

VM photoproduction at the LHC as a probe of nuclear structure

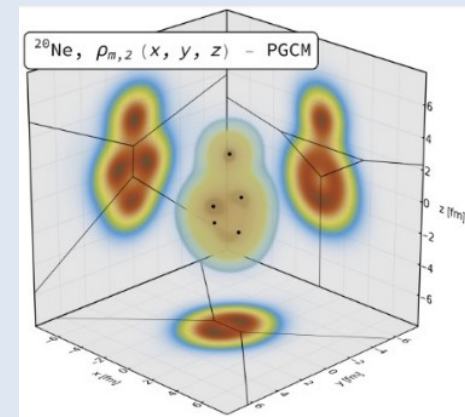
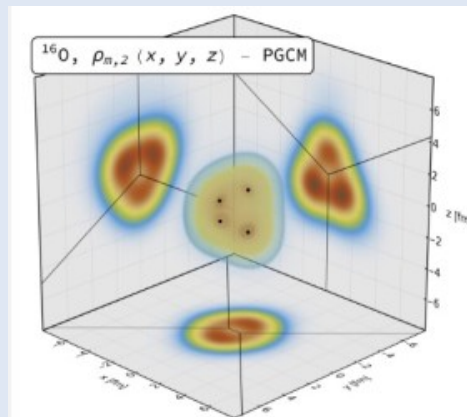
Olga Bessidskaia Bylund olga.bylund@cern.ch

IJCLab Orsay, Université Paris-Saclay, IN2P3/CNRS



anr[©]
agence nationale
de la recherche

The author acknowledges the support of the French Agence Nationale de la Recherche (ANR) under reference ANR-22-CE31-0005 MALICE



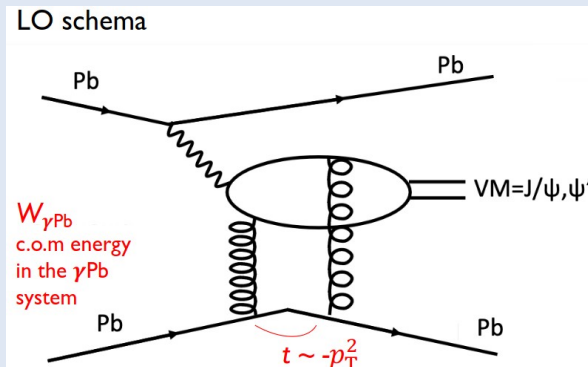
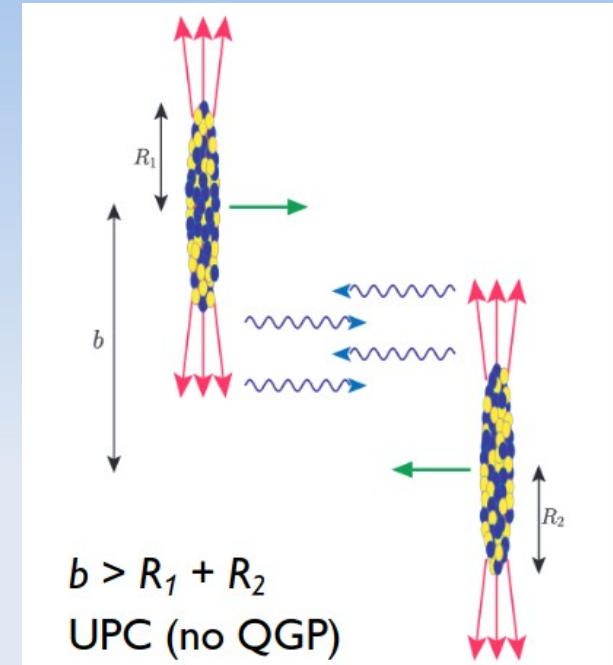
EMMI workshop on light ions, 24/9 2026

Outline

- **Theoretical** background for **vector meson (VM) photoproduction**
- My simulation study: can we see effects of **clustering** in VM photoproduction measurements at the LHC?
- New Ions: cases to study at the LHC in the **future** with VM photoproduction

Photon-induced processes at the LHC

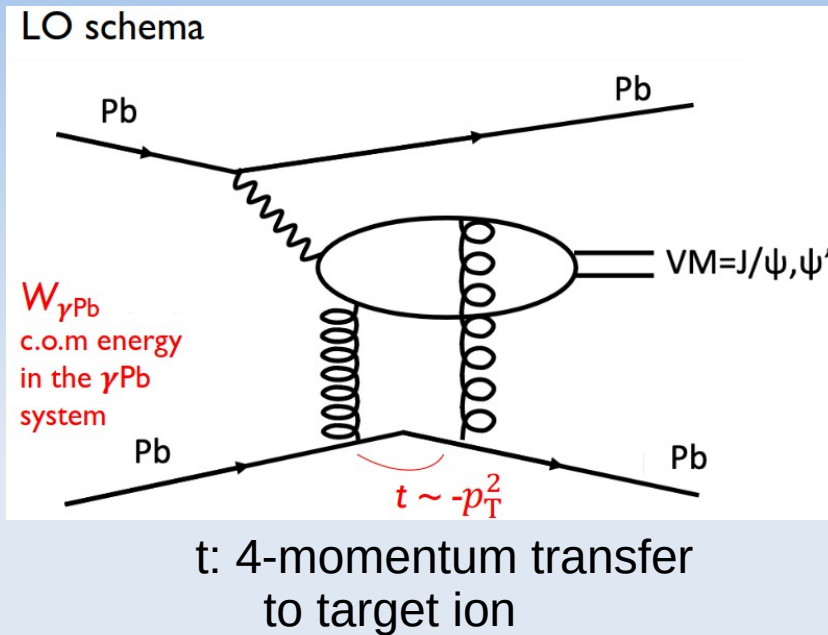
- The nuclei can interact **electromagnetically**:
 - Separation of pair of nuclei $>$ sum of their radii = **ultra-peripheral collisions** (UPC)
 - Extremely strong EM fields from ultra-relativistic highly charged ions described as a beam of quasi-real **photons**, number of photons $\propto Z^2$
- The LHC as a photon-hadron collider (**QCD**)
- Transverse **structure** from **diffraction** pattern



Complementarity with flow

- VM photoproduction probes **initial state**, flow probes deformation through final state particle-correlations generated by the QGP response
- More statistics needed for UPC measurements
- Different dependencies of observables on **modelling** (hydro models vs photoproduction models)

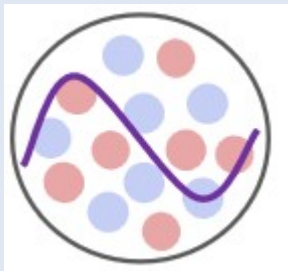
Vector meson photoproduction: some definitions



- E.g. for J/ψ : Quasi-real **photon** fluctuates into a colour **dipole**
- Interaction with the target nucleus via **gluon exchange**
- Dipole rescatters $\rightarrow$ on-shell **VM**
- The rapidity y of the VM is related to **Bjorken-x**

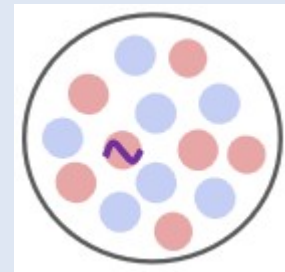
$$x_{\pm} = \frac{m_{J/\psi}}{\sqrt{s_{NN}}} e^{\pm y}$$

In **coherent** VM photoproduction,
the photon interacts coherently
with the **whole** target **nucleus**



$$\langle p_T^{\text{VM}} \rangle \sim 1/\text{Radius} \sim 60 \text{ MeV for Pb}$$

Incoherent VM photoproduction
occurs via the interaction of the
photon with a **single nucleon** or
subnucleonic structure



$$\langle p_T^{\text{VM}} \rangle \sim 500 \text{ MeV}$$

Nuclear imaging with VMs: target profile

$$\begin{array}{ccccccc}
 & & \text{Dipole-nucleus x-sec} & & \text{UPC x-sec} & & \\
 \text{Nuclear structure} & \rightarrow & T_A(\vec{b}) & \rightarrow & \frac{d\sigma_A^{\text{dip}}}{d\vec{b}} & \rightarrow & \mathcal{A}_{T,L}(x, Q^2, \vec{\Delta}) \rightarrow \frac{d\sigma}{d|t|} \\
 & & \text{Transverse target profile} & & \text{VM amplitude} & &
 \end{array}$$

In the hot spot model, the transverse profile of the gluonic **colour field** is constructed from **nucleons** and **sub-nucleonic hot spots**:

transverse position w.r.t
center of target nucleus

nucleons

transverse position of nucleon i

$$T_A(\vec{b}) = \frac{1}{2\pi B_{\text{hs}}} \sum_{i=1}^A \frac{1}{N_{\text{hs}}} \sum_{j=1}^{N_{\text{hs}}} \exp \left(-\frac{(\vec{b} - \vec{b}_i - \vec{b}_j)^2}{2B_{\text{hs}}} \right)$$

