La diffusion Compton profondément virtuelle à COMPASS

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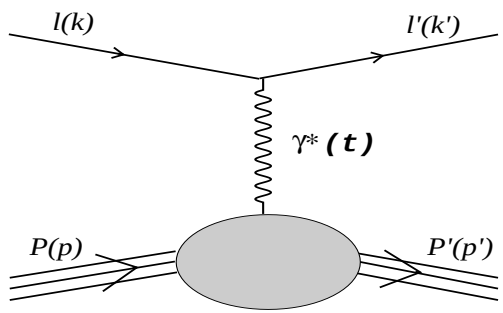
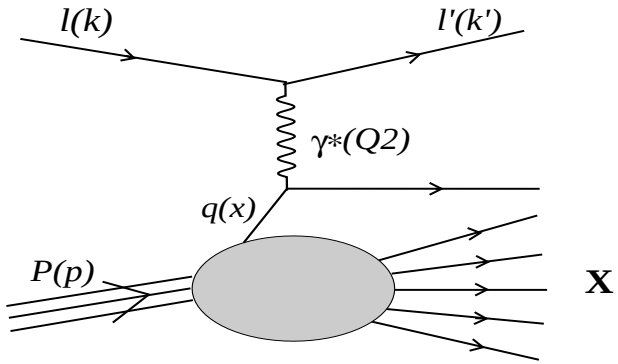
Motivations: la structure du nucléon

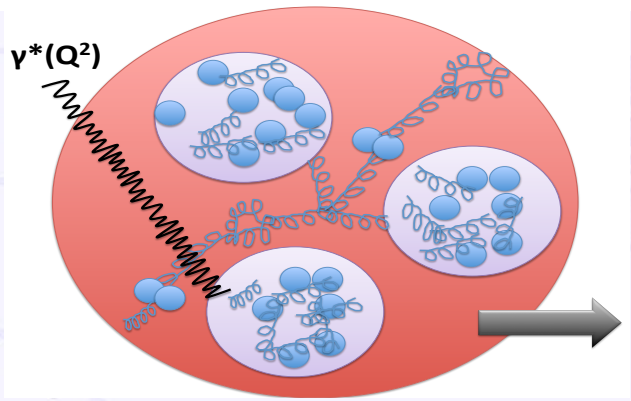
$\sim$ 1950
Diffusion élastique
facteurs de forme $G_{E,M}(t)$
distribution de charge E, M



$\sim$ 1970
Diff. profondément inélastique
fonctions de structure $F_{1,2}(x)$
distribution de partons q(x)
impulsion longitudinale x



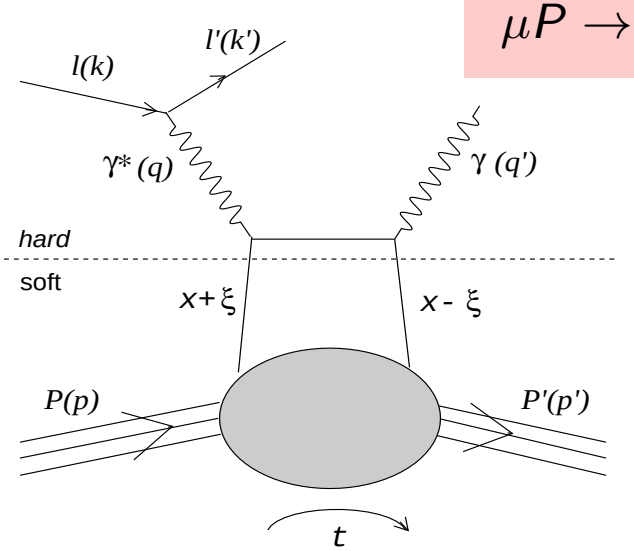
Modèle des partons: quarks+gluons
évolution résolution Q^2
$F_{1,2}(x, Q^2) \rightarrow q, g(x, Q^2)$



Passons en 3D...

... avec les processus exclusifs
DVCS= Diffusion Compton profondément virtuelle

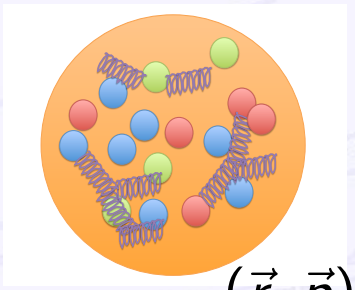
$\mu P \to \mu' P' \gamma$



facteurs forme Compton $\mathcal{H}$...
Distributions Partons Généralisées $H(x,\xi,t)$...

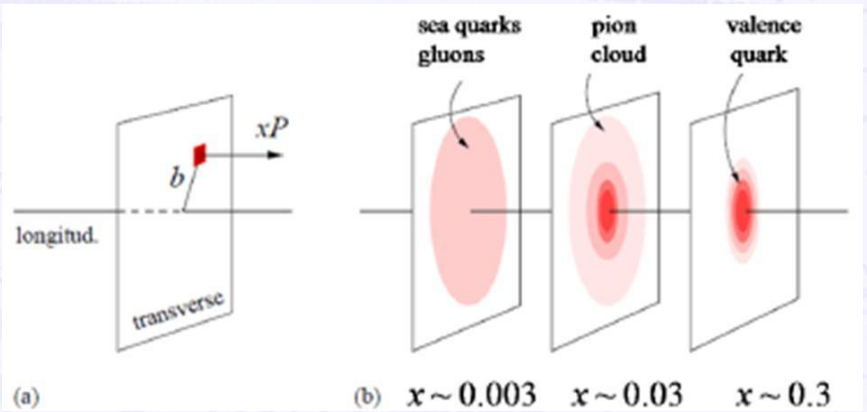
limite prof. inélastique
$H^q(x,\xi \to 0, t \to 0)$
$= q(x)$

limite élastique
$\int_{-1}^{1} dx\, H^q(x,\xi,t)$
$=$ facteur forme



$(\vec{r},\vec{p})$ "6D"

$(r_\perp, p_{//})$ "3D"

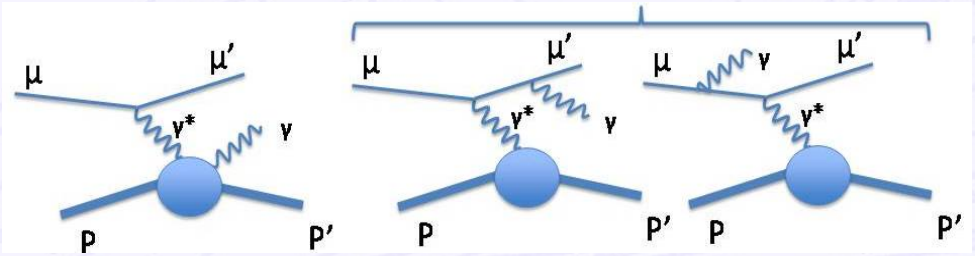


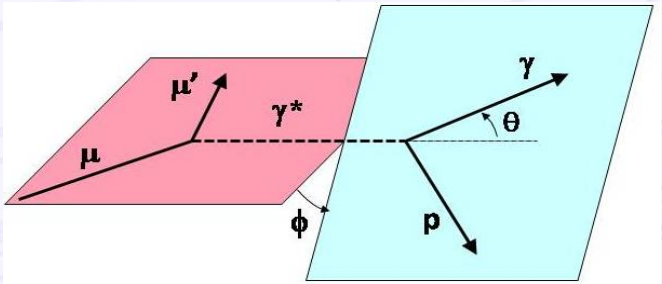
$\star$ $H(x, \xi = 0, t = -\Delta_\perp^2) \to H(x, b_\perp)$
x: "type de parton"

