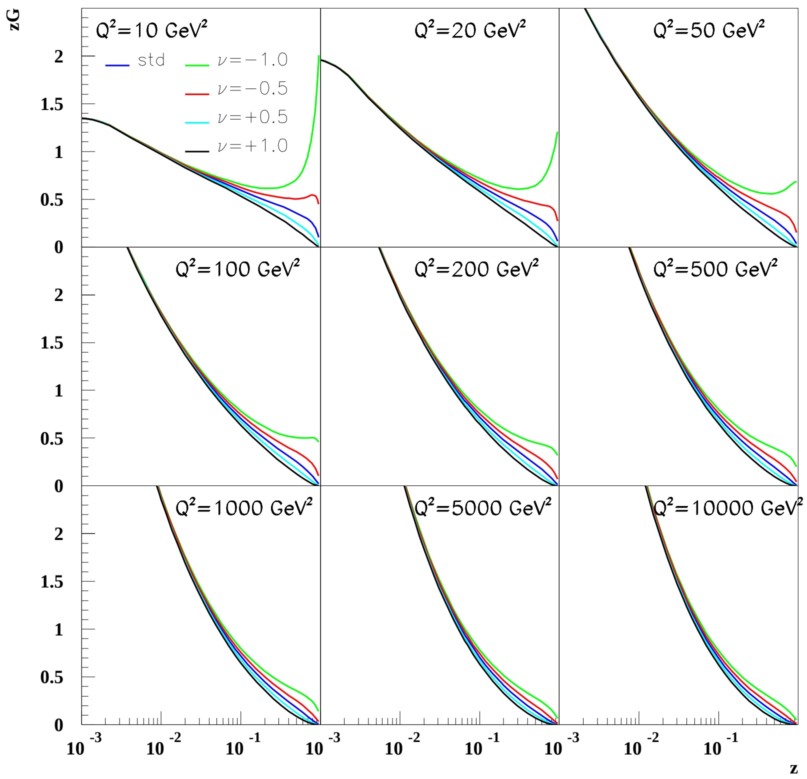


Some issues

- Gluon density in the pomeron: the HERA measurement is used to predict the cross sections at the LHC, how well is it constrained especially at high β?
- Gap survival probability? Can we test the models at the Tevatron/LHC?
- Exclusive events: Have they been observed already at the Tevatron and are the models describing the measurements?
- How to perform the measurements at the LHC? FP420, RP220

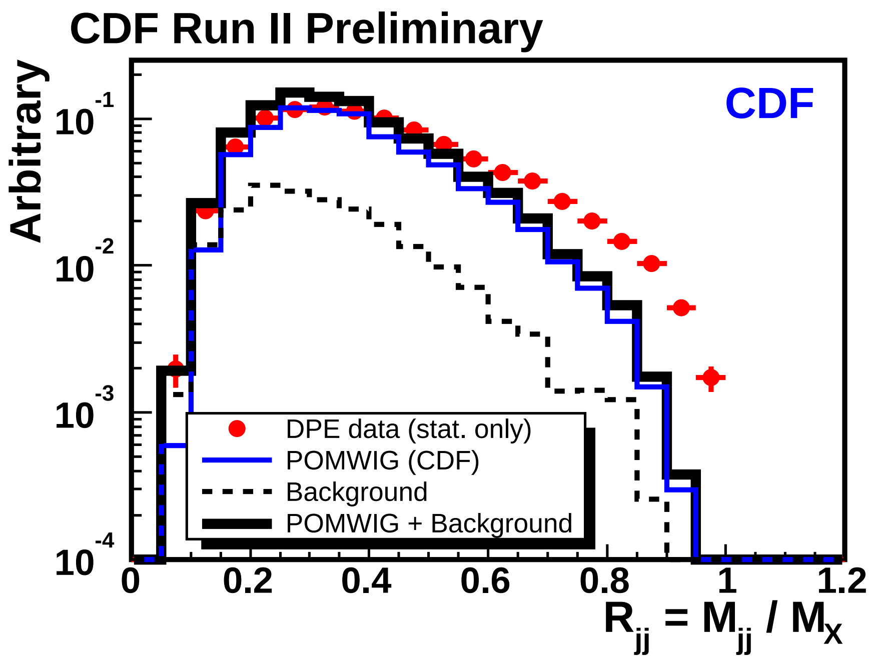
Uncertainty on high β gluon

- Important to know the high β gluon since it is a contamination to exclusive events
- Experimentally, quasi-exclusive events indistinguishable from purely exclusive ones
- Uncertainty on gluon density at high β: multiply the gluon density by $(1-\beta)^{\nu}$ (fit: $\nu = 0.0 \pm 0.6$)



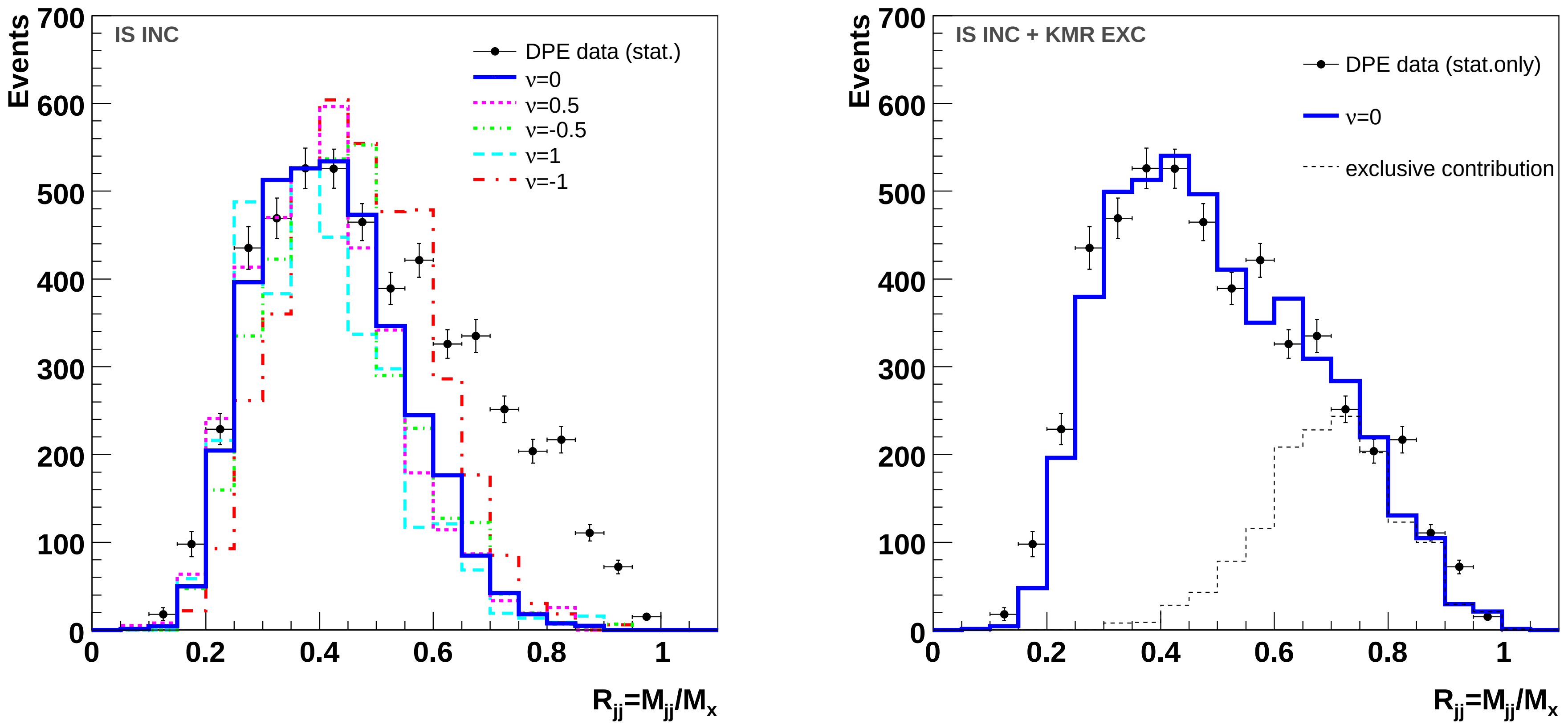
Look for exclusive events at the Tevatron