hot spot width

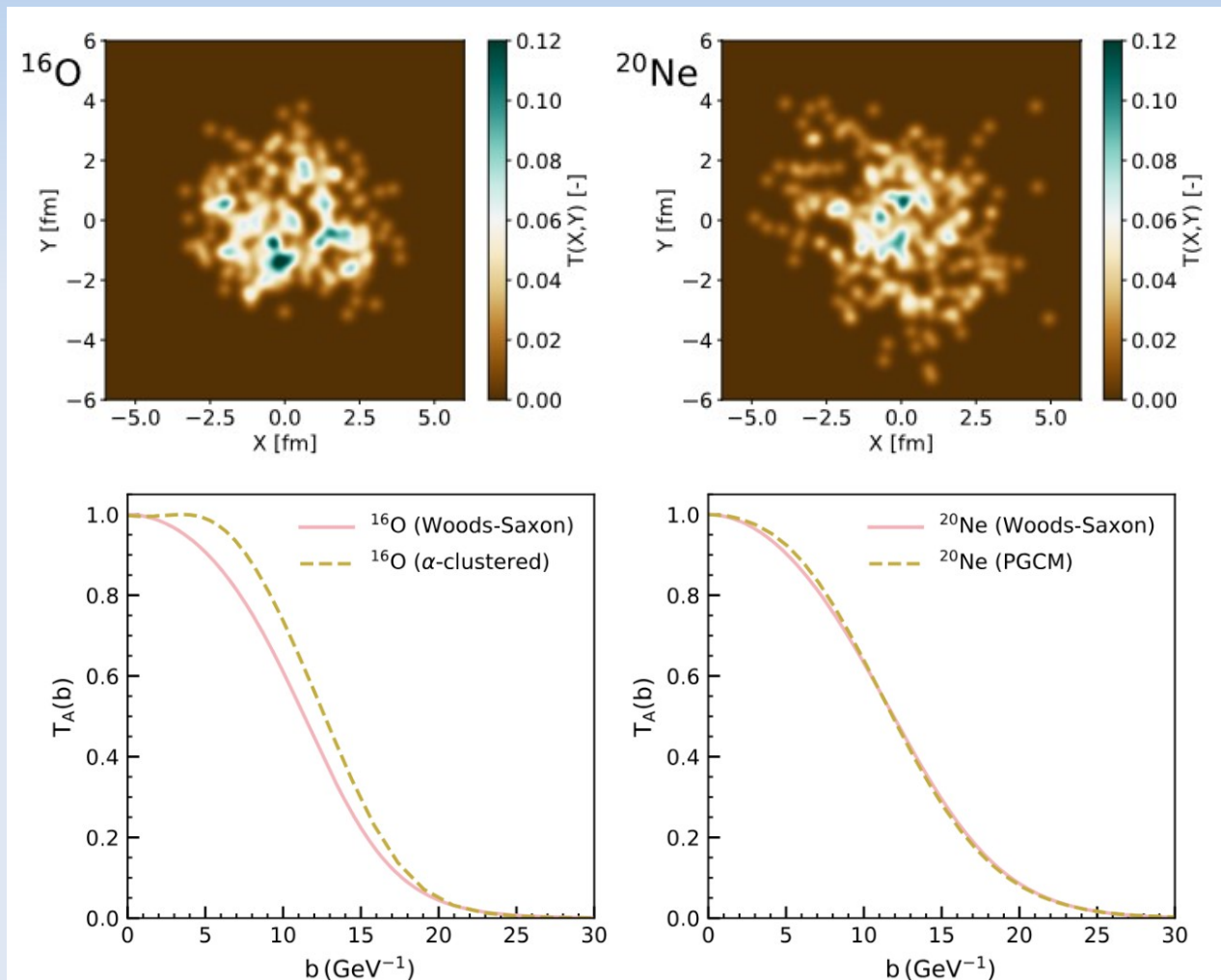
hot spots

transverse position
of hot spot j

J. Cepila et al., Phys. Rev. C. 113 (2026) 2, 025202

Nuclear imaging with VMs: hot spot distributions

Example **hot spot configurations** in the cluster model for ^{16}O and ^{20}Ne and the transverse profiles (1D) from clustering or a deformed Woods-Saxon



J. Cepila et al., Phys. Rev. C. 113 (2026) 2, 025202

Nuclear imaging with VMs: t-differential UPC cross section

$$\text{Nuclear structure} \rightarrow T_A(\vec{b}) \rightarrow \frac{d\sigma_A^{\text{dip}}}{d\vec{b}} \rightarrow \mathcal{A}_{T,L}(x, Q^2, \vec{\Delta}) \rightarrow \frac{d\sigma}{d|t|}$$

Good-Walker approach

Coherent VM cross section

- Proportional to the **average** over possible configurations of the colour field

$$\left. \frac{d\sigma^{\gamma^*H \rightarrow VH}}{d|t|} \right|_{T,L} = \frac{(R_g^{T,L})^2}{16\pi} |\langle \mathcal{A}_{T,L} \rangle|^2$$

- Gives **average transverse nuclear structure**
- Encodes the nucleon **one body density**

Incoherent VM cross section

- Proportional to the **variance** of possible configurations of the colour field

$$\left. \frac{d\sigma^{\gamma^*H \rightarrow VY}}{d|t|} \right|_{T,L} = \frac{(R_g^{T,L})^2}{16\pi} (\langle |\mathcal{A}_{T,L}|^2 \rangle - |\langle \mathcal{A}_{T,L} \rangle|^2)$$

- Probes internal gluonic **fluctuations** and the **substructure** of nuclei
- Contains the **two-body density**

Strategy for feasibility study

Feasibility study of $\rho \rightarrow \pi^+\pi^-$ and $J/\psi \rightarrow \mu^+\mu^-$ photoproduction in UPC events at LHCb

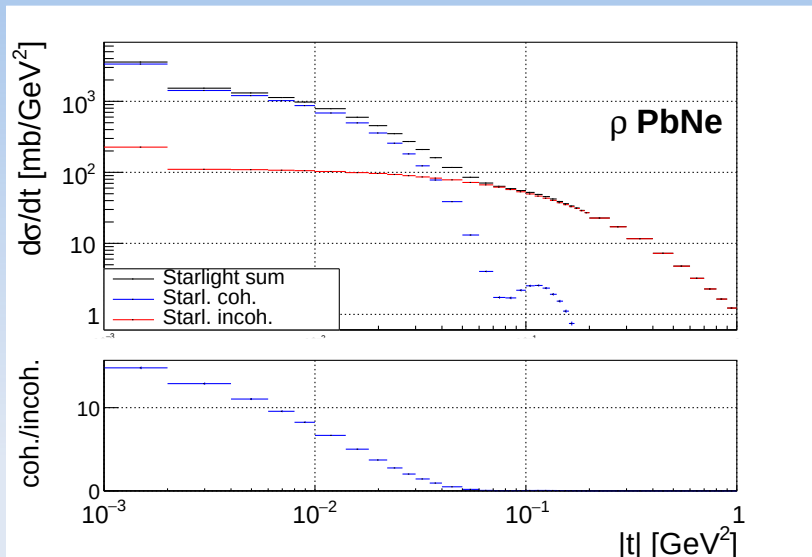
- Using the STARLIGHT event generator: applying the LHCb selection and estimating the number of events
 - Acceptance cuts: $2 < \eta(\pi, \mu) < 5$, $p_T(\pi, \mu) > 0.2 \text{ GeV}$, $2 < y(VM) < 5$
 - Assuming 100% acceptance*efficiency in this phase space
 - Assigning a **statistical uncertainty** of $\sqrt{N_{\text{LHCb}}}$ bin-wise and propagating it to the cross section (N_{LHCb} : upper limits), assuming that the statistical uncertainty dominates the uncertainty on the cross section
- **Fixed target** mode, $\sqrt{s_{\text{NN}}} = 71 \text{ GeV}$ with SMOG2 in Run 3 (many collision systems available)
- **Light ions** in symmetrical **collision** mode, $\sqrt{s_{\text{NN}}} = 5.36 \text{ TeV}$ in Run 3, including predictions from the hotspot model with variations of the **geometrical structure**, comparison to expected precision

Cross sections in fixed target mode

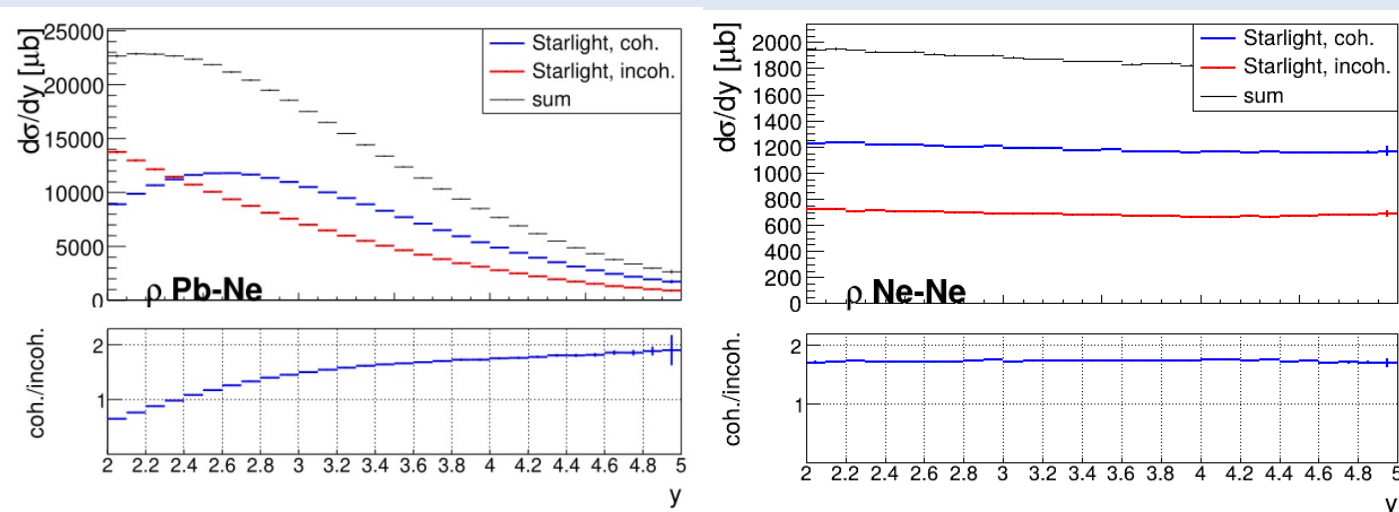
fid: $2 < y_{\text{VM}} < 5$	Pb-Ar, 71 GeV 2 nb^{-1}		Pb-Ne, 71 GeV 0.02 nb^{-1}		O-O, 5.36 TeV 5.5 nb^{-1}		Ne-Ne, 5.36 TeV 0.6 nb^{-1}	
	$\sigma_{\text{fid.}} \cdot \text{Br}$	N_{LHCb}	$\sigma_{\text{fid.}} \cdot \text{Br}$	N_{LHCb}	$\sigma_{\text{fid.}} \cdot \text{Br}$	N_{LHCb}	$\sigma_{\text{fid.}} \cdot \text{Br}$	N_{LHCb}
$\rho \rightarrow \pi\pi \text{ coh.}$	25.8 mb	52M	16.3 mb	980k	1.31 mb	7.2M	2.44 mb	1.5M
$\rho \rightarrow \pi\pi \text{ incoh.}$	15.5 mb	31M	10.1 mb	610k	0.69 mb	3.8M	1.23 mb	0.7M
$J/\psi \rightarrow \mu\mu \text{ coh.}$	52 nb	100	38 nb	2	145 nb	790	276 nb	170
$J/\psi \rightarrow \mu\mu \text{ incoh.}$	199 nb	400	125 nb	7	160 nb	860	285 nb	170

- In **fixed target** mode, ^{208}Pb is the **beam** and most interactions **probe** the **lighter nucleus**, with the heavier nucleus emitting the photon.
- **High statistics** for ρ photoproduction expected from collected data
- Inclusive **J/ψ** photoproduction measurements in **Pb-Ar, Ne-Ne** should be **feasible**, possibly differential J/ψ measurement in O-O
- Symmetrical light-ion collisions compared to fixed target Pb-X: higher energy and smaller system size (competing effects on σ)
 - Different collision energy dependence for ρ and J/ψ photoproduction