$\star$ $\frac{d\sigma^{DVCS}}{dt} \to r_\perp$

Mesure du DVCS

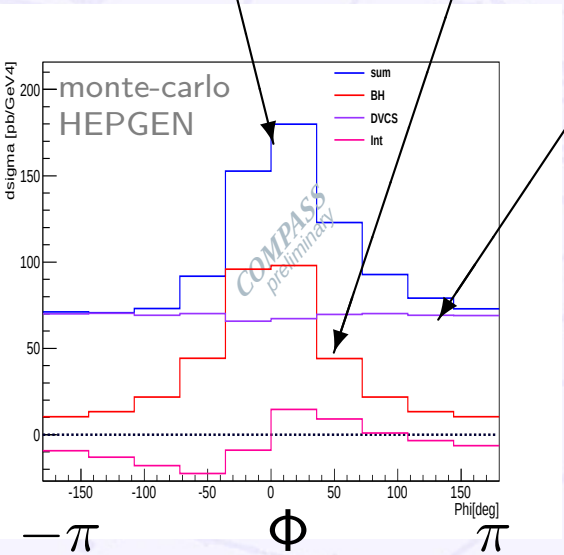
Production "exclusive" d'un γ= DVCS+Bethe-Heitler+Int.





COMPASS = $\mu^{+\leftarrow}$ et $\mu^{-\rightarrow}$ $\quad e_\ell$: *charge* ℓ, P_ℓ: hélicité ℓ

$$\frac{d^4\sigma(\ell P \to \ell' P' \gamma)}{dx_{bj}\,dQ^2\,d|t|\,d\phi}\Big/E_\ell = d\sigma^{BH} + (d\sigma^{DVCS}_{unpol} + P_\ell\, d\sigma^{DVCS}_{pol}) + e_\ell(\mathcal{R}e\ Int. + P_\ell\ \mathcal{I}m\ Int.)$$



$d\sigma^{\mu^{+\leftarrow},u}_{\gamma} + d\sigma^{\mu^{-\rightarrow},u}_{\gamma} \propto BH + DVCS_{unpol} + \mathcal{I}m(Int)$

$\mathcal{I}m(Int) = \ldots\ sin\Phi$

$\int d\Phi \dfrac{d\sigma^{DVCS}}{dt} \rightarrow r_\perp$

$\mathcal{I}m\,\mathcal{H} \propto \mathbf{H}(\xi,\xi,t)\ldots$

$d\sigma^{\mu^{+\leftarrow},u}_{\gamma} - d\sigma^{\mu^{-\rightarrow},u}_{\gamma} \propto DVCS_{pol} + \mathcal{R}e(Int)$

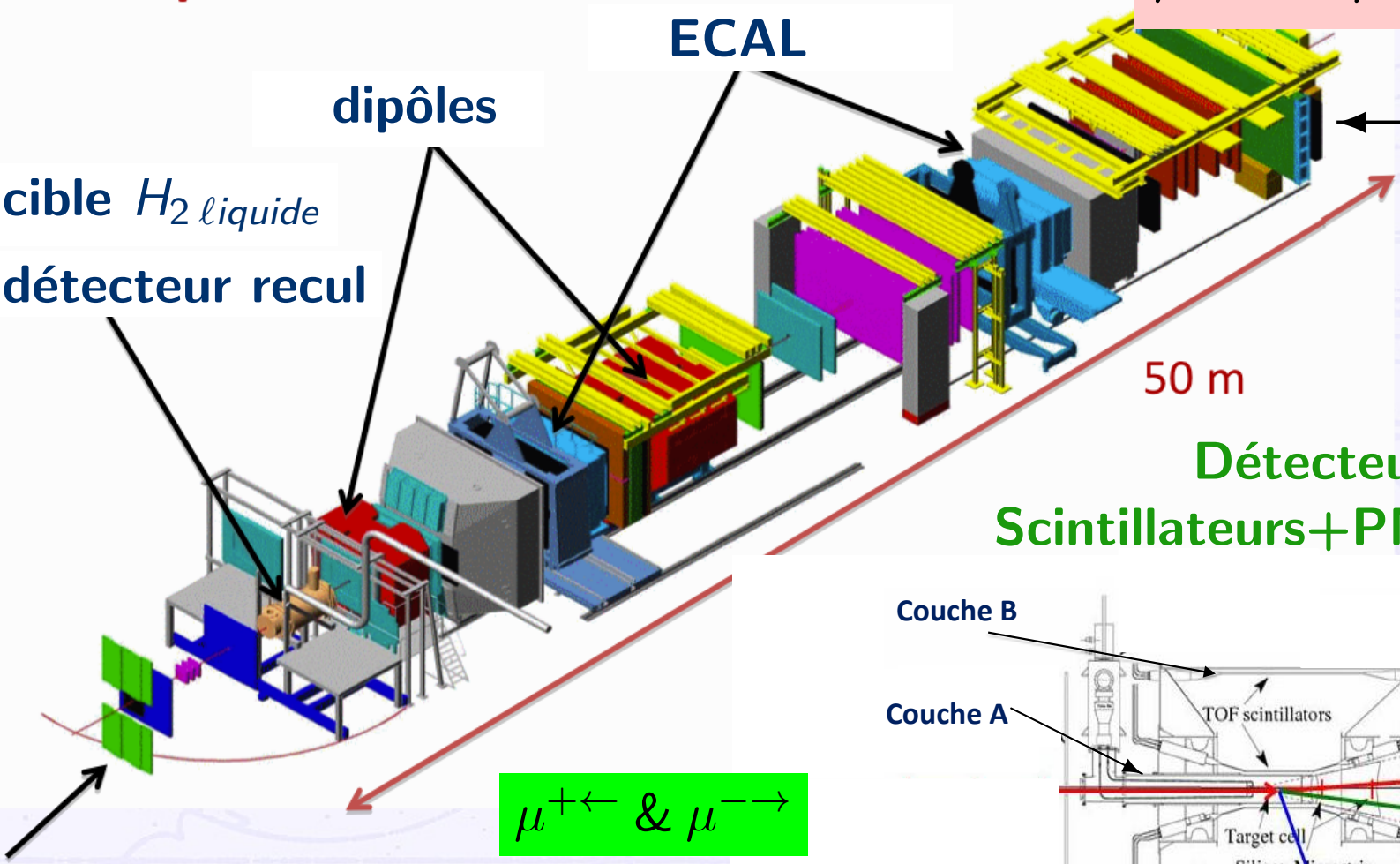
$\mathcal{R}e(Int) = \ldots\ cos\Phi$

$\mathcal{R}e\,\mathcal{H} \propto \int dx \mathbf{H}(x,\xi,t)\left(\frac{1}{\xi - x} - \frac{1}{\xi + x}\right)$

COMPASS au CERN @SPS (2009)