- Look for exclusive events (events where there is no pomeron remnants or when the full energy available is used to produce diffractively the high mass object)
- Select events with two jets only, one proton tagged in roman pot detector and a rapidity gap on the other side
- Comparison with POMWIG Monte Carlo using H1 gluon density in pomeron and DPEMC for exclusive signal



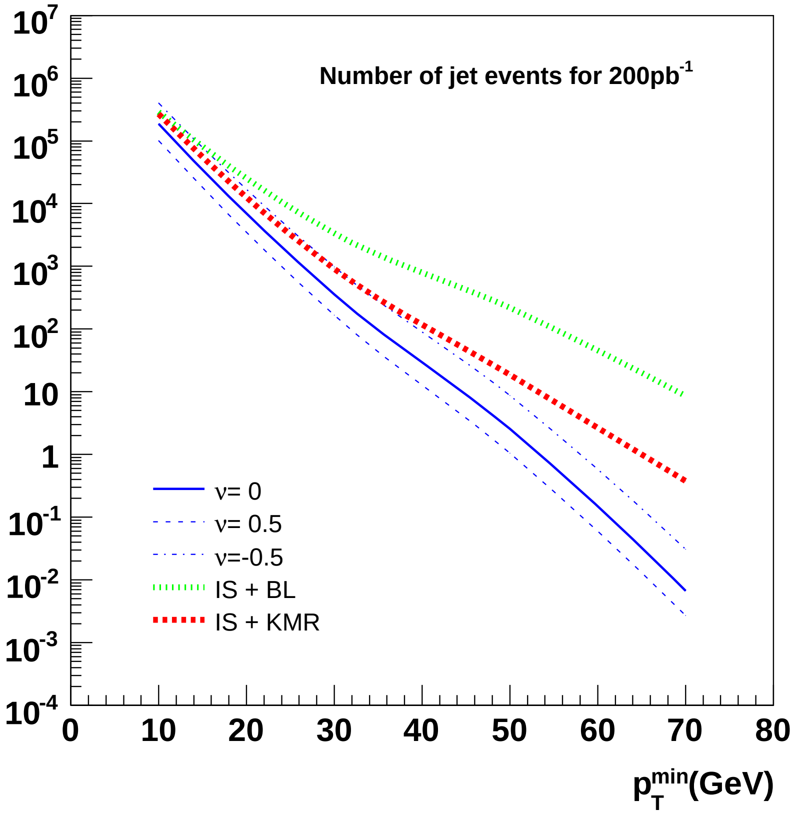
Exclusive production at the Tevatron?

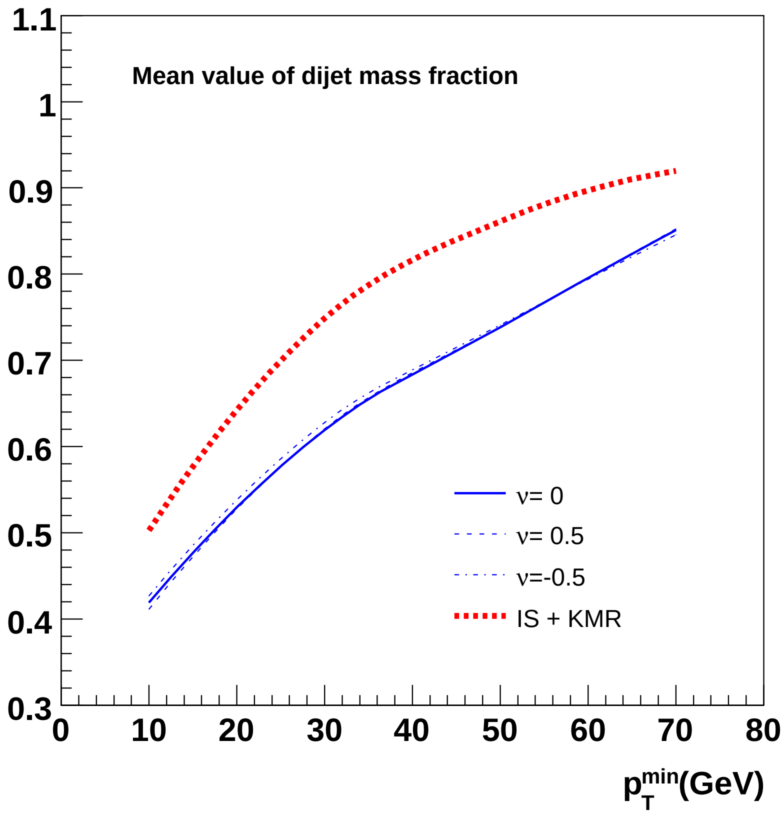
Look at the dijet mass fraction: exclusive events are supposed to appear around 1



Dijet mass fraction at the Tevatron?