Fixed target & symmetrical collisions

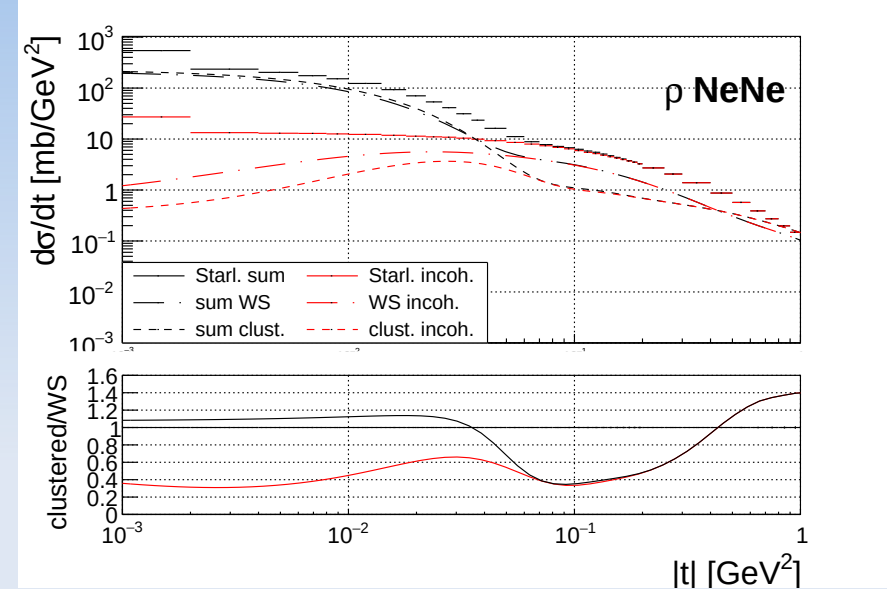
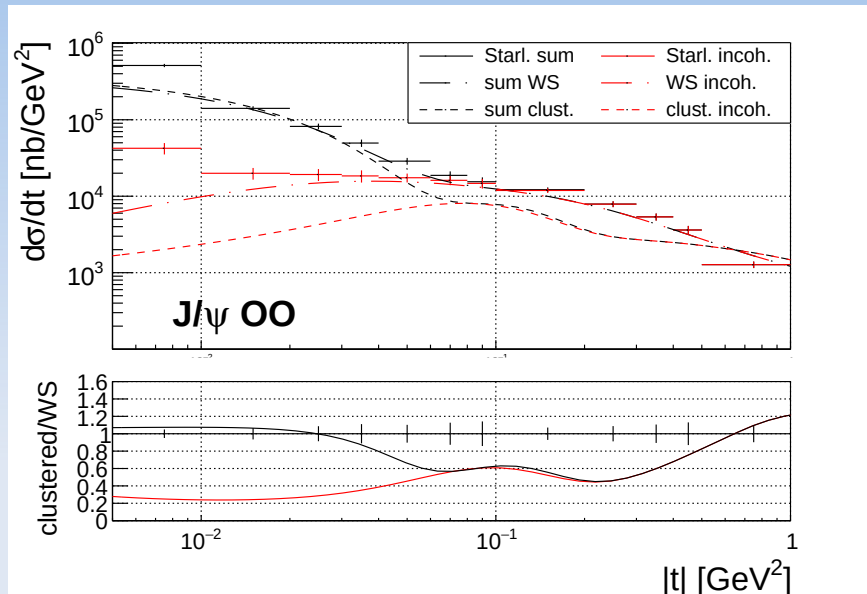


- The **nuclear structure** imprints on the **t**-distribution ($\sim$ momentum transfer to the target ion), evaluated as $|t| \sim p_T^2$ of the VM
- As expected, **coherent** photoproduction of VMs results in a much **lower average transverse momentum** than incoherent
 - The 2nd coherent diffractive peak is buried underneath the incoherent process



In **fixed target** kinematics: the **coherent** contribution is expected to peak at **larger rapidity** than the incoherent one

Adding the coherent and incoherent cross sections



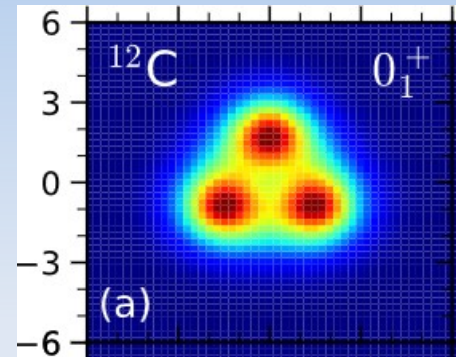
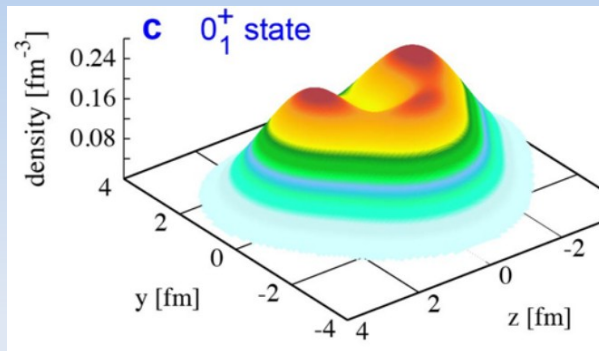
- The statistical uncertainty is shown as errorbars in both panels
- Sizeable **impact** from **structure** in the **incoherent prediction**
 - Better **separated** from the coherent process at **higher |t|**

$0.07 < t < 0.2 \text{ GeV}^2$	ρ O-O	J/ψ O-O	ρ Ne-Ne	J/ψ Ne-Ne
difference in pred.	35%	43%	61%	65%
stat. precision	0.09%	6%	0.2 %	14%

- Should consider **luminosity** uncertainty $\sim 6\%$ or mitigate it with ratios

^{12}C and ^{24}Mg for New Ions@LHC

- Recent simulation studies suggest **clustering** component in the **ground state** of ^{12}C (in contrast with previous paradigm)

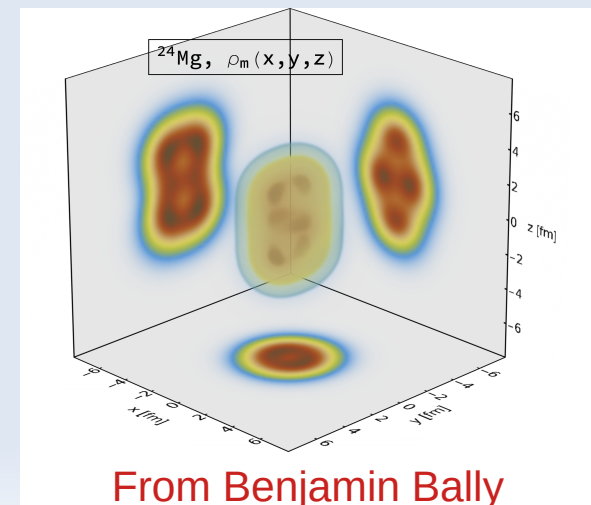


T. Otsuka et al, Nat Commun 13, 2234 (2022)

S. Shen et al, Nat. Commun. 14 (2023) 2777

- Recent **analyses** of low-energy ^{12}C reactions suggest presence of **clustering**
K. Yoshida, M. Kimura arXiv:2606.31437
W. Horiuchi, N. Itagaki Phys.Rev.C 107 (2023) 2

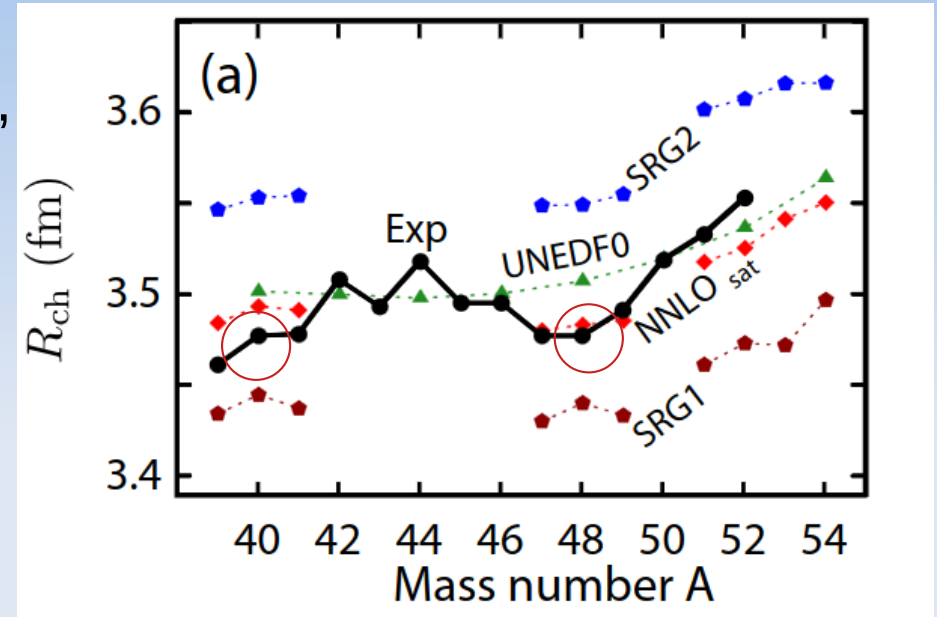
- Improving understanding of **transitions** to excited **Hoyle** state in ^{12}C and ^{24}Mg synthesis from ^{12}C in **supernovae**
- Studying **clustering** in both **small** and **intermediate** sized systems