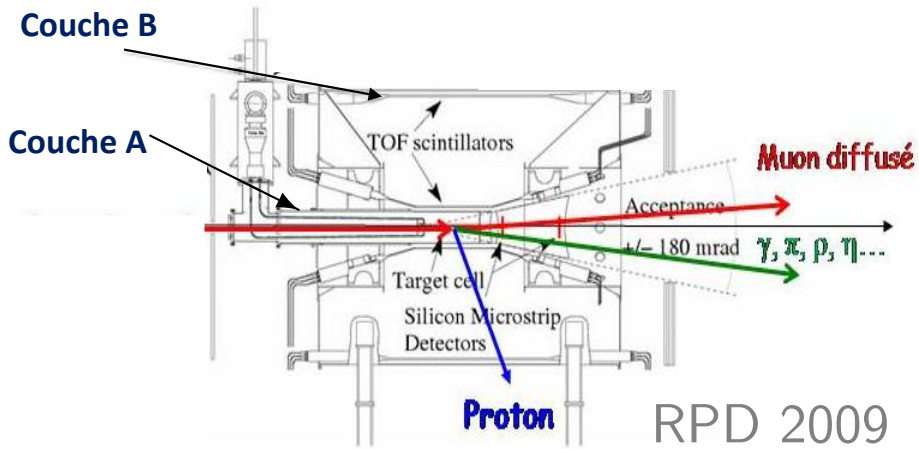
❖ Le Spectromètre COMPASS

$\mu P \to \mu' P' \gamma\ (\pi^0)$



$E_\mu = 160\,GeV$

Détecteur de recul
Scintillateurs+PM (tps vol)

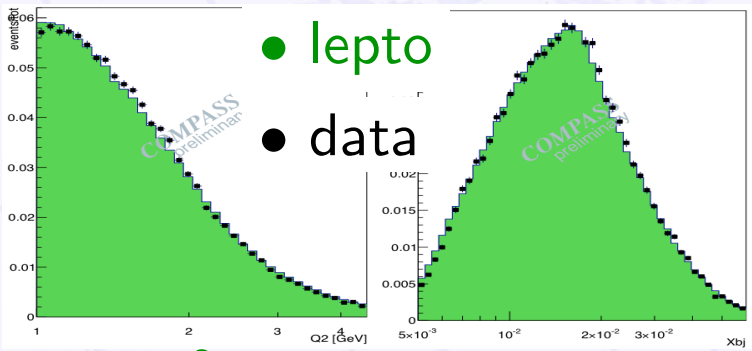


Normalisation et mesure de $F_2^p(x_{bj}, Q^2)$

$$\frac{d^2\sigma_{1\gamma}(x,Q^2,E)}{dxdQ^2} = F_2(x,Q^2).\frac{4\pi\alpha^2}{x.Q^4}.\{1-y-\frac{Q^2}{4E^2}+(1-\frac{2m^2}{Q^2}).\frac{y^2+Q^2/E^2}{2(1+R(x,Q^2))}\}$$

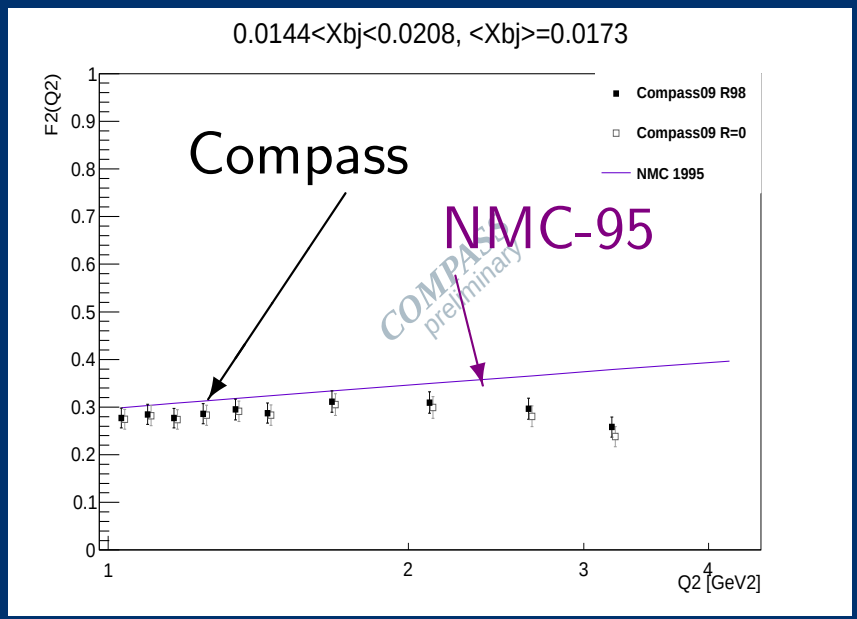
⋆ Validation mesure $\mathcal{L}_{eff} = 2.48 pb^{-1}(5.6\%)$
⋆ Domaine validité $x_{bj} \simeq x$ et Q^2

1. Géométrie (vertex, impacts, bords...)
2. Cinématique
3. Corrections radiatives $\frac{\sigma_{1\gamma}}{\sigma_{mes}}(x_{bj}, y)$
4. Paramètres Monte-Carlo
5. Acceptance
6. Normalisation, systématiques



Q^2 x_{bj}

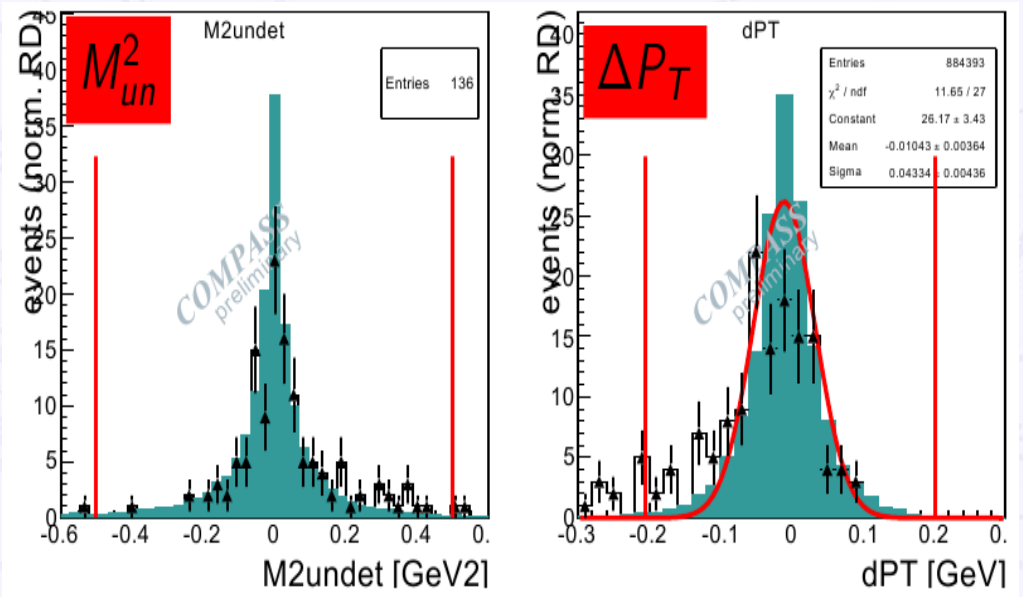
$F_2^p(x_{bj}, Q^2)$, $< x_{bj} >= .017$