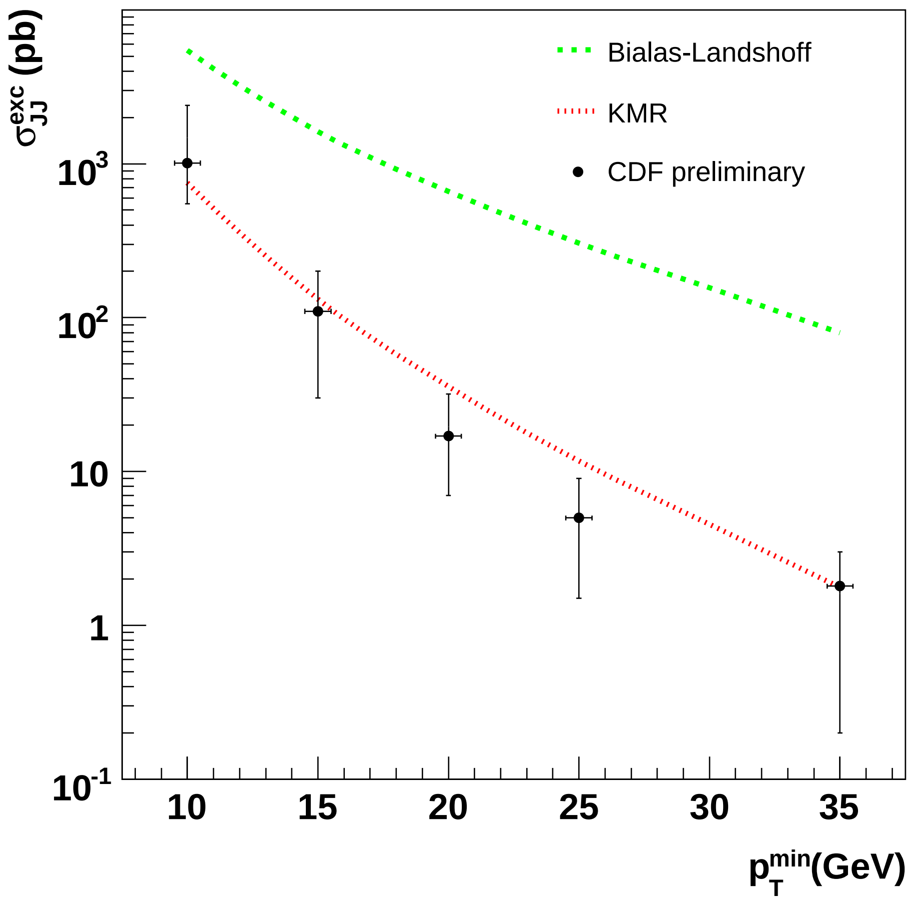
Exclusive contribution more visible at jet p_T of 30-40 GeV





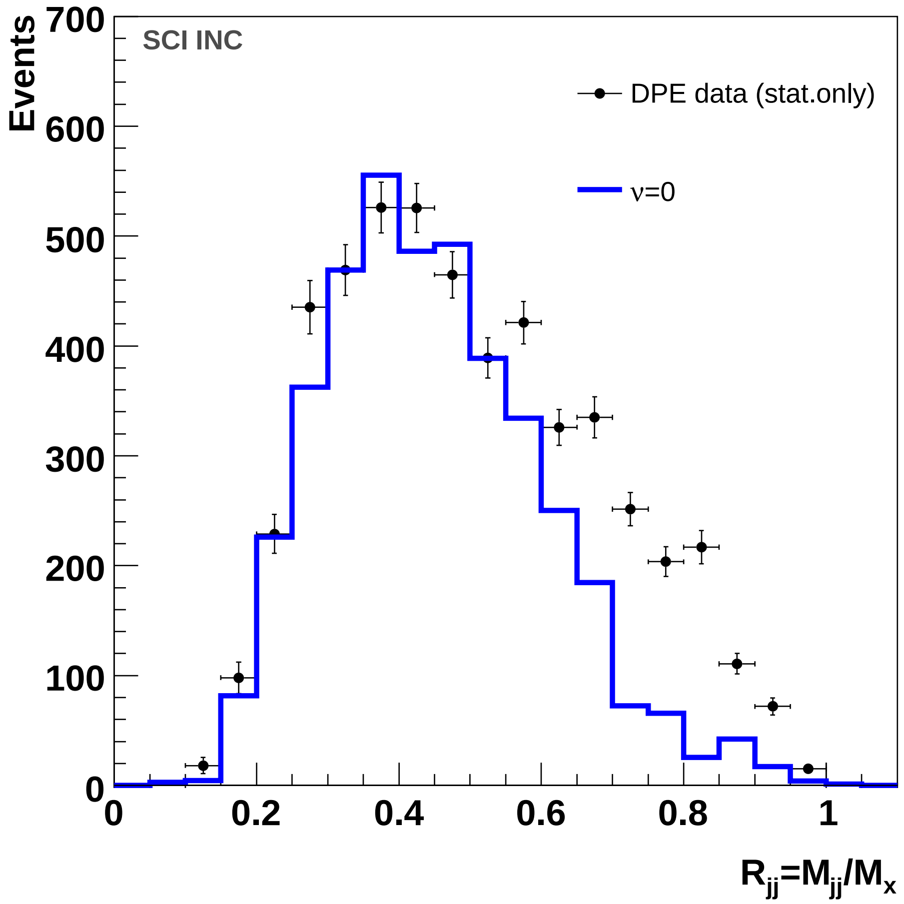
Exclusive contribution?

Exclusive contribution obtained by subtracting the inclusive one: the Bialas Landshoff model leads to a too small p_T dependence if the inclusive part is well described by Ingelman Schlein inpired models



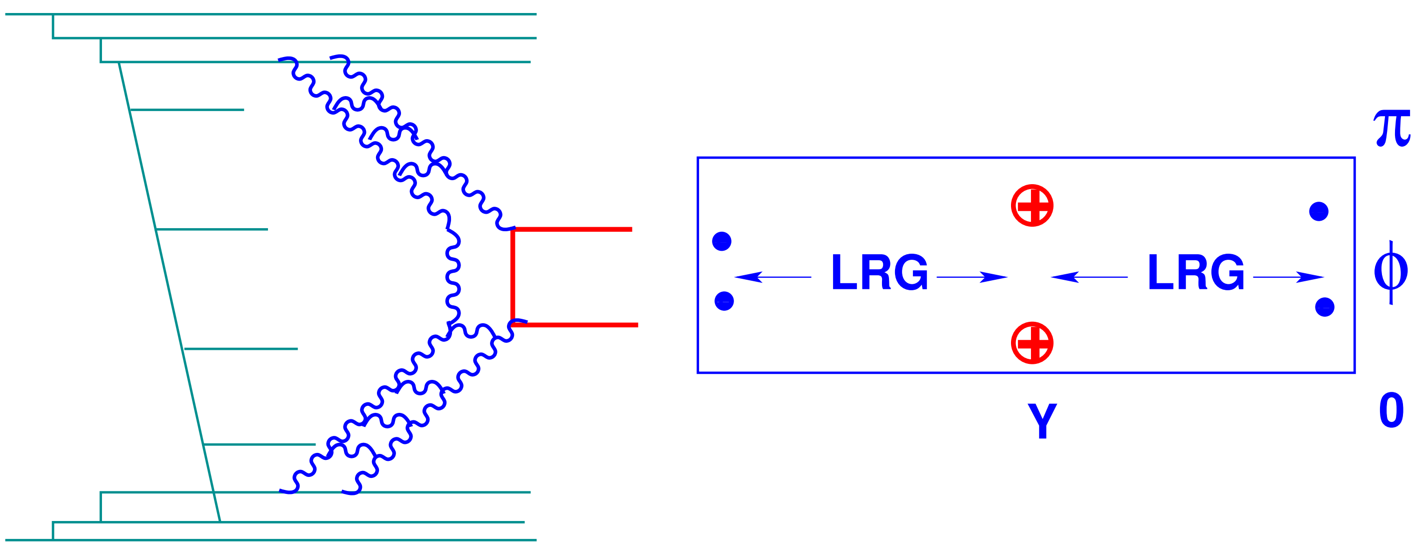
What about SCI?

