



# SPIN PHYSICS DETECTOR AT NICA

A. Guskov

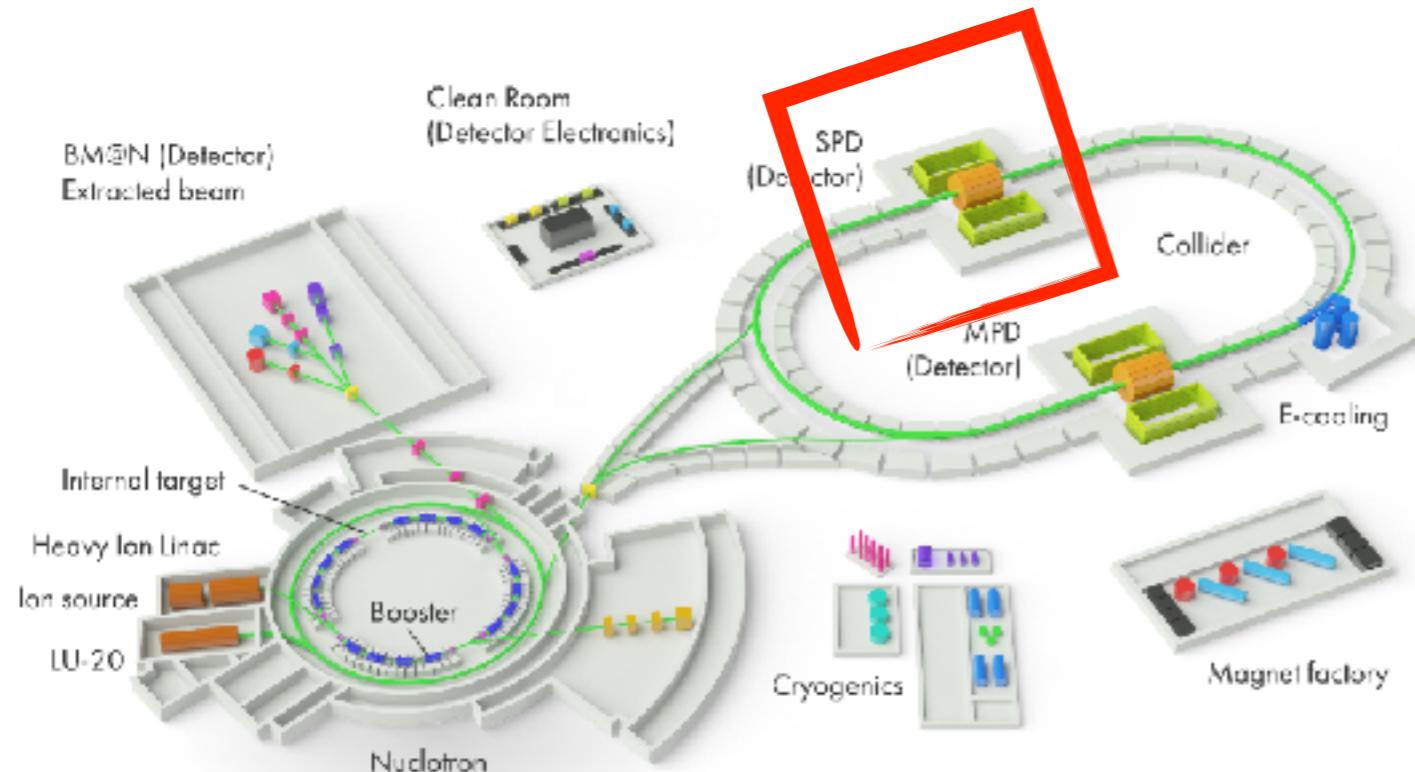
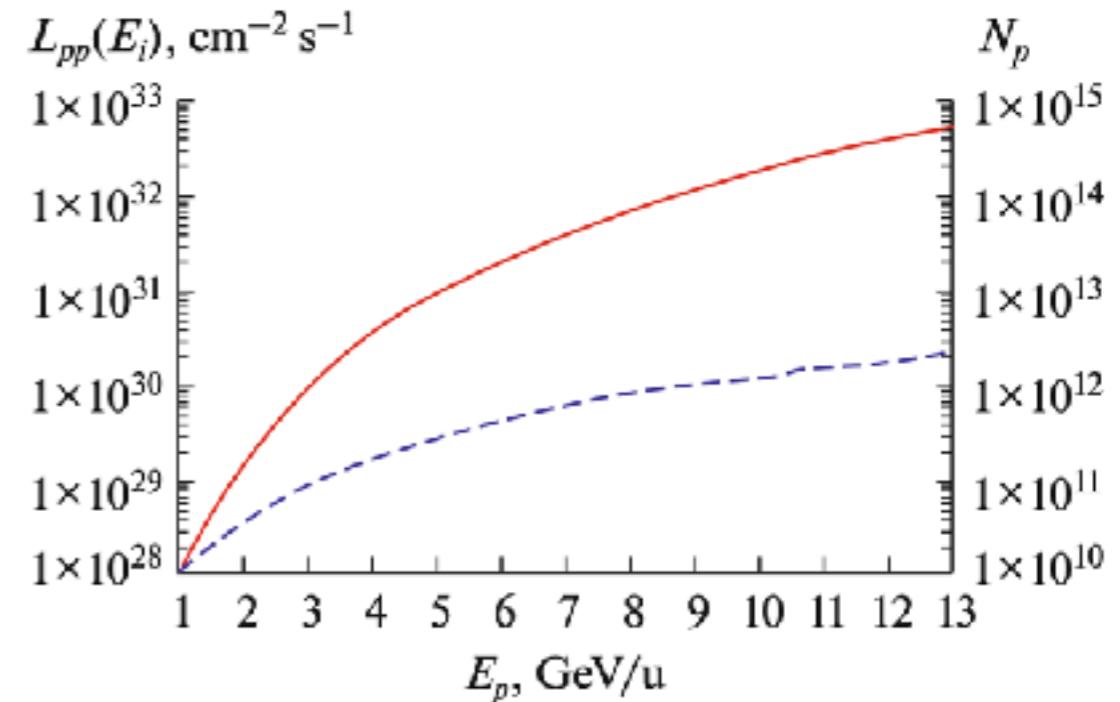
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18.5.2021