petit Q^2: écart $\ll \delta(stat + sys)$ DVCS
grand Q^2: acceptance sur-estimée

Sélection des processus exclusifs $\mu P \to \mu' P' \gamma$

1. Topologie: coincidence $\mu' P' \gamma$
2. Cinématique
3. "Exclusivité": 5 observables

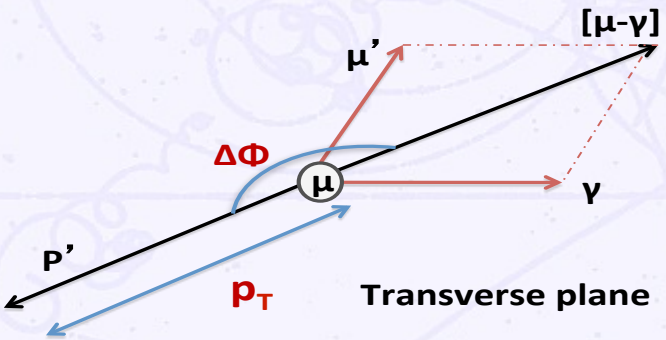


⋆ **bilan en masse et en énergie**

$(\mu P) - (\mu' P' \gamma) \quad \to$ M^2_{undet} E_{undet}

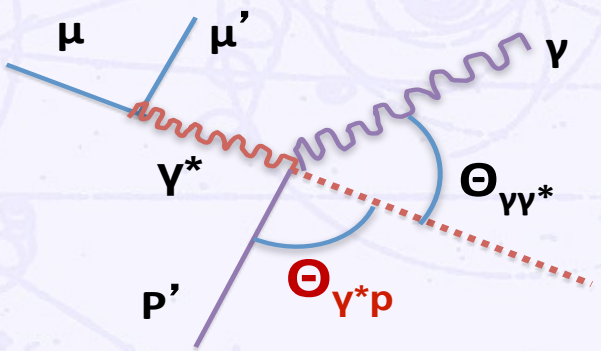
⋆ **bilan en impulsion**

$\Delta\phi \pm \pi$ ΔP_T



⋆ **état final** $\gamma^* P \to \gamma P'$

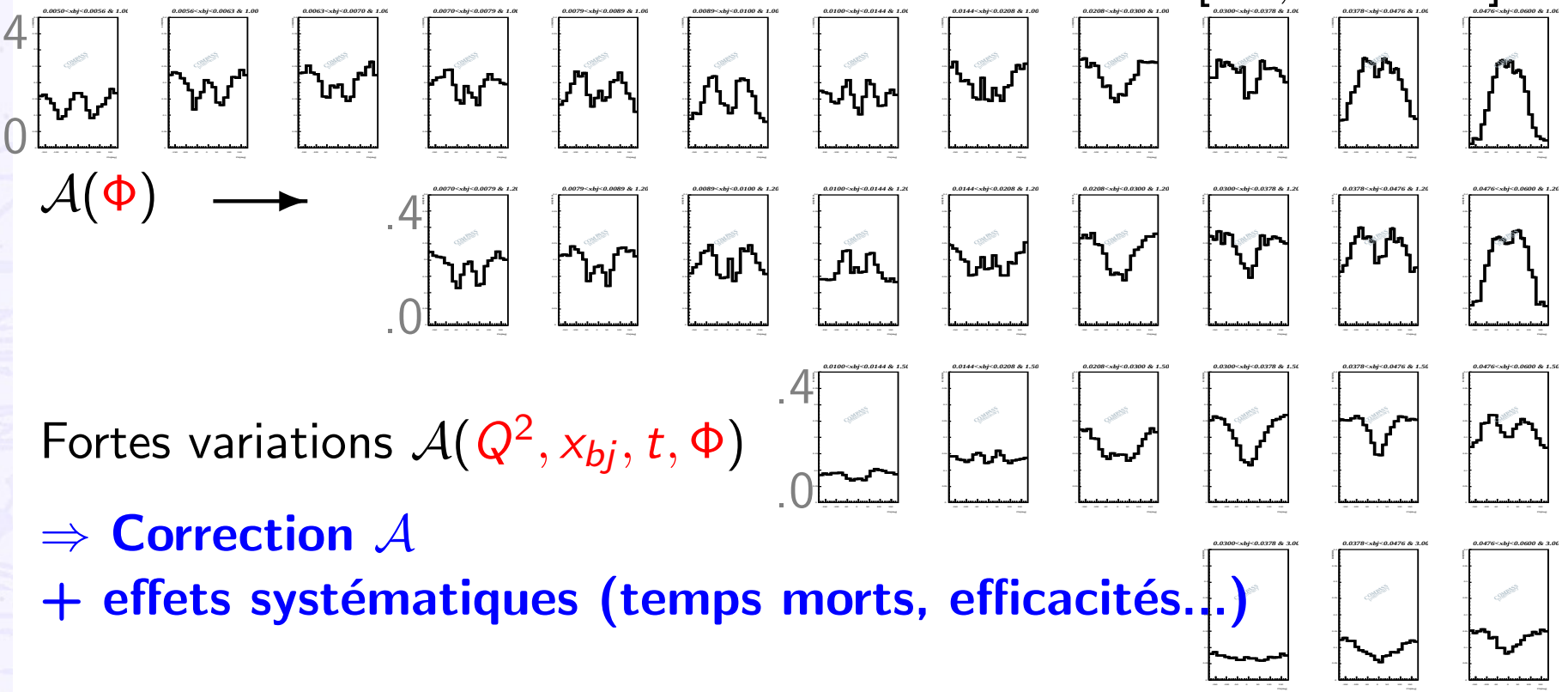
$\Delta cos\theta^{\gamma^* P}$



Acceptance (DVCS+BH)

x_{bj} ⟶ $-t \in [0.2, 0.8 GeV^2]$

Q^2 ↓

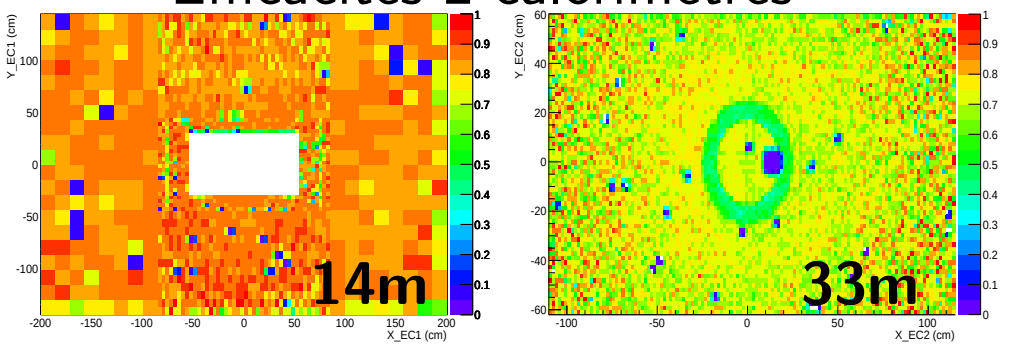


Fortes variations $\mathcal{A}(Q^2, x_{bj}, t, \Phi)$

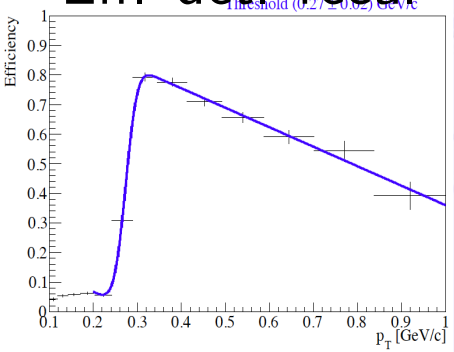
⇒ **Correction $\mathcal{A}$**

+ effets systématiques (temps morts, efficacités...)