SCI cannot describe the full tail at high dijet mass fraction, but rate of exclusive events smaller



Concept of survival probability

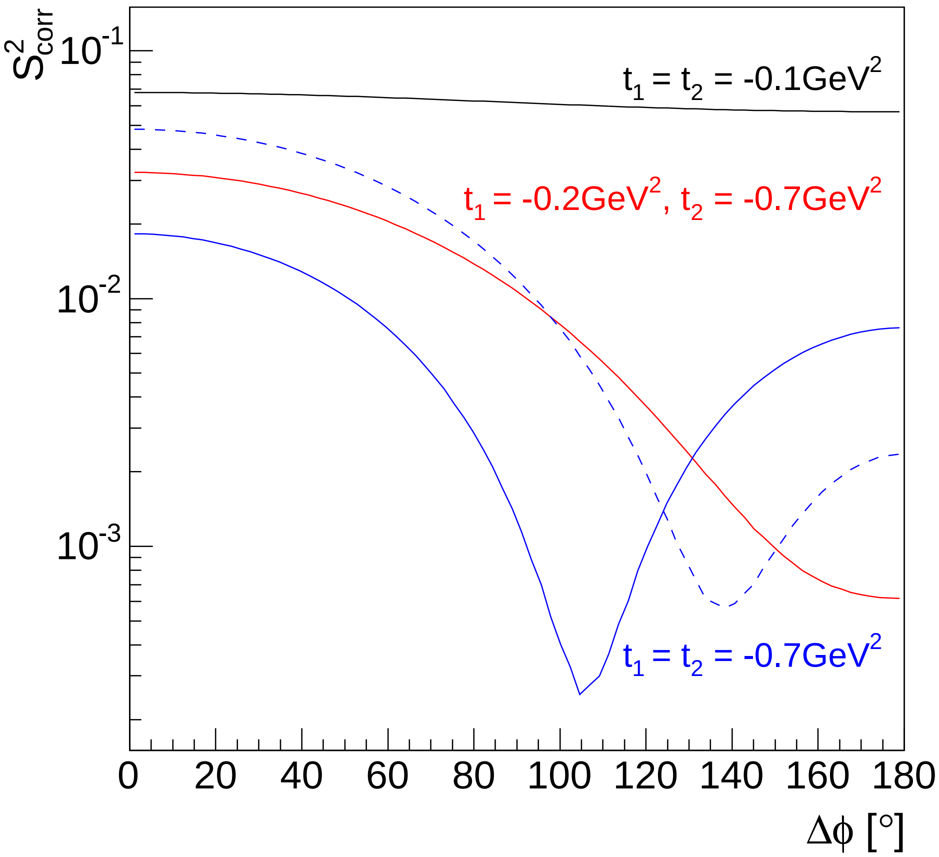
- Survival probability: Probability that there is no soft additional interaction, that the diffractive event is kept
- Important to measure the survival probability in data: estimated to be of the order of 0.1 at the Tevatron



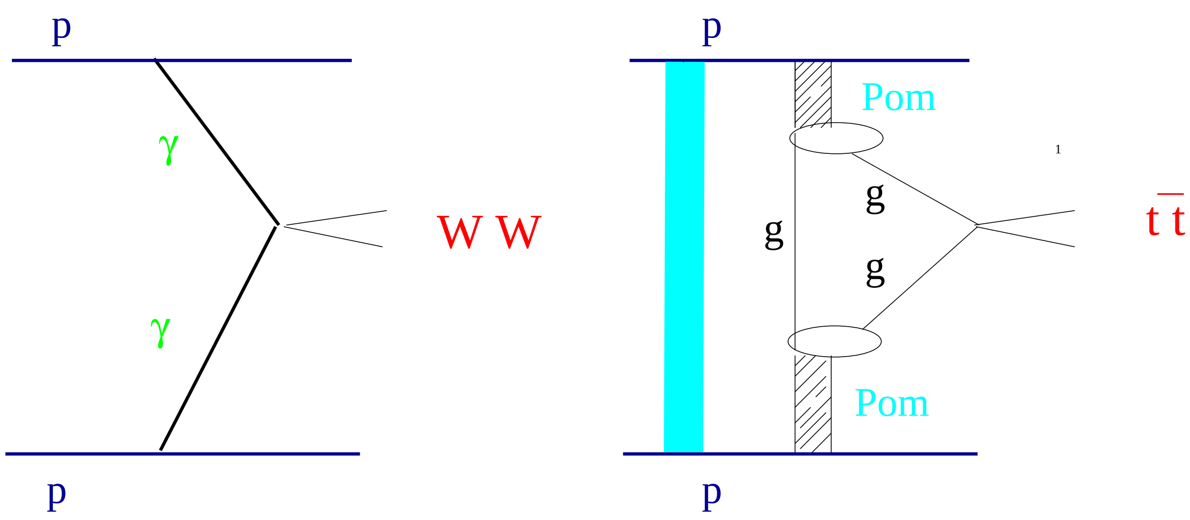
a) b)

$\Delta\Phi$ dependence of survival probabilities

Survival probability strongly $\Delta\Phi$-dependent where $\Delta\Phi$ is the difference in azimuthal angles between p and $\bar{p}$