From Benjamin Bally

Ca for New Ions@LHC

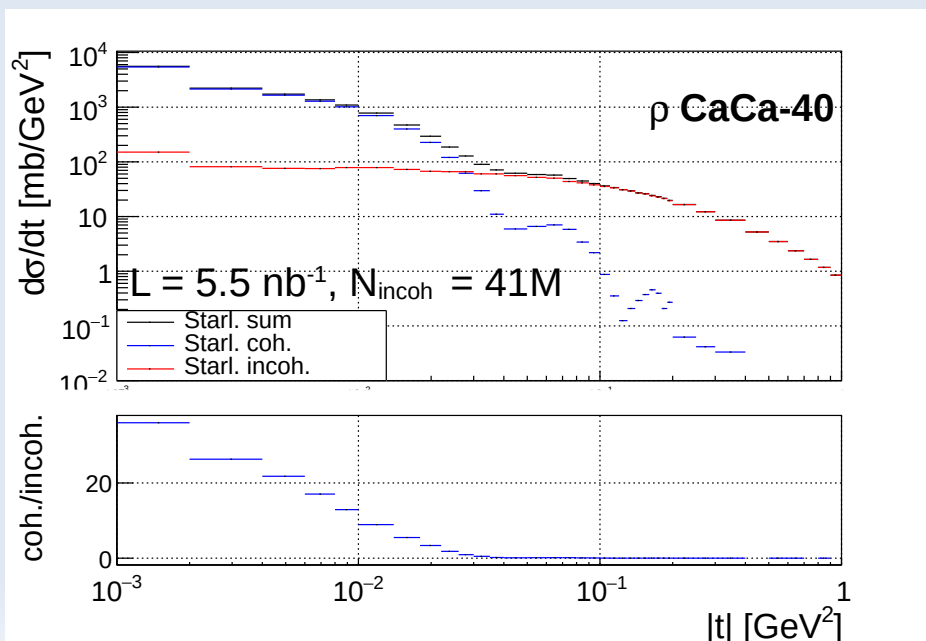
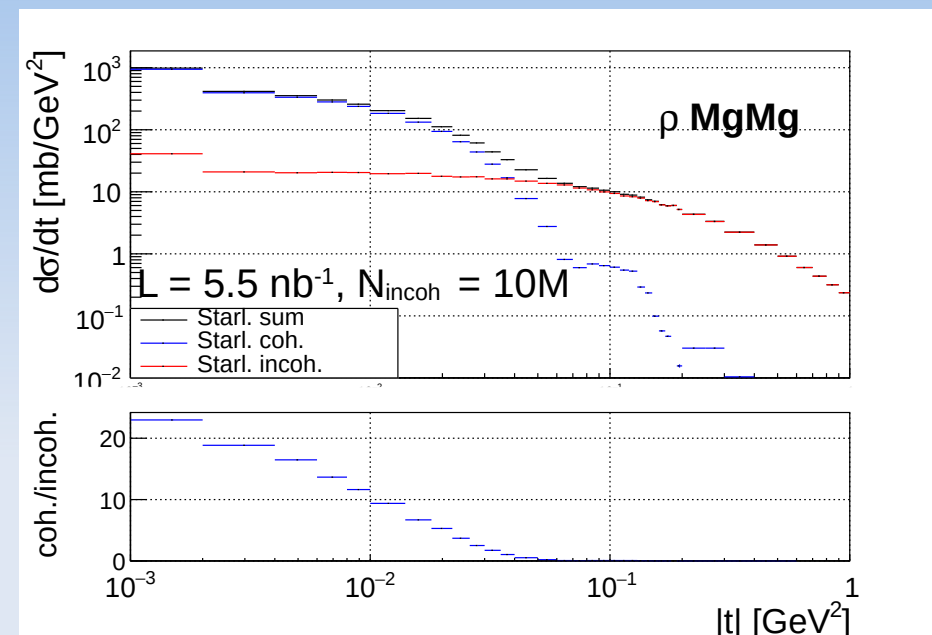
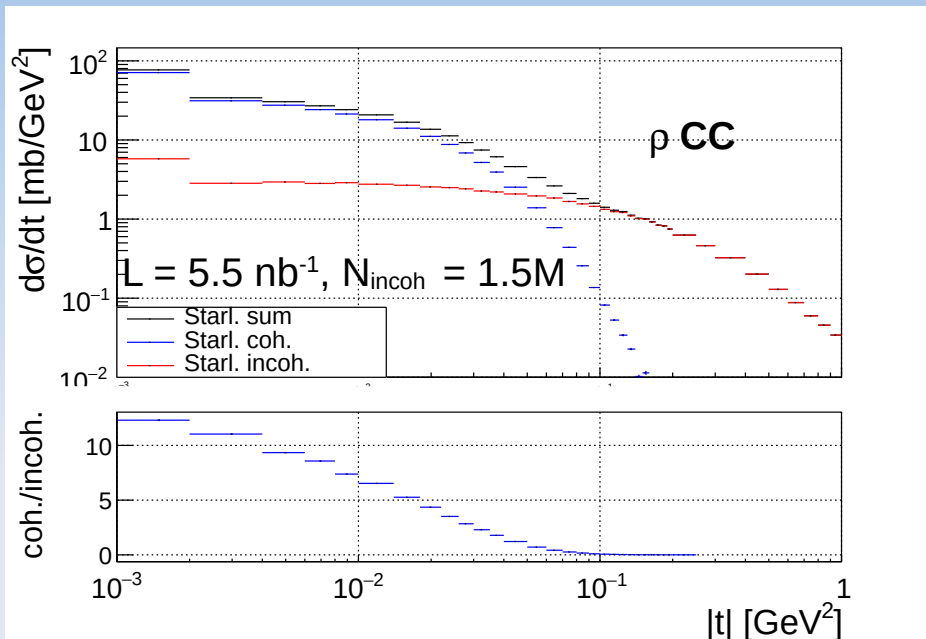
- Strange trend in **calcium charge radii**: similar size for $A=40$, $A=48$, and larger radii for intermediate even-even isotopes
- Benchmarks for ab initio models in nuclear theory
- **Ideally** would like to measure **2-3 isotopes** to test differences



Garcia Ruiz, R. *Nature Phys* 12, 594–598 (2016)

- But it currently looks like we may get **at most one** isotope, with a preference for $A=48$ to measure the neutron skin and use as input to equation of state for **neutron stars**
- Maybe ^{40}Ca would be the most interesting in the context of the charge radii: unusually small, with possible cluster substructure

A first look at the t-distributions



$\langle p_T^{\text{VM}} \rangle$ decreases with system size
for the coherent process → better
access to incoherent process at
lower $|t|$ at high A

What is our sensitivity to structure?

$N_{J/\psi}$: 2-3 orders of magnitude smaller

Summary and conclusions

- Investigating **feasibility** to measure **VM photoproduction** in light ion collisions and with SMOG2 in collected Run 3 data with LHCb
 - Millions of p events are expected in both modes
 - Hundreds of J/ψ events expected in O-O, Ne-Ne and Pb-Ar runs
- **Diffraction** structure simulated in $|t|$, with a **softer coherent spectrum**
- Probing the **sensitivity to clustering** in O-O and Ne-Ne collisions, in the framework of the hot spot model
 - Looks **promising** in a region enriched in **incoherent** events
 - By evaluating ratios in $|t|$ intervals one could cancel out the luminosity uncertainty
 - The uncertainty on the **modelling** should be kept in mind
- Preparing for the New Ions initiative, currently focusing on ^{12}C , ^{24}Mg
 - 3D density obtained for ^{24}Mg from Benjamin Bally
 - Also considering ^{40}Ca (^{48}Ca), ^{76}Ge

Thank you! Merci! Danke!

Thank you to Laure Massacrier, J. Guillermo Contreras, Vladimir Manea, Didier Beaudamel, David Verney, Thomas Duguet and others for fruitful discussions!

Thank you to **Alexandra Ridzikova** for predictions in the LHCb acceptance region!

Thank you, all, for your attention!

Complementarity low-high energy

Low energy measurements

- Great **flexibility** in choice of nuclei to probe
- Ground and excited **states accessible**
- More **contamination** of the probed state from excitations
- Need to construct Kumar invariant by exciting to all states, measure and sum over results (not all states available)

T. Duguet, slide 37-39

Heavy ions at LHC

- Very **short interaction times** → clean ground state
 - Possible contamination from excited states if they are close in energy?
- **Expensive** beam time, with priority to pp/PbPb/pPb
 - Still, **new collision systems** possible for Run 4
 - Fixed (gas) target mode with **SMOG2** can provide larger **variety** of systems

Will we see the same thing at low and high energy?

Complementarity flow – photoproduction in UPC

Flow

- Measure **correlations** between charged particles in hadronic collisions
- Can get useful measurements even from very short runs
- **Indirect** measurement: how do final state particles imprint on the QGP?
- Relies on **hydrodynamic modelling** and well-calibrated **centrality**

VM photoproduction

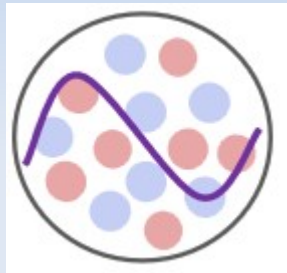
- Probes the **initial state** (more direct measurement)
- Ultra-peripheral collisions
 - Clean signature
 - Less statistics than for hadronic events
- **Theoretical modelling** of the process needs to be well understood

Will the measurements give a consistent picture?

Coherence of VM photoproduction

Coherent VM photoproduction

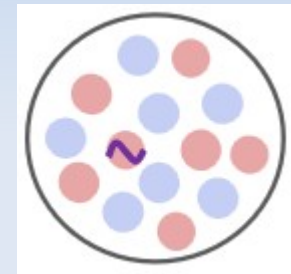
- The photon interacts coherently with the whole target nucleus



- $\langle p_T^{VM} \rangle \sim 1/\text{Radius} \sim 60 \text{ MeV}$ for Pb
- Usually no breaking of target nucleus
- Sensitive to **nuclear parton distribution functions**

Incoherent VM photoproduction

- A single nucleon emits the gluon

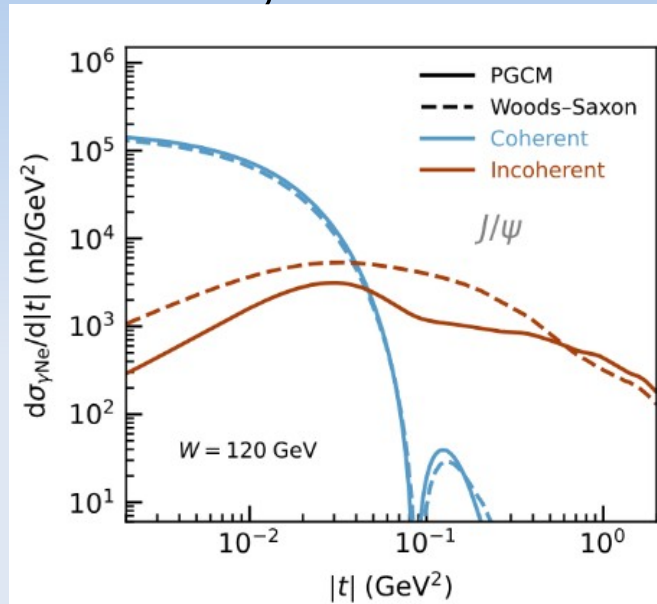


- **Higher** $\langle p_T^{VM} \rangle \sim 500 \text{ MeV}$
- Usually breaks the target nucleus
- Sensitive to nuclear **geometry**

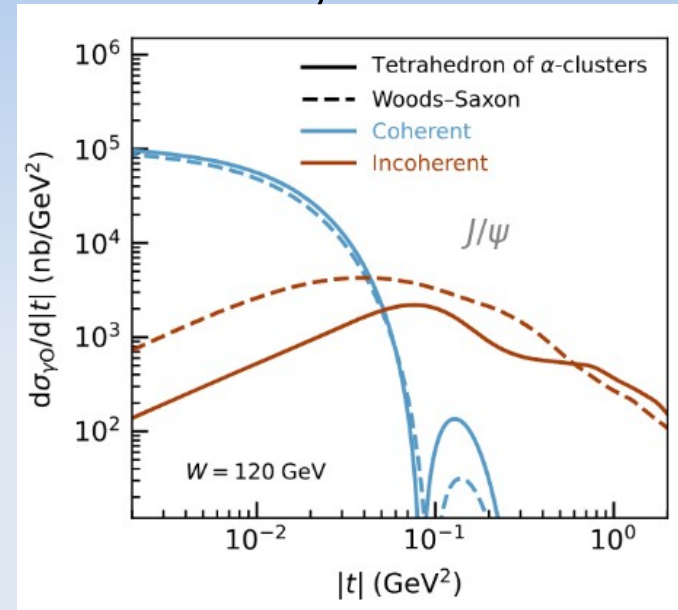
p_T : projection of the momentum on the plane transverse to the beam axis

How does nuclear structure affect the VM cross section?