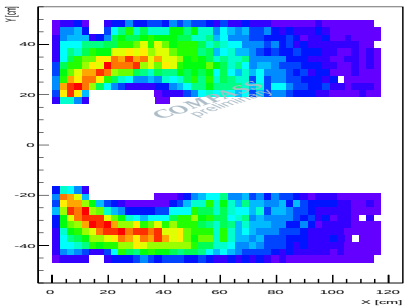
Efficacités 2 calorimètres



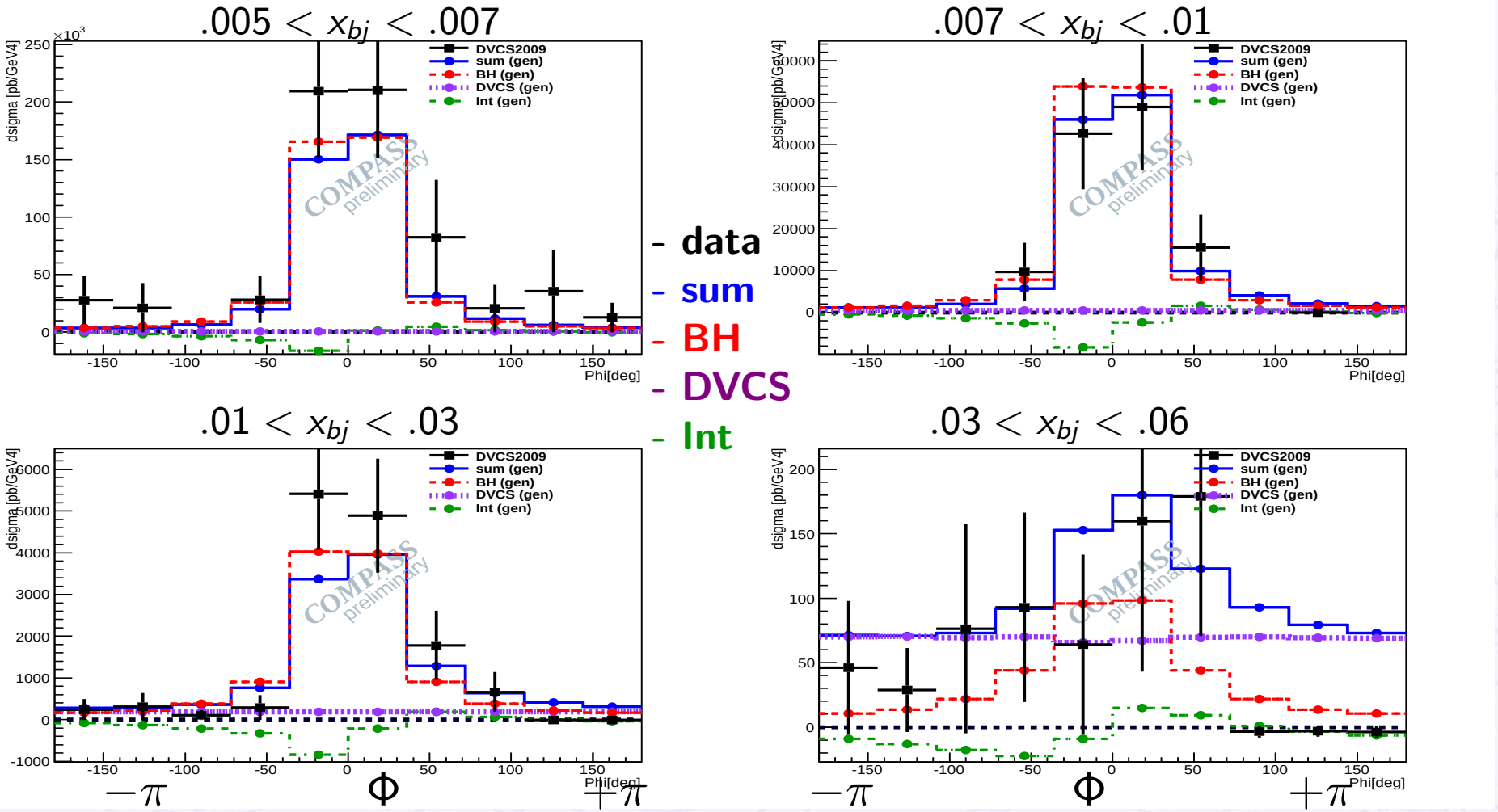
Eff. dét. recul



Forme trigger



Section efficace DVCS+Bethe-Heitler



$-t \in [0.06; 0.8 GeV^2]$ et $Q^2 \in [1; 4.5 GeV^2]$

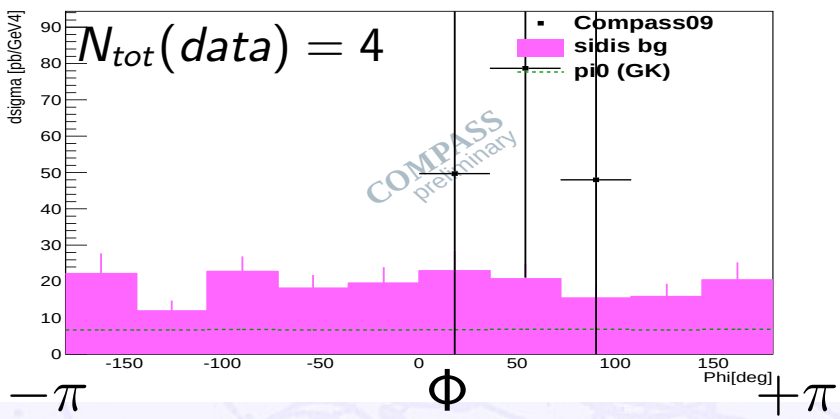
- petit x_{bj}: $d\sigma^{BH}$
- grand x_{bj}: $d\sigma^{DVCS+BH}$ $\rightarrow$ modèle (FFS) compatible

Systématiques et production exclusive de π^0

Contaminations au DVCS+BH (grand x_{bj})

- ⋆ (semi-inclusif, lepto) $\mu P \to \mu' P' + \pi^0, \eta... \to (\mu' P' \gamma) + X$ [$\sim 8\%$]
- ⋆ (π^0 exclusif, GK) $\mu P \to \mu' P' \pi^0 \to (\mu' P' \gamma) + \gamma$ [$< 2\%$]
- ⋆ diffraction cible $\mu P \to \mu' P^* \gamma \to (\mu' P' \gamma) + X$ [$\ll 1\%$]

Section efficace π^0 exclusif



$x_{bj} \in [.03; .06]$, $-t \in [0.06; 0.8 GeV^2]$, $Q^2 \in [1; 4.5 GeV^2]$

$$d\sigma^{\pi^0}/dx_{bj}.dQ^2.dt.d\Phi < 8.2\ pb.GeV^{-4}\ (1\sigma)$$

- Bruit semi-inclusif important ($\pi^0 + X$)
- Modèle (GK, 7.8 $pb.GeV^{-4}$) compatible

Incertitudes	$\delta\sigma^{DVCS+BH}$
luminosité	5.6 %
ϵ ECAL	10 %
ϵ proton	5 %
ϵ tracking	3 %
ϵ trigger	2 %
coincidences triggers	1 %
taux occupation	1 %
Correction acceptance	$\ll 1$ %
soustraction bruit	< 0.2 %
total	$\sim 13\%$

Conclusion & Perspectives

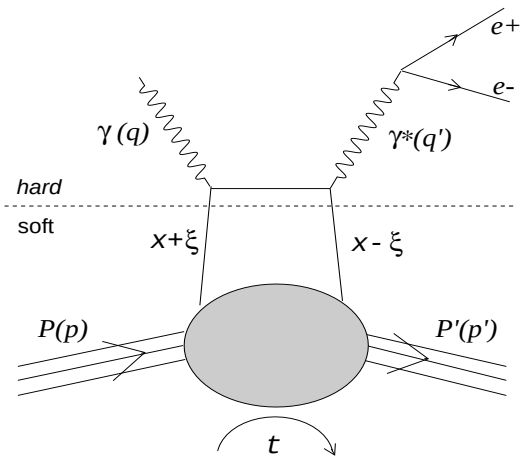
Etude DVCS à COMPASS

- Luminosité, $\mathbf{F_2(x_{bj}, Q^2)}$ et amplitude **Bethe-Heitler**
- **Sections efficaces: DVCS+Bethe-Heitler et π^0 exclusif**