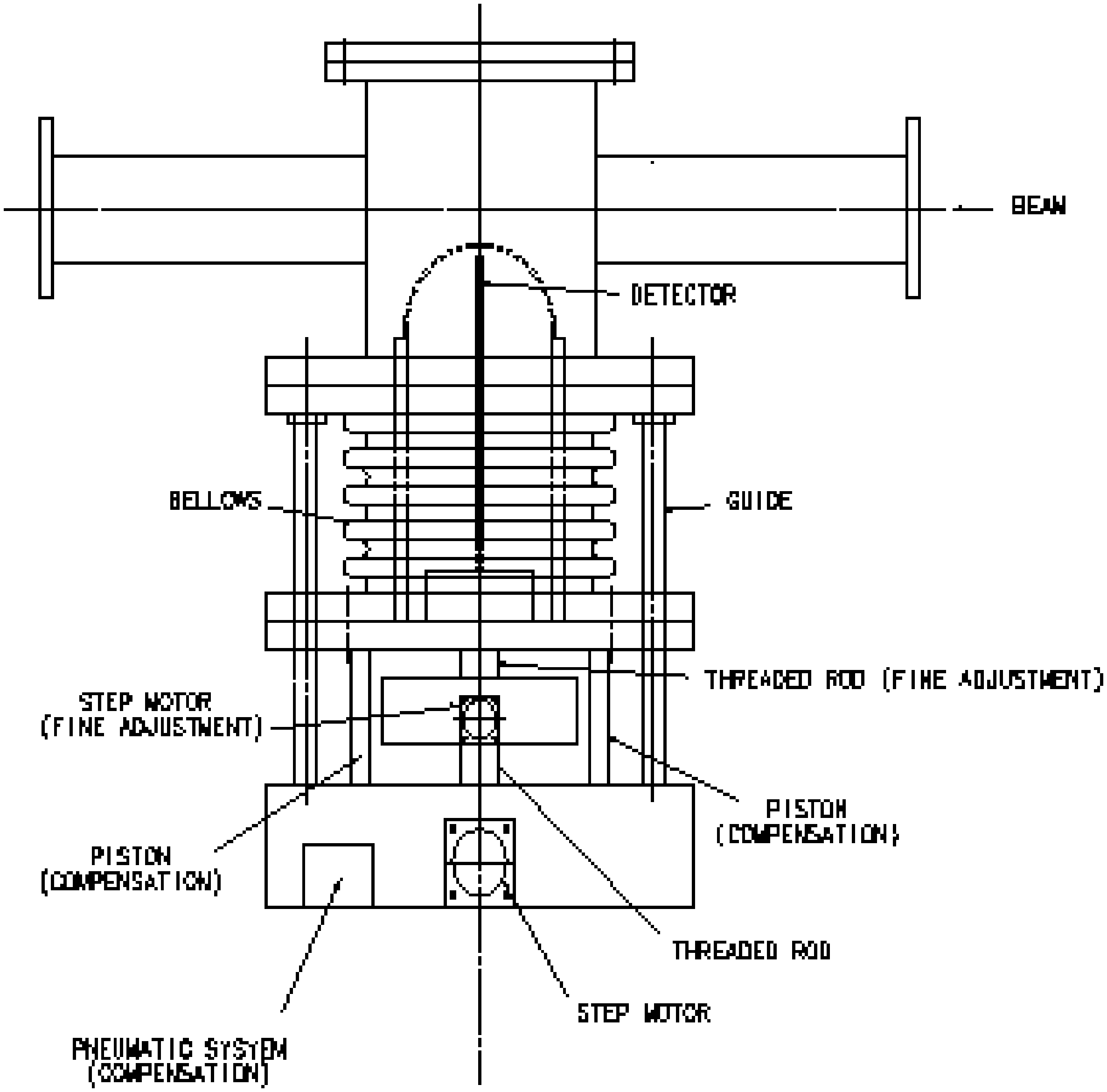
W, top and stops



All the energy is used to produce the W, top (stop) pairs: W: QED process, cross section perfectly known, top: QCD diffractive process