# SPD AT NICA

$p^\uparrow p^\uparrow : \sqrt{s} \leq 27 \text{ GeV}$   
 $d^\uparrow d^\uparrow : \sqrt{s} \leq 13.5 \text{ GeV}$   
 $d^\uparrow p^\uparrow : \sqrt{s} \leq 19 \text{ GeV}$

$U, L, T$   
 $|P| > 70\%$



**2021, January:** CDR presented  
[arXiv:2102.00442](https://arxiv.org/abs/2102.00442)

**2021, June:** report of the  
International Detector Advisory  
Committee (under formation)

**2022, January:** Technical Design  
Report

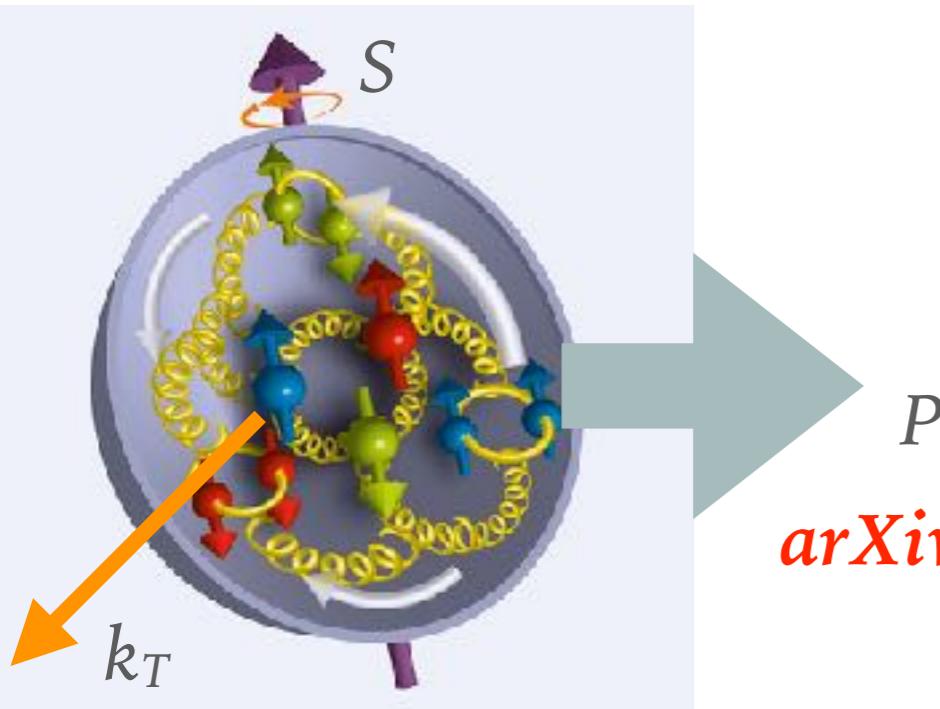