$\Rightarrow$ **1^{ere} mesure de sections efficaces pour COMPASS-II**

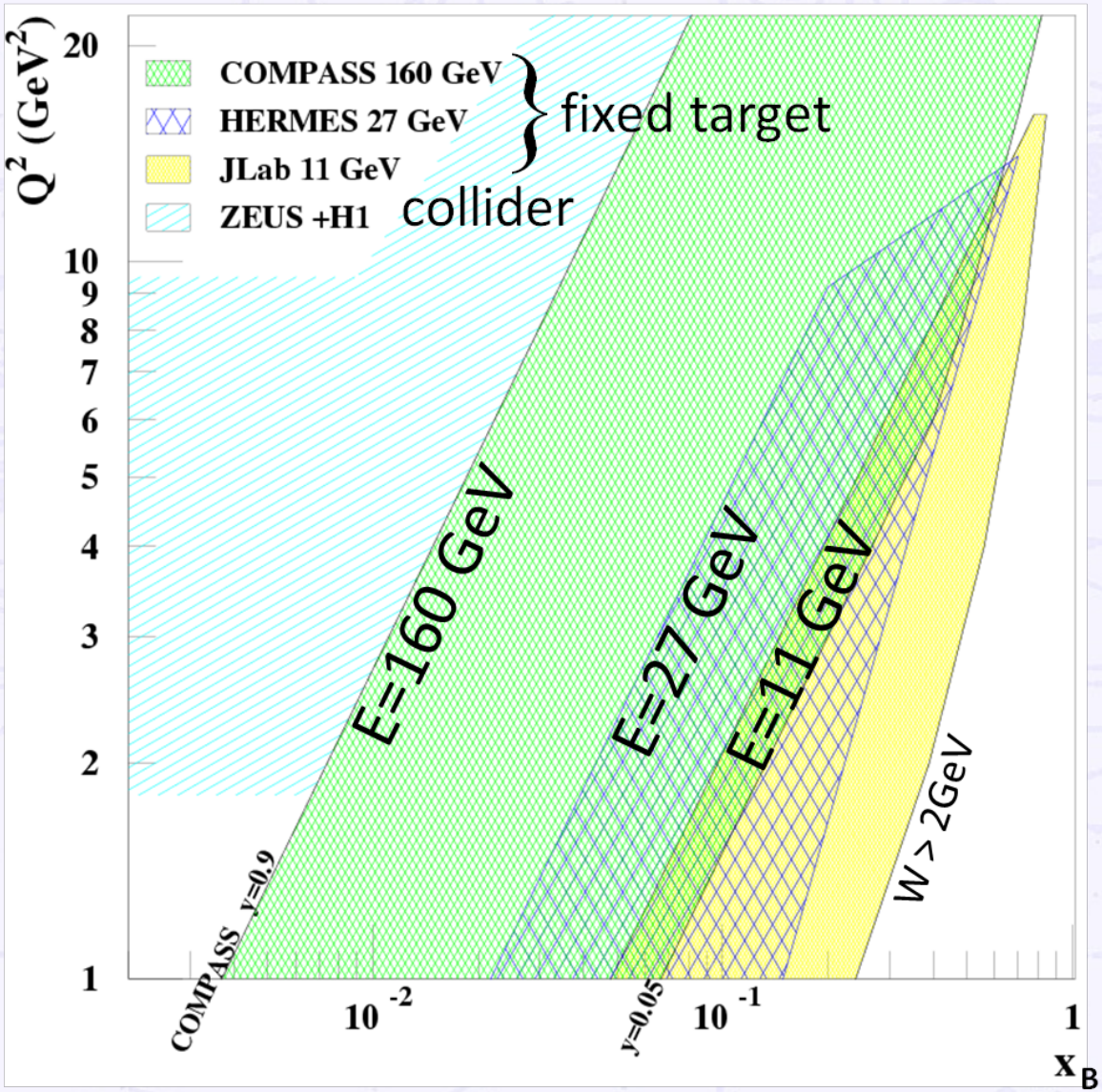
Perspectives: diffusion Compton "time-like" à JLAB

- Mesures 6GeV
- Accès GPD, partie $\mathcal{R}e\,\mathcal{H}$
- Observables + extraction GPD



SPARE

Situation expérimentale actuelle & future



⋆ Résultats publiés:

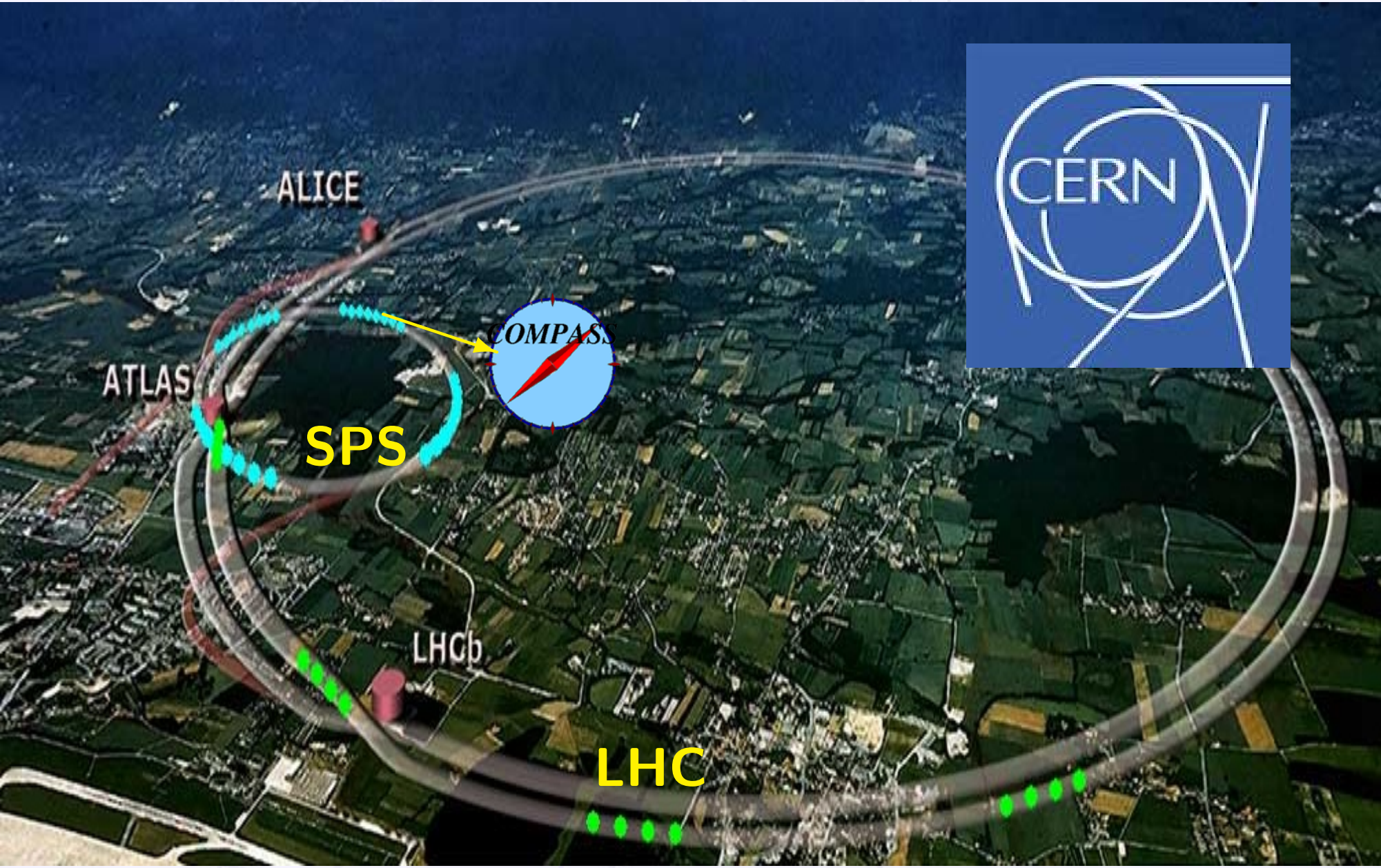
- H1, ZEUS, HERMES
- JLAB 6GeV

⋆ Futur:

- JLAB 12GeV
- COMPASS-II $\mu^+\mu^-$160GeV

Domaines complémentaires

COMPASS au CERN



Cadre de l'analyse

Proposition d'expérience COMPASS-II, processus exclusifs: 2016-2017

Données test 2009

- 10 jours, dispositif non optimisé
- Cible 40cm + petit détecteur recul

Mise en place méthode
Optimisation paramètres
Test faisabilité mesure
1^{ere} mesure σ^{DVCS}

Données test 2012

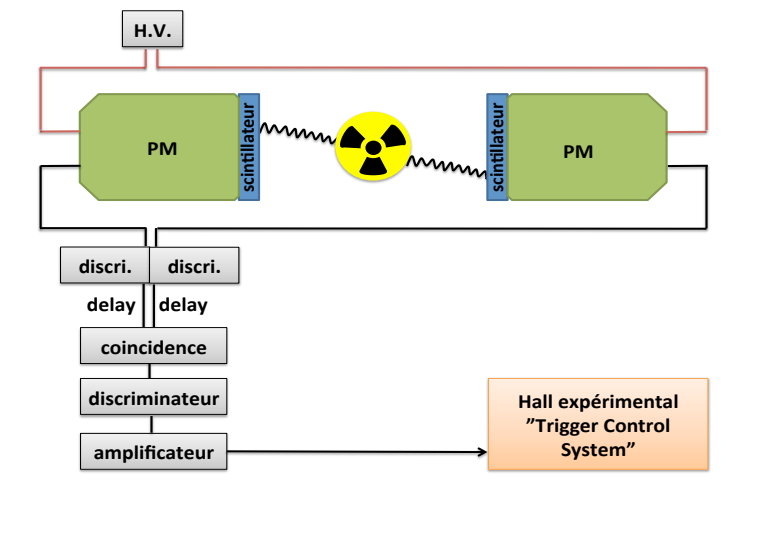
- 1 mois, test dispositif "final"
- Cible 2.5m + détecteur recul CAMERA
- plus grande couverture cinématique

Validation expérience
Mesure plus précise

Normalisation des données

Luminosité effective avec déclenchements aléatoires

$$\mathcal{L}_{eff} = \mathcal{L} * \tau^{DAQ} * \tau^{veto} * \epsilon^{muon} = \mathcal{F}_{eff} * N_{cible}$$



(luminosité intégrée)

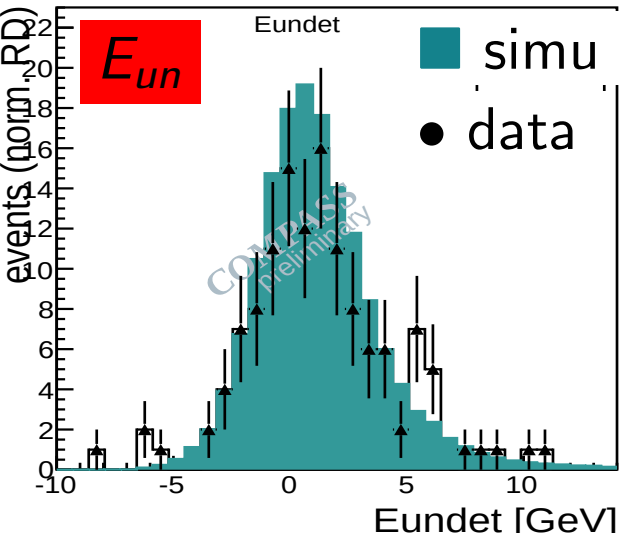
$$\mathcal{L}^{\mu^+}_{eff} = 2.48 pb^{-1}\ (5.6\%)$$
$$\mathcal{L}^{\mu^-}_{eff} = 0.787 pb^{-1}\ (5.5\%)$$

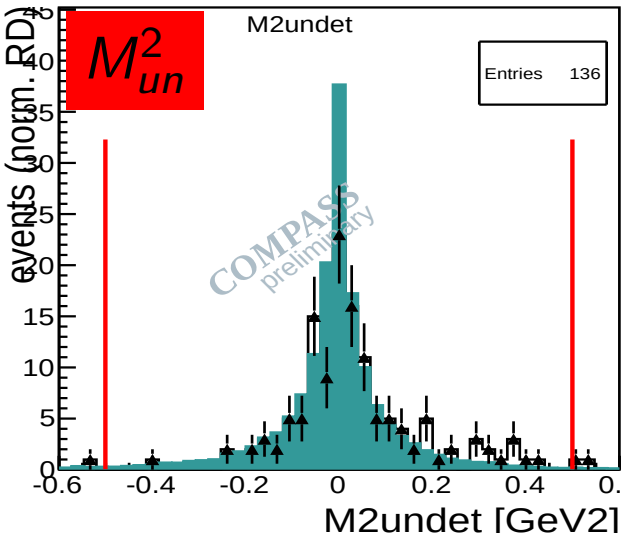
$$\mathcal{F} \propto N_\mu / temps / S_{cible}$$

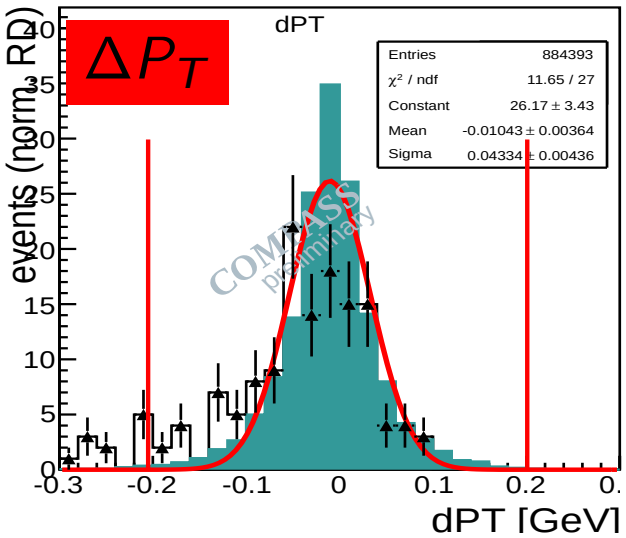
- ouverture trigger $\Delta t_{trigger}$
- faisceau: (E, p), θ, impacts...
- correction temps morts...
- $\int dt\ [N_\mu / trigger] * N_{cible}$