O-O, 5.36 TeV



Ne-Ne, 5.36 TeV



J. Cepila et al., Phys. Rev. C. 113 (2026) 2, 025202

- **Coherent** process: main impact from nuclear structure is on the magnitude of the **second diffractive peak**
- **Incoherent** process: change in **shape** of the t-differential cross section and the **position** of the **dips**

Nuclear imaging with VMs: dipole-nucleus cross section

$$\text{Nuclear structure} \rightarrow T_A(\vec{b}) \rightarrow \frac{d\sigma_A^{\text{dip}}}{d\vec{b}} \rightarrow \mathcal{A}_{T,L}(x, Q^2, \vec{\Delta}) \rightarrow \frac{d\sigma}{d|t|}$$

dipole-nucleus cross section

target profile, encoding
nuclear structure

$$\left(\frac{d\sigma_A^{\text{dip}}}{d\vec{b}} \right) = 2 \left[1 - \left(1 - \frac{1}{2A} \sigma_0 N(x, r) T_A(\vec{b}) \right)^A \right]$$

dipole scattering amplitude related to small-x QCD dynamics

- depends on Bjorken-x and the transverse size of the dipole
- Includes cold nuclear matter effects (shadowing, saturation)

Nuclear imaging with VMs: vector meson amplitude

$$\text{Nuclear structure} \rightarrow T_A(\vec{b}) \rightarrow \frac{d\sigma_A^{\text{dip}}}{d\vec{b}} \rightarrow \mathcal{A}_{T,L}(x, Q^2, \vec{\Delta}) \rightarrow \frac{d\sigma}{d|t|}$$

dipole extension

VM wave function

Dipole-nucleus interaction profile

$$\mathcal{A}_{T,L}(x, Q^2, \vec{\Delta}) = i \int d\vec{r} \int_0^1 \frac{dz}{4\pi} \int d\vec{b} |\Psi_V^* \Psi_{\gamma^*}|_{T,L} \exp \left[-i \left(\vec{b} - \left(\frac{1}{2} - z \right) \vec{r} \right) \cdot \vec{\Delta} \right] \frac{d\sigma_H^{\text{dip}}}{d\vec{b}}$$

VM production amplitude,
dependent on Bjorken- x ,
photon virtuality Q^2 and t

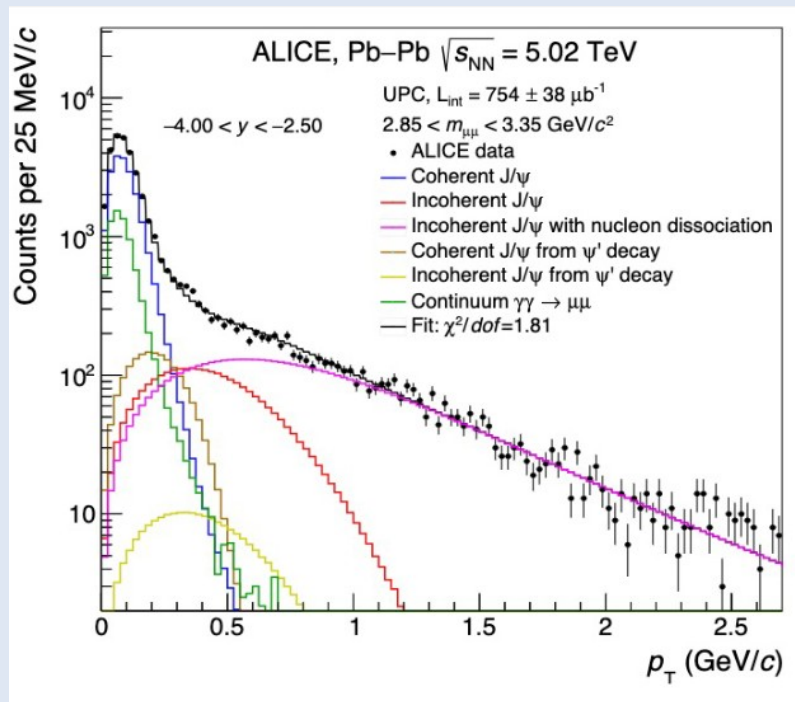
dipole wave function

Momentum transfer
to target ion, $\Delta^2 = |t|$

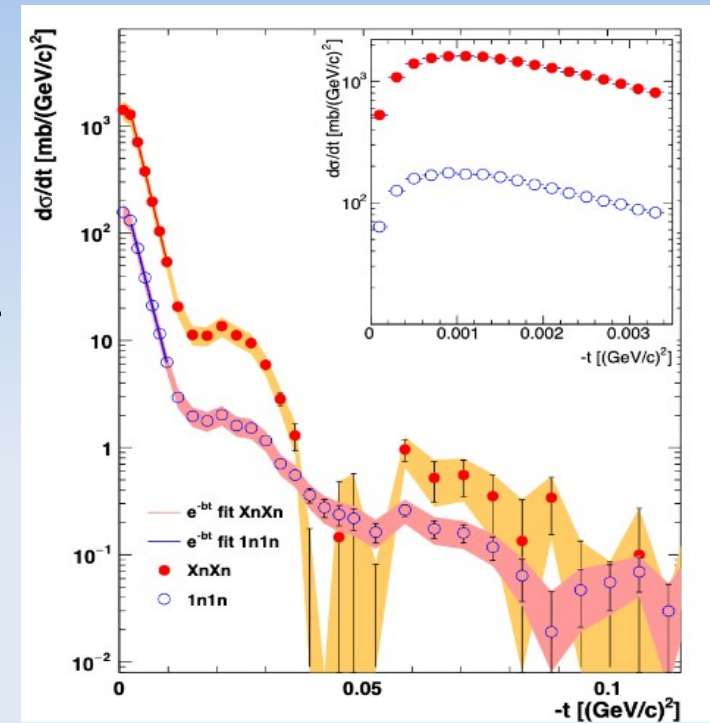
The **spatial structure** in $\vec{b}$ is related to the
momentum transfer $\vec{\Delta}$ via a Fourier transform

Feasibility to constrain nuclear structure with VMs in UPC

- Extraction of second peak challenging in coherent VM photoproduction.
 - Measurements exist for the abundant ρ^0
- Clean coherent/incoherent separation (p_T cut or template fits of p_T distributions). Requires good p_T (t) **resolution**



ALICE, Phys. Lett. B798 (2019) 134926

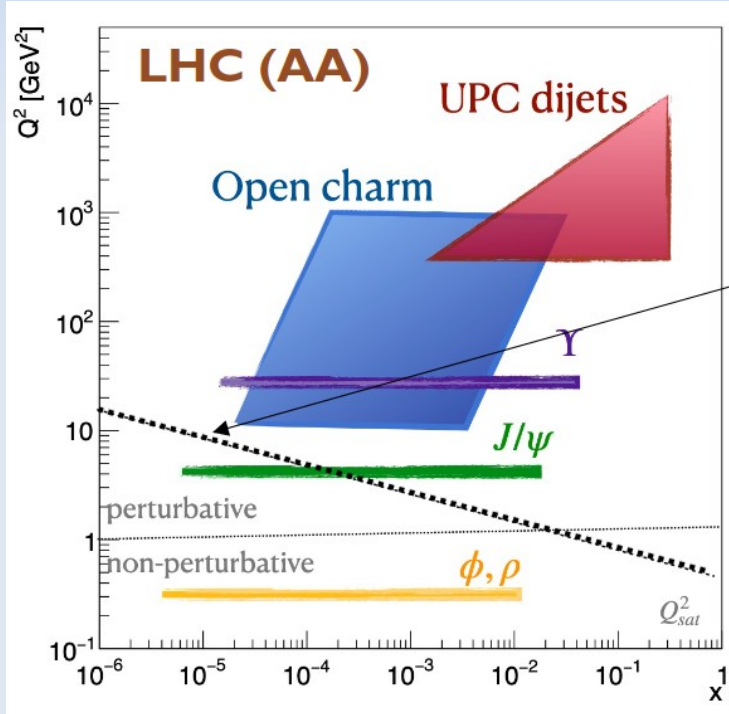


STAR, Phys. Rev. C. 96 054904

- I perform **projections** for some of the many available systems available at **LHCb**
 - **fixed target** and **collision** modes

Complementarity of VM photoproduction measurements

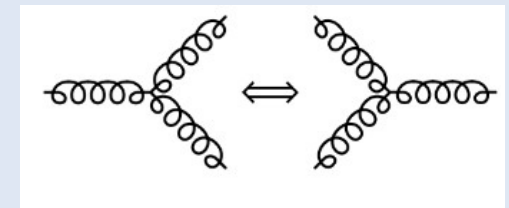
- Using **different VMs** changes the spatial resolution of the probe
 - Same nuclear geometry, hotspot model, formalism
 - But different VM wave function, different dipole sizes, pdf sensitivity