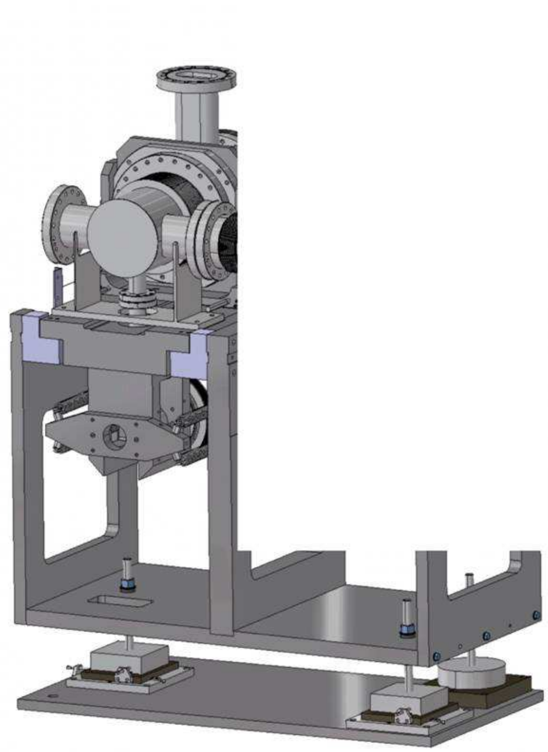
Scheme of a roman pot detector

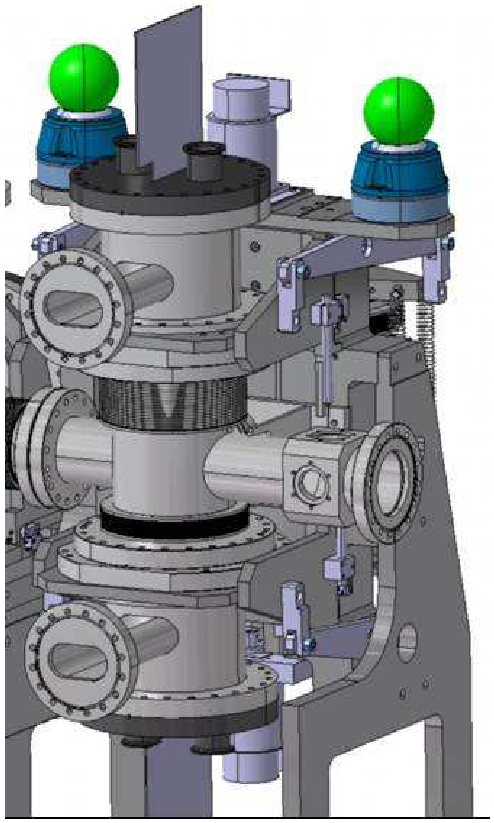
Scheme of roman pot detector



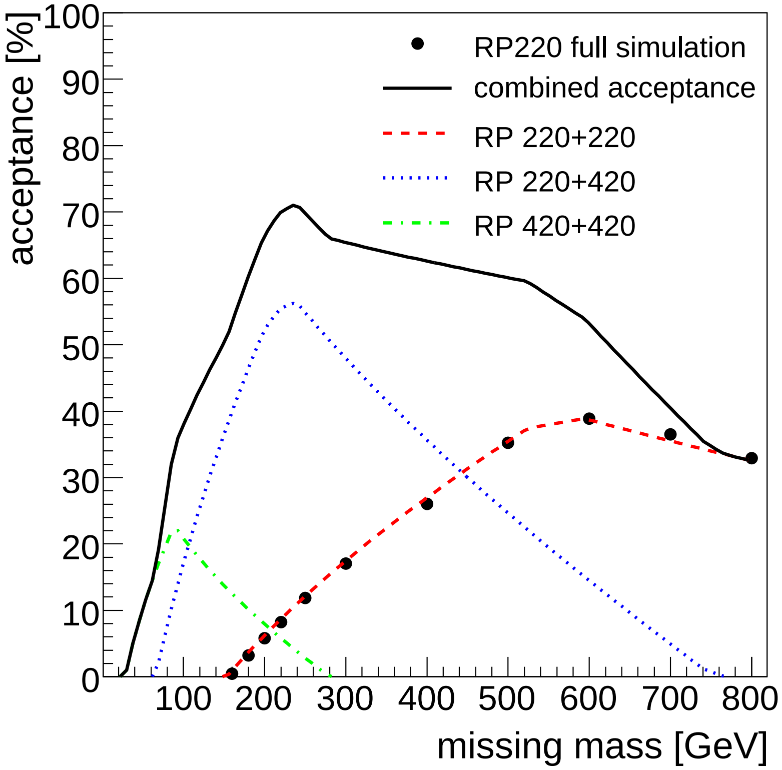
Roman pots at 220 m

Schematic view of 220 m pots: keep horizontal pots only from the TOTEM pots





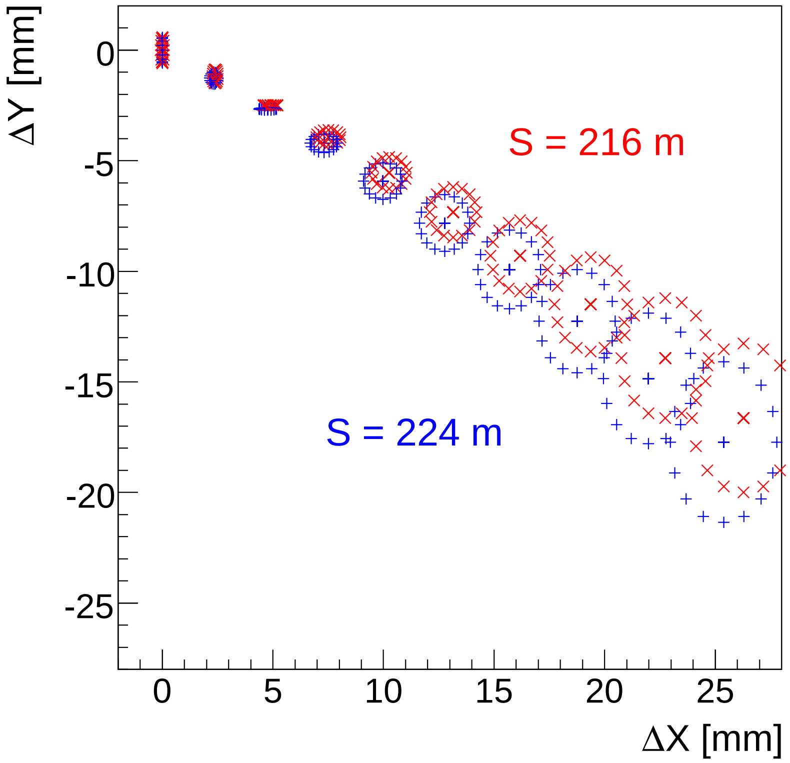
Roman pot projects

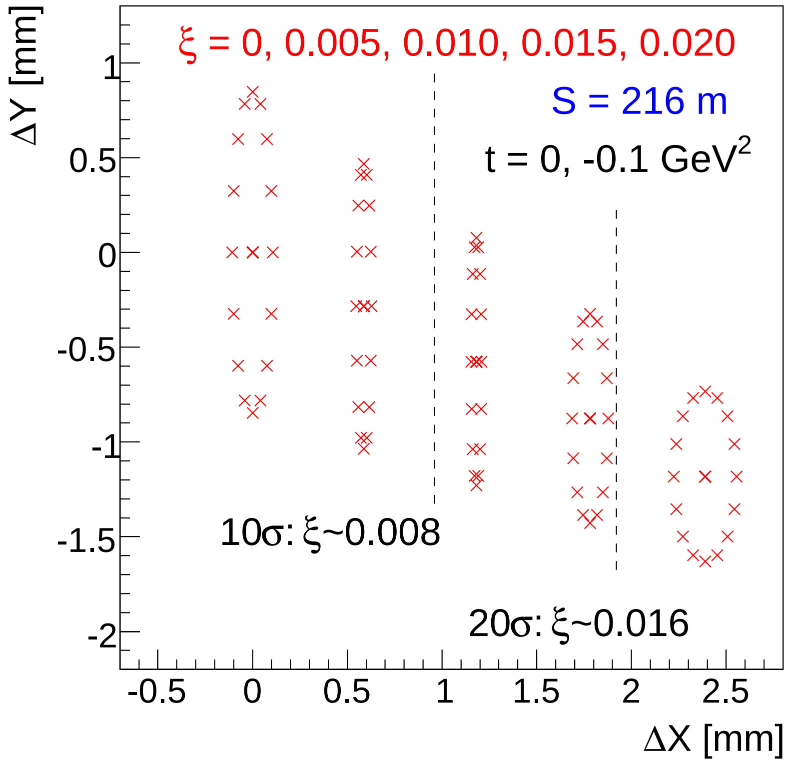


- FP420: Project of installing roman pot detectors at 420 m both in ATLAS, CMS; collaboration being built
- Roman pot detectors at 220 m in ATLAS: Collaboration between Saclay. Prague, Giessen, Cracow, Paris 6 and Stony Brook (so far) being pursued
- For more information, see the web pages of FP420, CMS, TOTEM, ATLAS

Acceptance for 220 m pots

- Steps in ξ: 0.02 (left), 0.005 (right), $|t|$=0 or 0.05 GeV^2
- Detector of 2 cm $\times$ 2 cm will have an acceptance up to $\xi \sim 0.16$, down to 0.008 at 10 σ, 0.016 at 20 σ
- As an example Higgs mass acceptance using 220 m pots down to 135 GeV and upper limit due to cross section and not kinematics





Which kind of detectors?