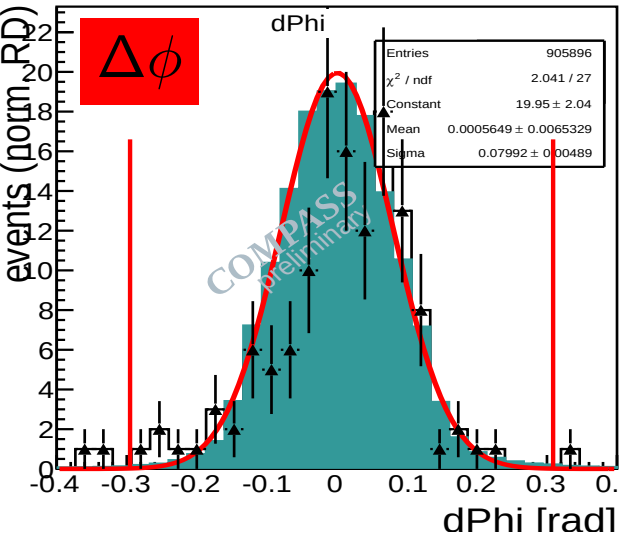
Incertitudes	% (μ^+)	% (μ^-)
stat.	~ 0.01	~ 0.1
N_{cible}	5.0	5.0
taux veto	2.0	2.0
reconstruction traces	1.0	1.0
structure faisceau	0.8	0.3
coincidences triggers	0.3	0.2
total	5.6	5.5

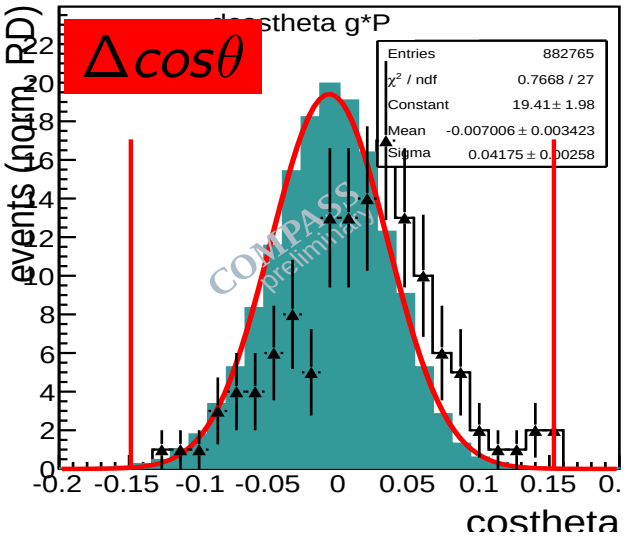
Variables d'exclusivité $\mu P \rightarrow \mu' P' \gamma$











Sélections

$\Delta P_T < 0.2 GeV$

$\Delta cos\theta < 0.15$

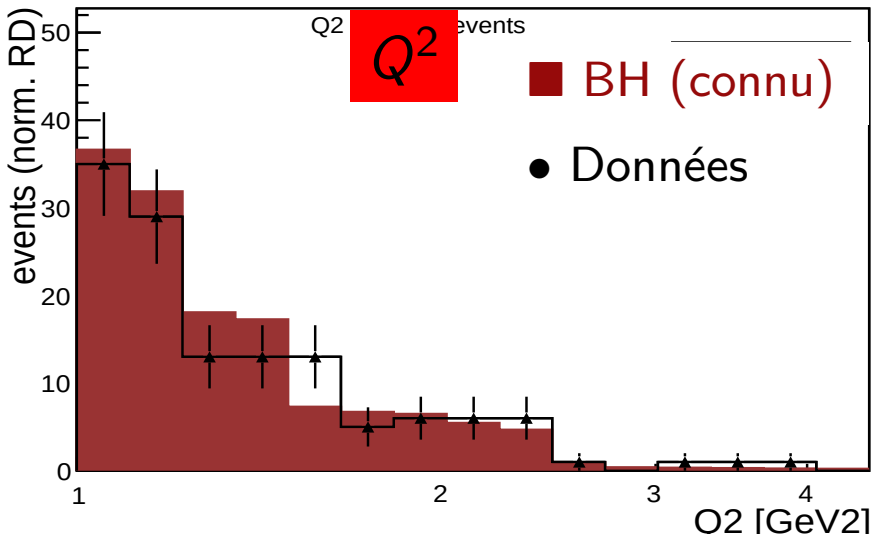
$\Delta\phi < 0.3 rad$

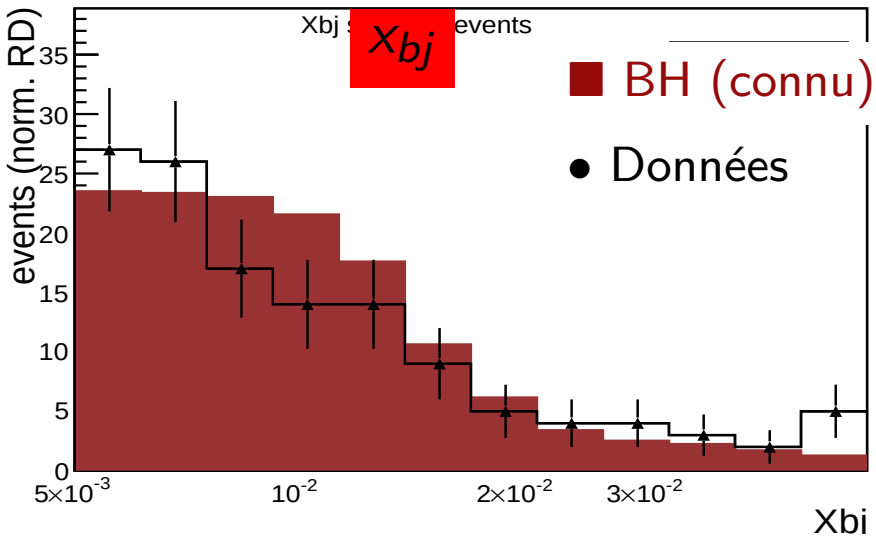
$M^2_{un} < 0.5 GeV^2$

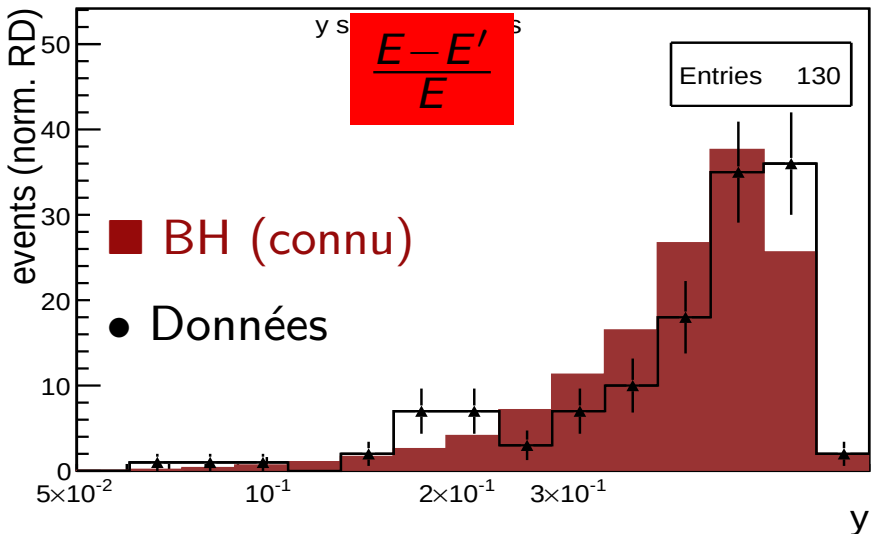
E_{un}: aucune

- Accord données/Monte-Carlo: permet définir sélections

Validation simulation: données vs Bethe-Heitler







Cinématique du Bethe-Heitler reproduite dans le Monte-Carlo

Taux de comptage bruit de fond

Contaminations DVCS+BH: taux comptage