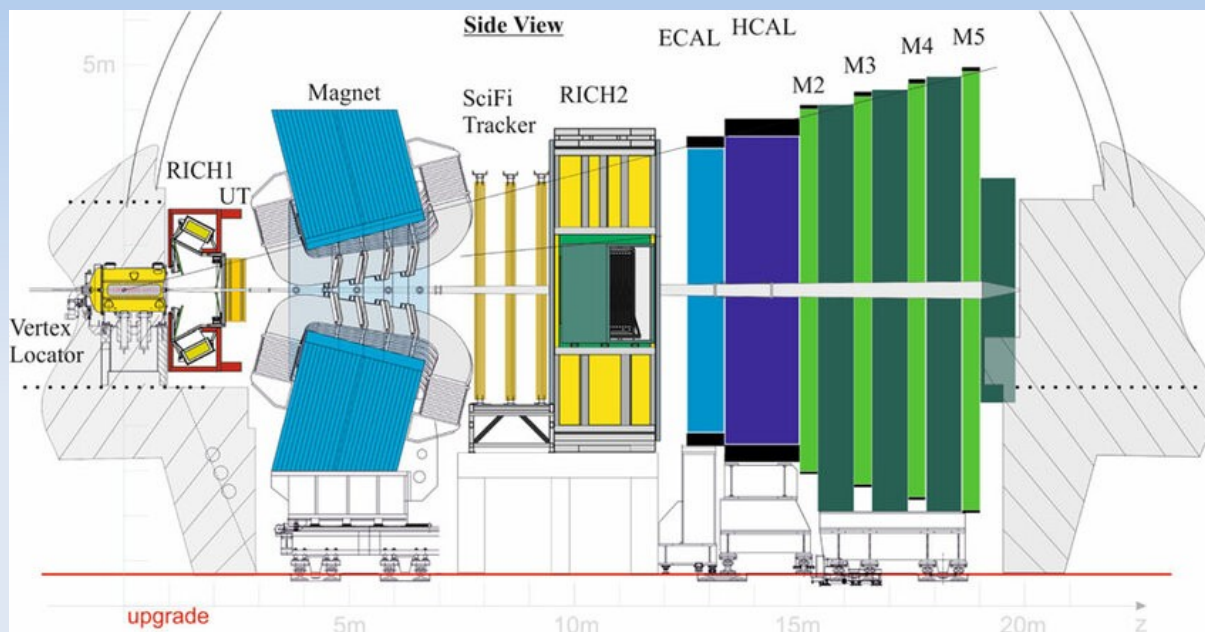
N. Burmasov LHCP 2026

Vector meson	ρ^0	J/ψ
Quark content	light (u, d)	charm pair ($c\bar{c}$)
Mass	0.77 GeV	3.1 GeV
Dipole size	large	small
Typical Q^2	small $\sim 0.3 \text{ GeV}^2$	larger $\sim 4 \text{ GeV}^2$
Typical x range	$7 \cdot 10^{-5} - 10^{-2}$	$5 \cdot 10^{-5} - 10^{-2}$
Interaction regime	Non-perturbative	More perturbative
Saturation sensitivity	Stronger	Weaker; non-negligible small x

Saturation: (hypothetical) stop of growth of gluon density with decreasing x

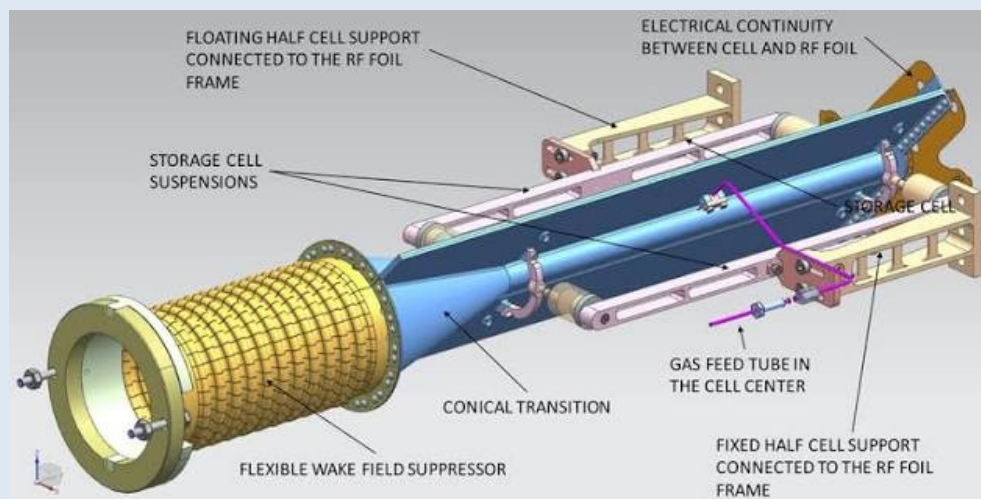


The LHCb experiment



LHCb is a forward single-arm spectrometer, covering $2 < \eta < 5$

- Provides **excellent p_T resolution**



- **Fixed target mode with SMOG2**
 - large flexibility in choice of gas target
- Typical c.o.m. energies: ~ 5 TeV for collision mode, ~ 70 GeV for fixed target

Cross sections in fixed target mode

^{208}Pb beam on ^{40}Ar or ^{20}Ne target. Most interactions **probe** the **lighter nucleus**, with the heavier nucleus emitting the photon.

Pb-Ar, 71 GeV, 2 nb^{-1}			
	σ	σ_{LHCb}	N_{LHCb}
$\rho \rightarrow \pi^+ \pi^-$ coherent	40.1 mb	25.8 mb	52M
$\rho \rightarrow \pi^+ \pi^-$ incoherent	60.7 mb	15.5 mb	31M
$J/\psi \rightarrow \mu^+ \mu^-$ coherent	84.1 nb	52 nb	100
$J/\psi \rightarrow \mu^+ \mu^-$ incoherent	449.0 nb	119 nb	400
Pb-Ne, 71 GeV, 0.06 nb^{-1}			
$\rho \rightarrow \pi^+ \pi^-$ coherent	26.4 mb	16.3 mb	1.5M
$\rho \rightarrow \pi^+ \pi^-$ incoherent	37.3 mb	9.9 mb	0.7M
$J/\psi \rightarrow \mu^+ \mu^-$ coherent	58 nb	38 nb	2
$J/\psi \rightarrow \mu^+ \mu^-$ incoherent	255 nb	123 nb	7

- **High statistics** for ρ photoproduction expected from collected data
- A J/ψ photoproduction measurement in **Pb-Ar** looks **feasible**

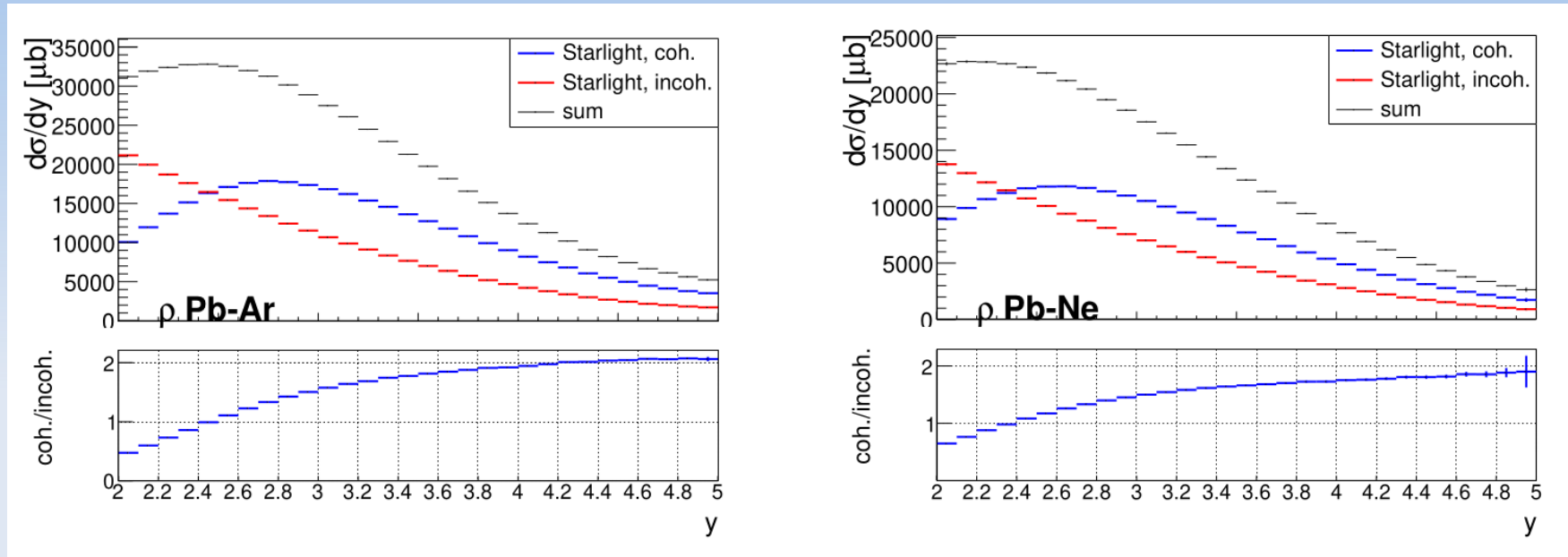
Cross sections in collision mode

Symmetrical collisions of ^{16}O - ^{16}O and ^{20}Ne - ^{20}Ne at **5.36 TeV**

O-O, 5.36 TeV, 5.5 nb^{-1}			
	σ	σ_{LHCb}	N_{LHCb}
$\rho \rightarrow \pi^+\pi^-$ coherent	8.65 mb	1.31 mb	7.2M
$\rho \rightarrow \pi^+\pi^-$ incoherent	6.62 mb	0.69 mb	3.8M
$J/\psi \rightarrow \mu^+\mu^-$ coherent	$1.34 \mu\text{b}$	$0.14 \mu\text{b}$	790
$J/\psi \rightarrow \mu^+\mu^-$ incoherent	449.0 nb	119 nb	400
Ne-Ne, 5.36 TeV, 0.6 nb^{-1}			
$\rho \rightarrow \pi^+\pi^-$ coherent	15.9 mb	2.4 mb	980k
$\rho \rightarrow \pi^+\pi^-$ incoherent	11.8 mb	1.2 mb	590k
$J/\psi \rightarrow \mu^+\mu^-$ coherent	$2.6 \mu\text{b}$	$0.28 \mu\text{b}$	170
$J/\psi \rightarrow \mu^+\mu^-$ incoherent	$2.8 \mu\text{b}$	$0.29 \mu\text{b}$	170