- Requirement: good resolution in position (good measurement of mass, kinematical propwerties), and in timing
- Position detectors:
  - Size of Si detectors: 2cm $\times$ 2cm
  - Spatial resolution of the order of 10-15 μm: Si strip detectors of 50 μm, as a first proposal: 5 layers, 2 vertical, 1 horizontal, 1 U, 1 V (45 degrees), or 3D Silicon detectors (in collaboration with FP420)
  - Edgeless detectors: Between 30 to 60 μm
  - First prototype of detector being made by CANBERRA: test-stand (laser and radioactive source) to be installed in Saclay following the Paris 6 experience
  - 2 additional layers used for the trigger: Strip detectors of 100-200 μm (to be optimised given the fact that we have 1 μs to send the trigger to ATLAS)
  - Readout and trigger chip ABCNext: standard Si readout for ATLAS

Which kind of detectors?

- Timing detectors
  - Why do we need timing detectors? At the LHC, up to 30 interactions by bunch crossing, and we need to identify from which vertex the protons are coming (for instance, for a Higgs event, we need to know if the protons are coming from the main interaction)
  - Timing detector resolution needed: of the order of 5 picoseconds (space resolution slightly more than 1 mm)
  - Development: new timing detectors in collaboration with the Universities of Chicago, Stony Brook, and Argonne, and with Photonis
  - For more information, see: http://www-d0.fnal.gov/ royon/timing/, Saclay workshop on timing detectors on March 8 and 9

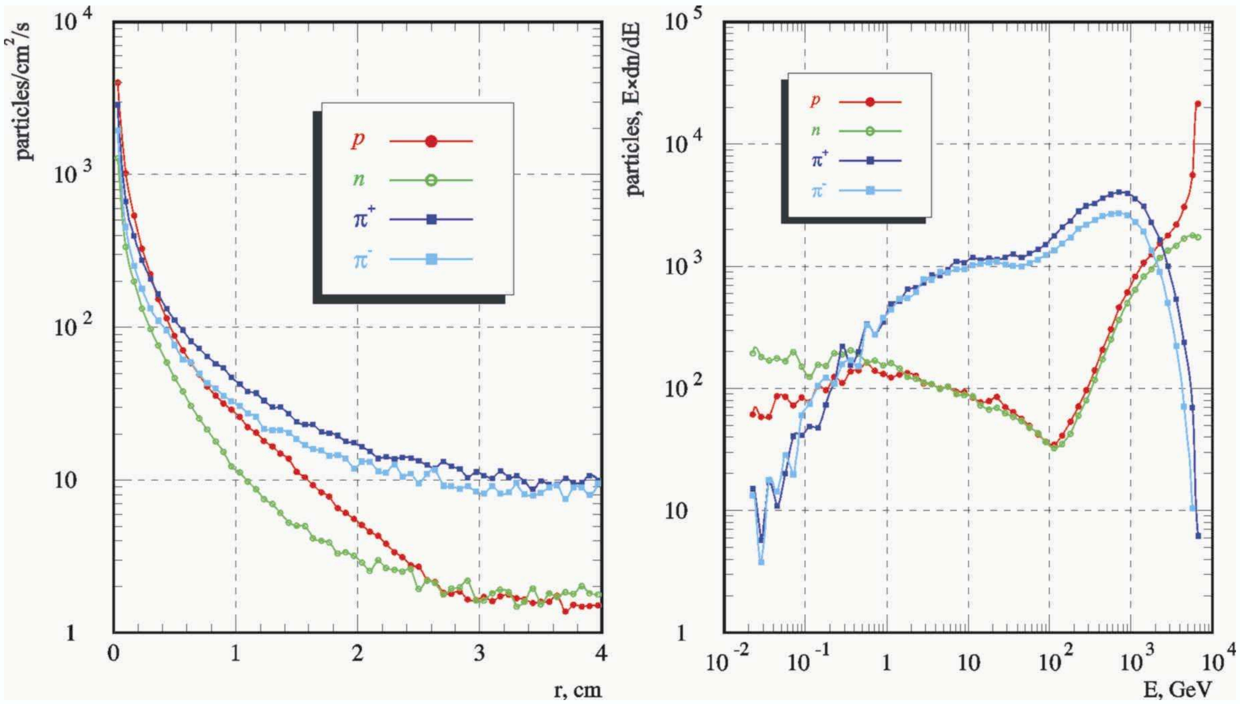
Fluxes in roman pot detectors (from Vadim Talanov)

Fluxes at 220 m at high lumi (10^{34}) (plots for 2.10^{29})

RATE EVOLUTION WITH CUTS [MD2005]

Particle flux in [Hz]