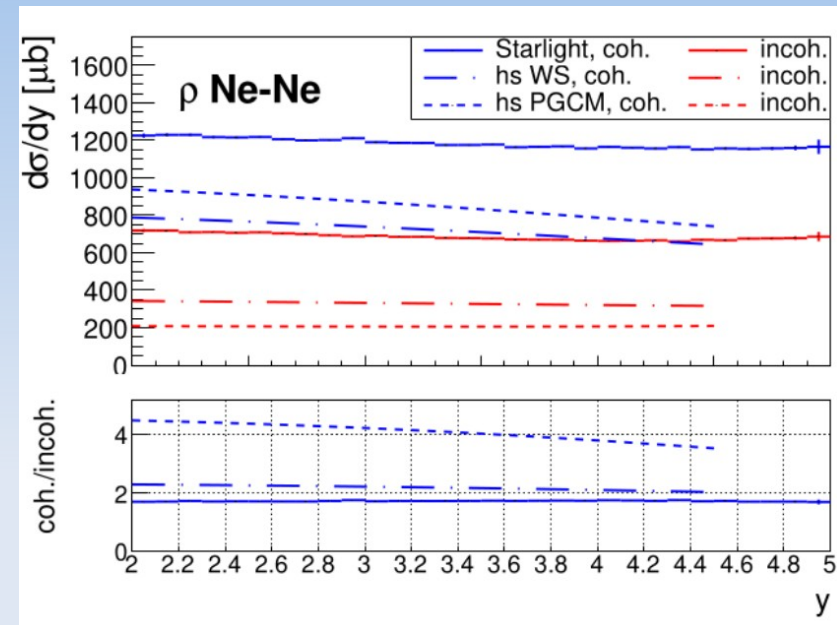
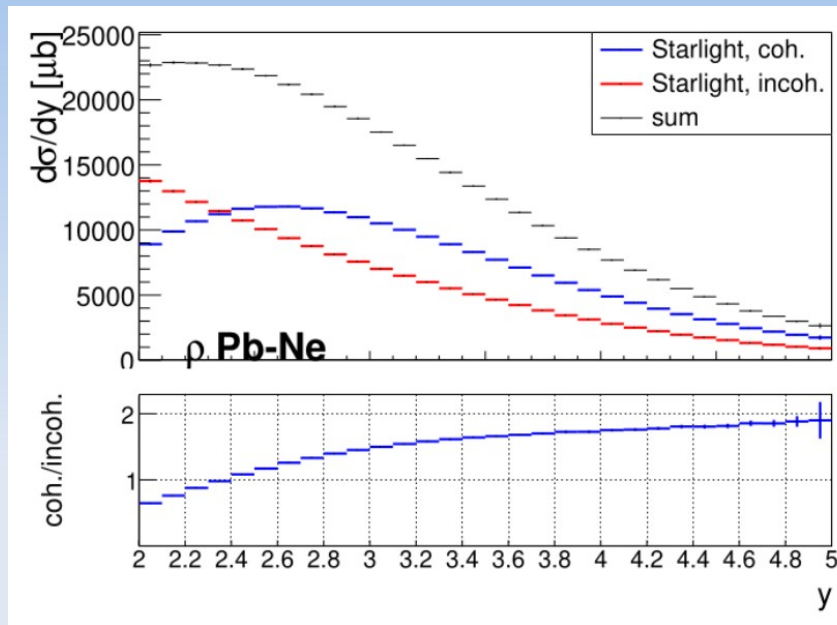
- Higher energy and **smaller system size** (competing effects on σ)
 - Different energy dependence for ρ and J/ψ photoproduction
- High statistics for ρ and J/ψ measurements are feasible

Rapidity in fixed target events



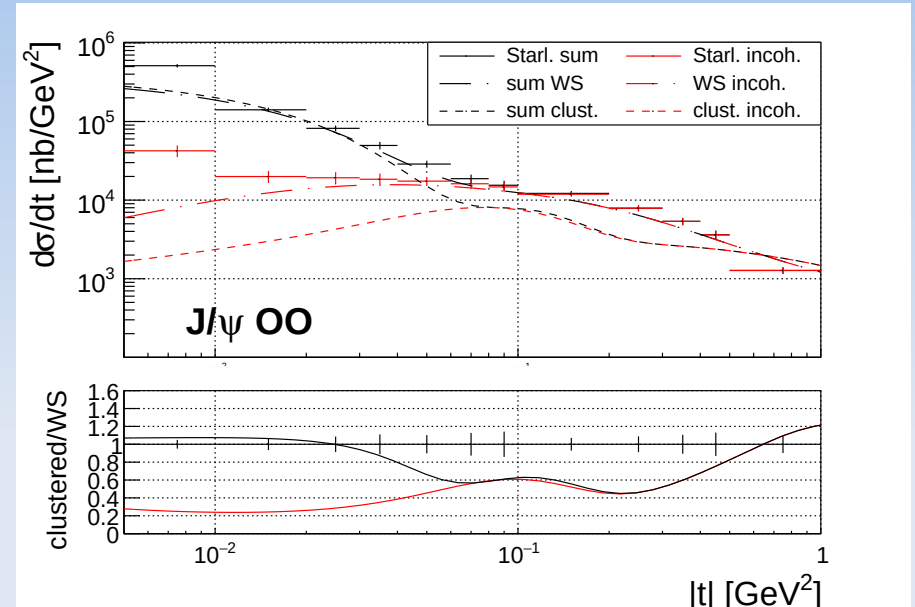
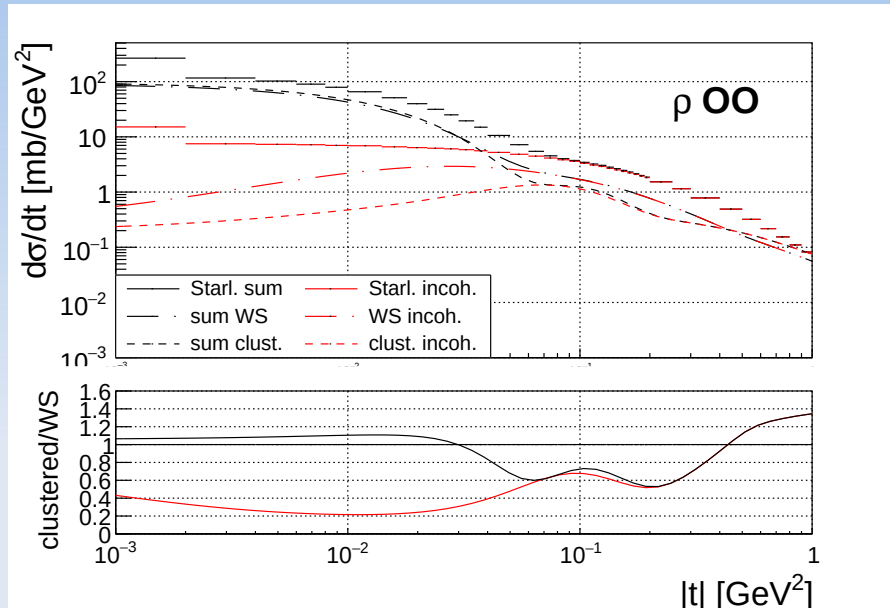
- The **coherent** process, which has lower p_T , and is **boosted** to **higher rapidity** than the incoherent one
- The LHCb acceptance cuts result in an enrichment of coherent events for fixed target interactions

Rapidity: fixed target vs symmetrical



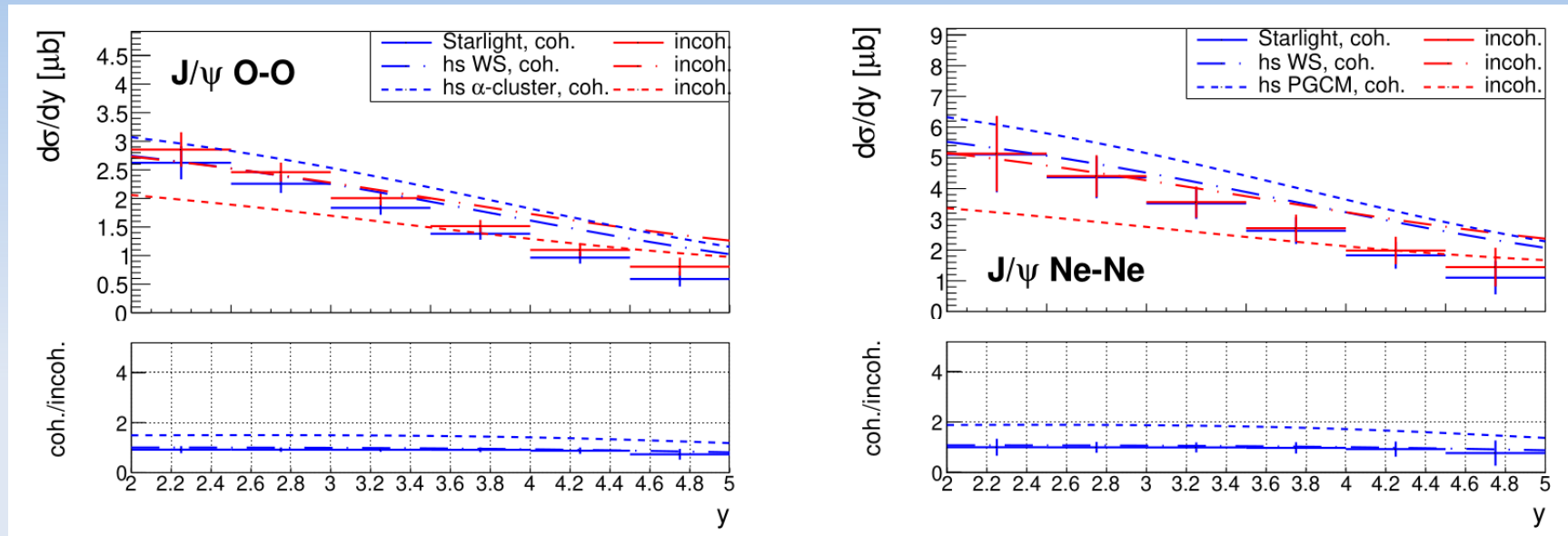
- The **coherent** process, which has lower p_T , and is **boosted** to **higher rapidity** than the incoherent one in fixed target events
- A small statistical uncertainty on ρ cross sections
- The Woods-Saxon and clustered predictions result in **different yields**, with no major impact on shape in y in Ne-Ne collisions.

Adding the coherent and incoherent cross sections, O-O



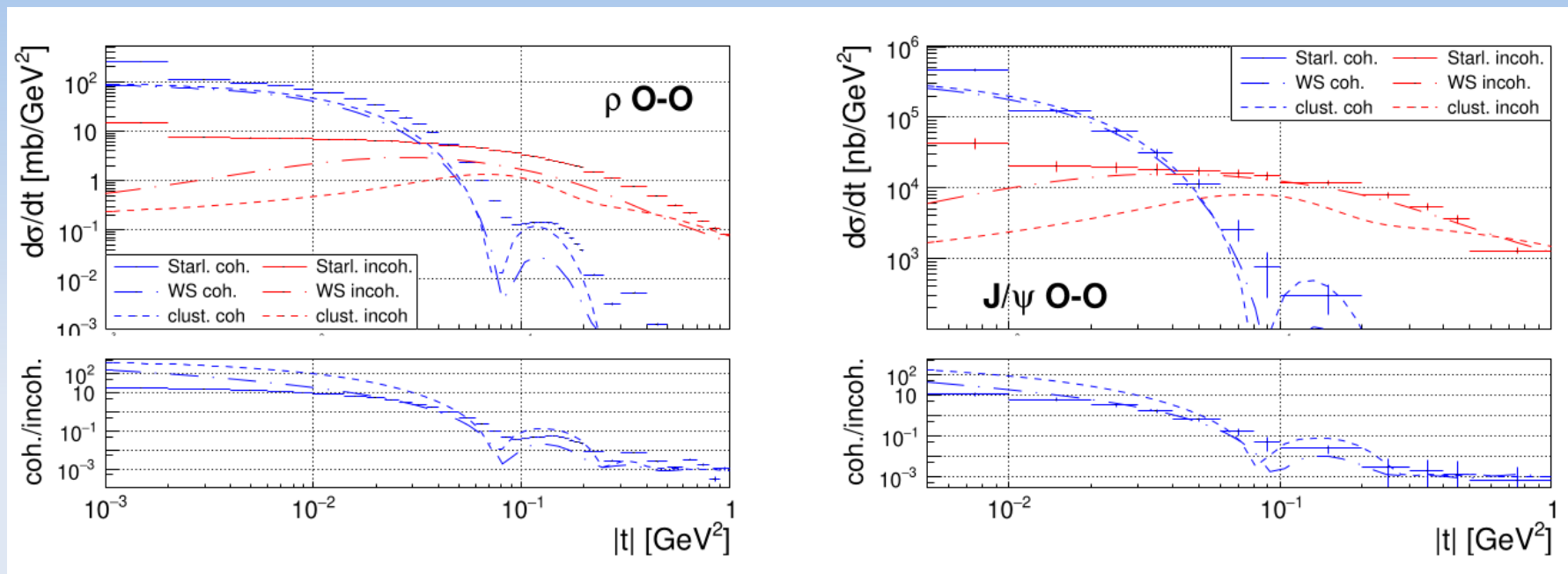
- Sizeable **impact** from **structure** in the **incoherent prediction**
 - Better **separated** from the coherent process at **higher $|t|$**
- Considering **sum** of the 2 processes rather than attempting separation
 - 30-40% lower clustered** prediction at **intermediate $|t|$** $\sim 10^{-1}$
- The statistical uncertainty is shown as errorbars in both panels
- Cold nuclear matter effects in the hot spot model are prominent at low $|t|$