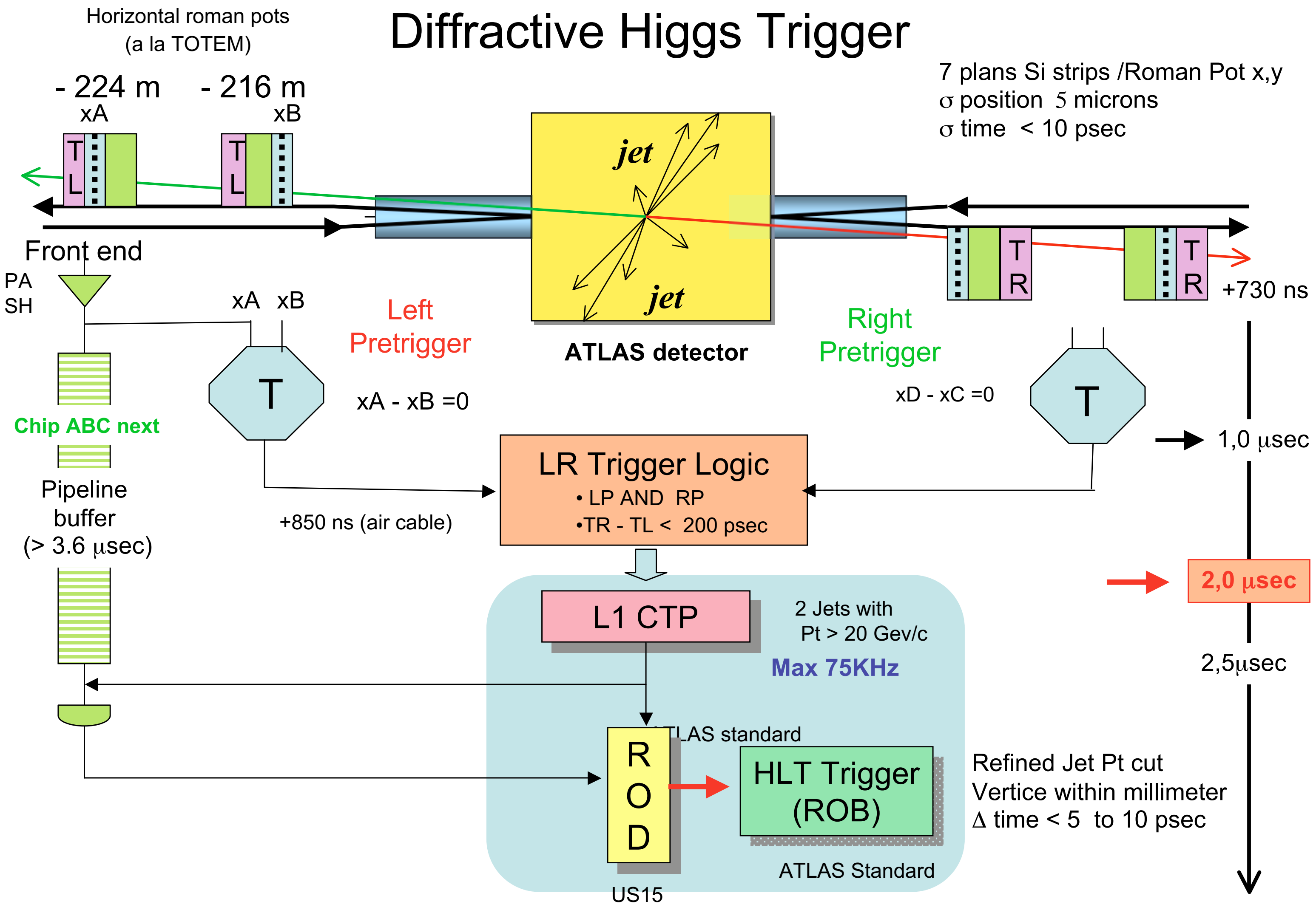
	p	n	π^+	π^-	e^+	e^-	γ
Pot at 220m	344	174	616	406	4630	3361	9.4×10^4



Requirements for timing detectors

- Where to install them? On each side of ATLAS at 224 m
- Timing resolution: as good as we can, typically 5-10 ps
- Size: The total available width in the roman pot is 4.5 cm, typically 2 cm for Si strip detectors and 2.5 cm for timing detectors
- Radiation hardness: important to resist the LHC radiation
- Detector space resolution: few mm, the total lateral size of the detectors being 2 cm
- Reference clock: either the LHC clock (resolution of 7-8 ps), or atomic clock (they need to be calibrated on each side)
- Trigger information: at L1 (rough compatibility between both sides of ATLAS) and specially at L2 (compatibility with vertex position)
- Availability: A preliminary version by 2009-2010 (40-50 ps resolution?) and the final version by 2011-2012

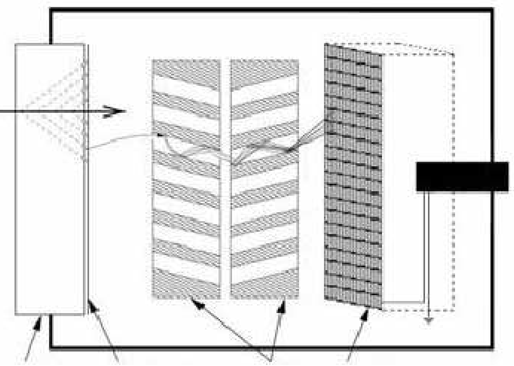
Trigger: principle



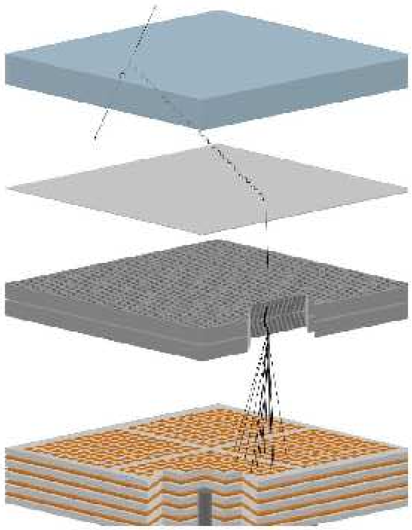
Timing detectors

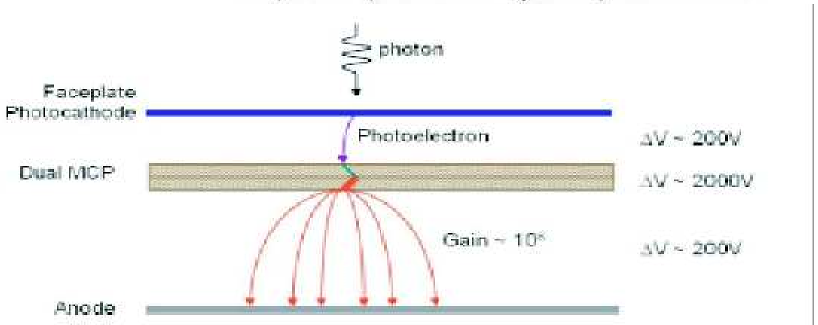
Ultra fast (psec) Timing

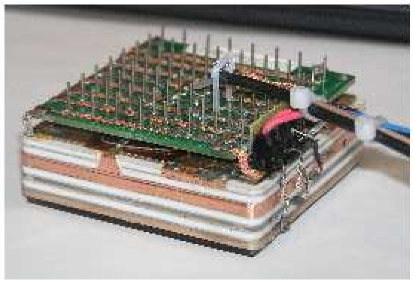
Use Cherenkov light ---> fast



- Use UC Chicago /ANL (Henry Frisch et al.) generic development
  - New MCP 2x2 inches tubes developed Burle/Photonis
- Apllications for ultra fast Timing for future detectors (SLHC,ILC,CLIC) and medical imaging (PET)
- Target performance : The Picosecond
  - TOF with precision of 0.3 mm







Conclusion

- Exclusive Higgs: Signal over background: ~ 1 if one gets a very good resolution using roman pots (better than 1 GeV), (enhanced by a factor up to 50 for SUSY Higgs at high $tan\beta$)
- QED WW pair production: cross section known precisely, allow to calibrate precisely the roman pot detectors, study of photon anomalous coupling
- Project of installing roman pot detectors in ATLAS well started: collaboration between Prague, Cracow, Saclay, Stony Brook, Giessen, Paris 6,... concerning the building and tests of Si strip detectors, or 3D Si detectors
- Collaboration about timing detectors (and medical applications): University of Chicago, Argonne, Saclay, Photonis
- Other collaborators very much welcome for diffractive physics in ATLAS (FP420/RP220)