γ distributions for J/ψ , light ions



- Smaller statistical precision for J/ψ
- The coherent and incoherent predictions are very similar in the clustered case
- **Higher slope** than for ρ photoproduction

t distributions, O-O



- Cold nuclear matter effects (shadowing, saturation) are included in the hotspot model and are prominent at low $|t|$, resulting in a lower cross section than in the STARLIGHT simulation
- Second diffractive coherent peak buried under the incoherent process
- Sizeable **impact** from **structure** in the **incoherent prediction**
 - Better **separated** from the coherent process at **higher $|t|$**

New Ions @ LHC

What ions should we collide in **LHC Run 4** (2029-)? Science case?
Syneries?

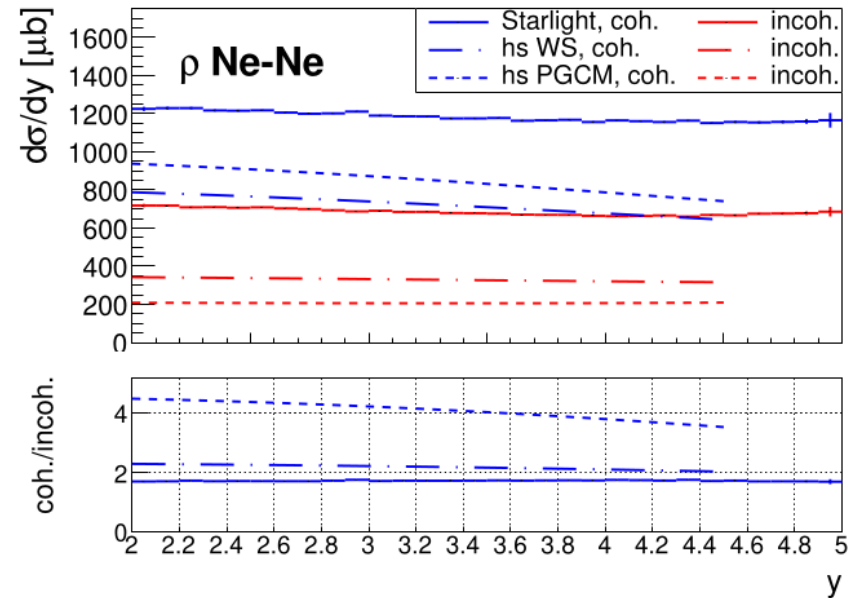
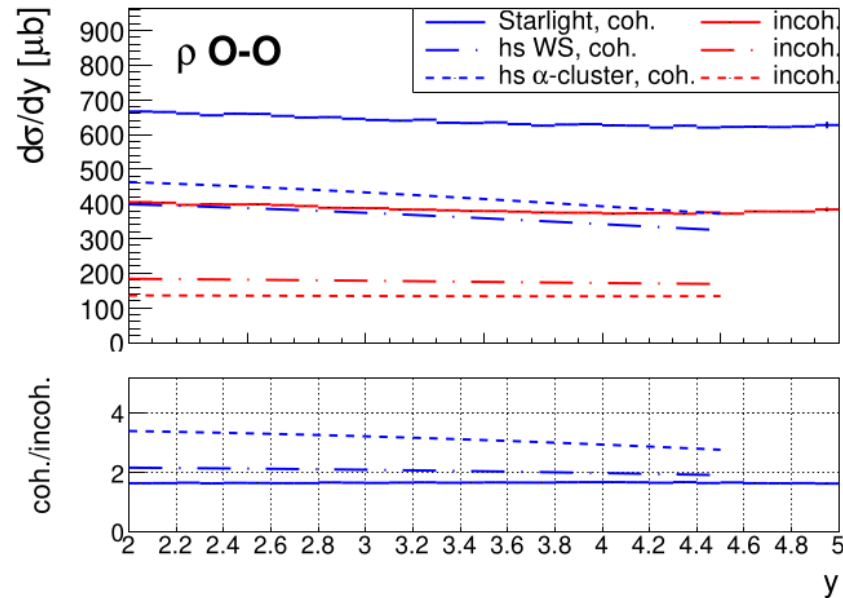
Possible candidates for symmetrical collisions:

Species $\rightarrow$ ^4He , ^{12}C , ^{16}O , ^{24}Mg , ^{40}Ar , $^{40,44,48}\text{Ca}$, $^{76}\text{Ge-Se}$, ^{86}Kr , $^{136}\text{Ba-Xe}$

- Abstract submissions to White Paper by 31st of October
- Contributions to New Ions White Paper by October 2028. Results can also appear as standalone publications

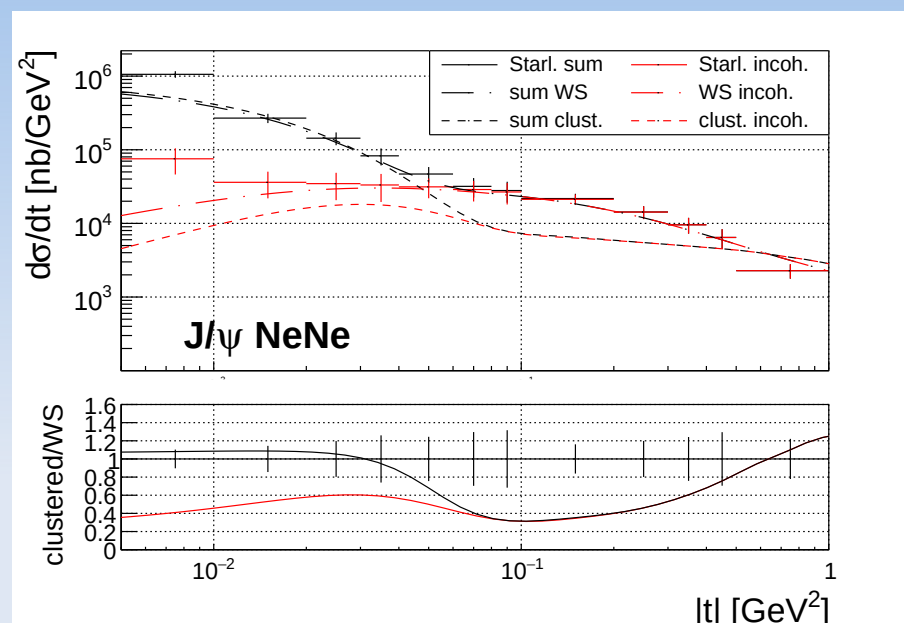
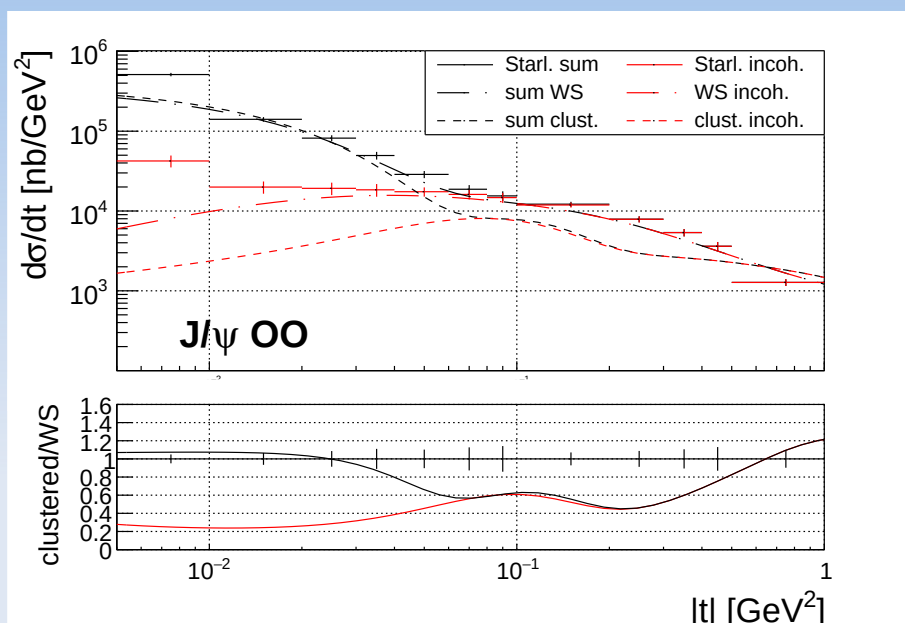
<https://indico.cern.ch/event/1697777/>

y distributions for ρ , light ions



- Again, a **small statistical uncertainty** on the ρ cross sections.
- In collider mode with the same nuclei in both beams, we do not profit from the boost to separate the two processes in rapidity.
- The Woods-Saxon and clustered predictions result in **different yields**, with no major impact on shape in y .

t distributions for J/ψ, light ions



Incoherent cross sections for potential New Ions

At 5.36 TeV and assuming an integrated **luminosity** of **5.5nb⁻¹**, while waiting for luminosity estimates (that may well be lower):

species	$\sigma^{\text{incoh.}}(\rho)$	N_{ρ}^{LHCb}	$\sigma^{\text{incoh.}}(J/\psi)$	$N_{J/\psi}^{LHCb}$
¹² C- ¹² C	2.66 mb	1.5M	586 nb	340
¹⁶ O- ¹⁶ O	6.62 mb	3.8 M	1.52 μ b	880
²⁴ Mg- ²⁴ Mg	19.0 mb	10M	4.50 μ b	2500
⁴⁸ Ca- ⁴⁸ Ca	81 mb	44M	20.8 μ b	11k

But what is our **sensitivity** to **geometrical shape**? Obtained density with clustering for ²⁴Mg. Requested **input densities** for ¹²C. Considering also ^xCa, ⁷⁶Ge

Thank you for your attention!