**2025+:** Operation

*The SPD international collaboration is forming now*

# PARTONIC STRUCTURE OF PROTON AND DEUTERON

$\sigma(x_F, p_T)$   $A_{LL}(x_F, p_T)$   $A_{TT}(x_F, p_T)$   $A_N(x_F, p_T)$

*Gluon content of proton and deuteron: TMD PDFs*

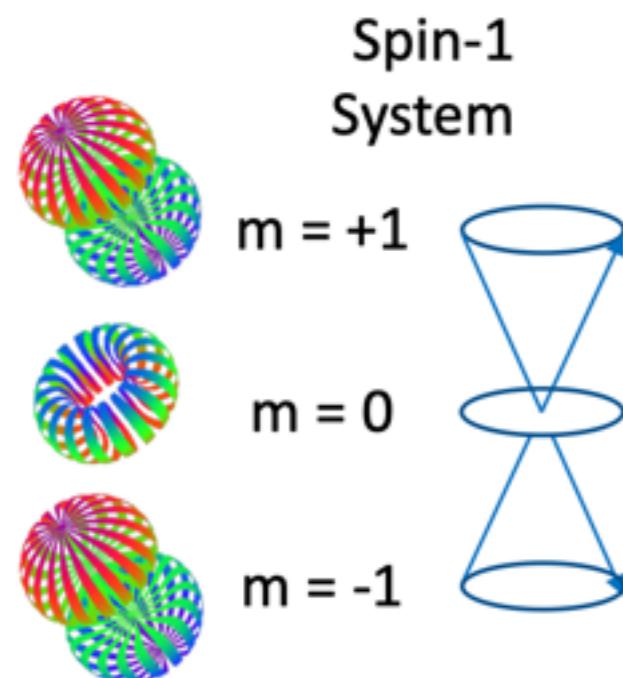


GLUONS	unpolarized	circular	linear
U	$f_1^g$		$h_1^{\perp g}$
L		$g_{1L}^g$	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	$g_{1T}^g$	$h_{1T}^g, h_{1T}^{\perp g}$

*arXiv:2011.15005*

*Physics of the first stage*

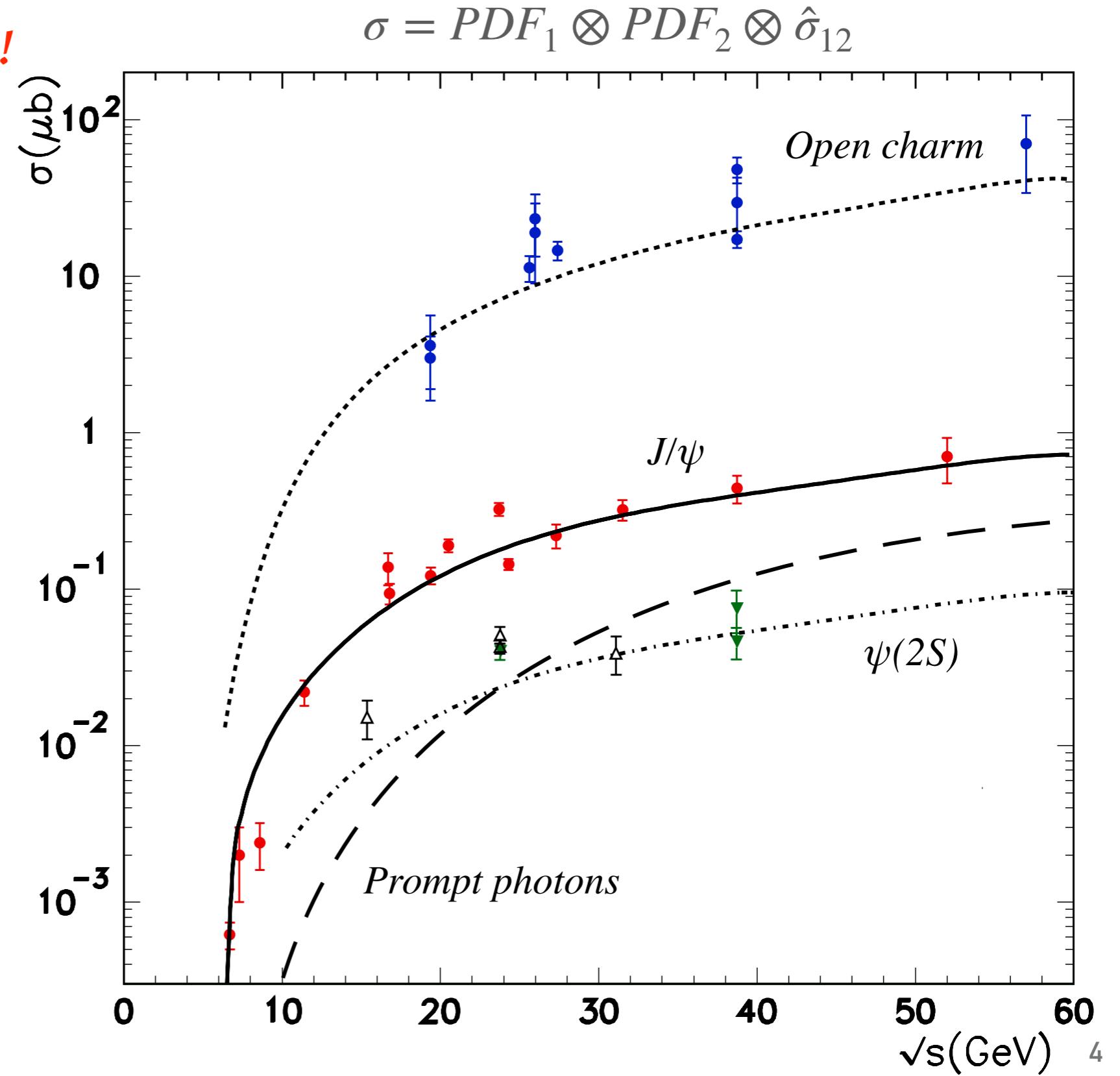
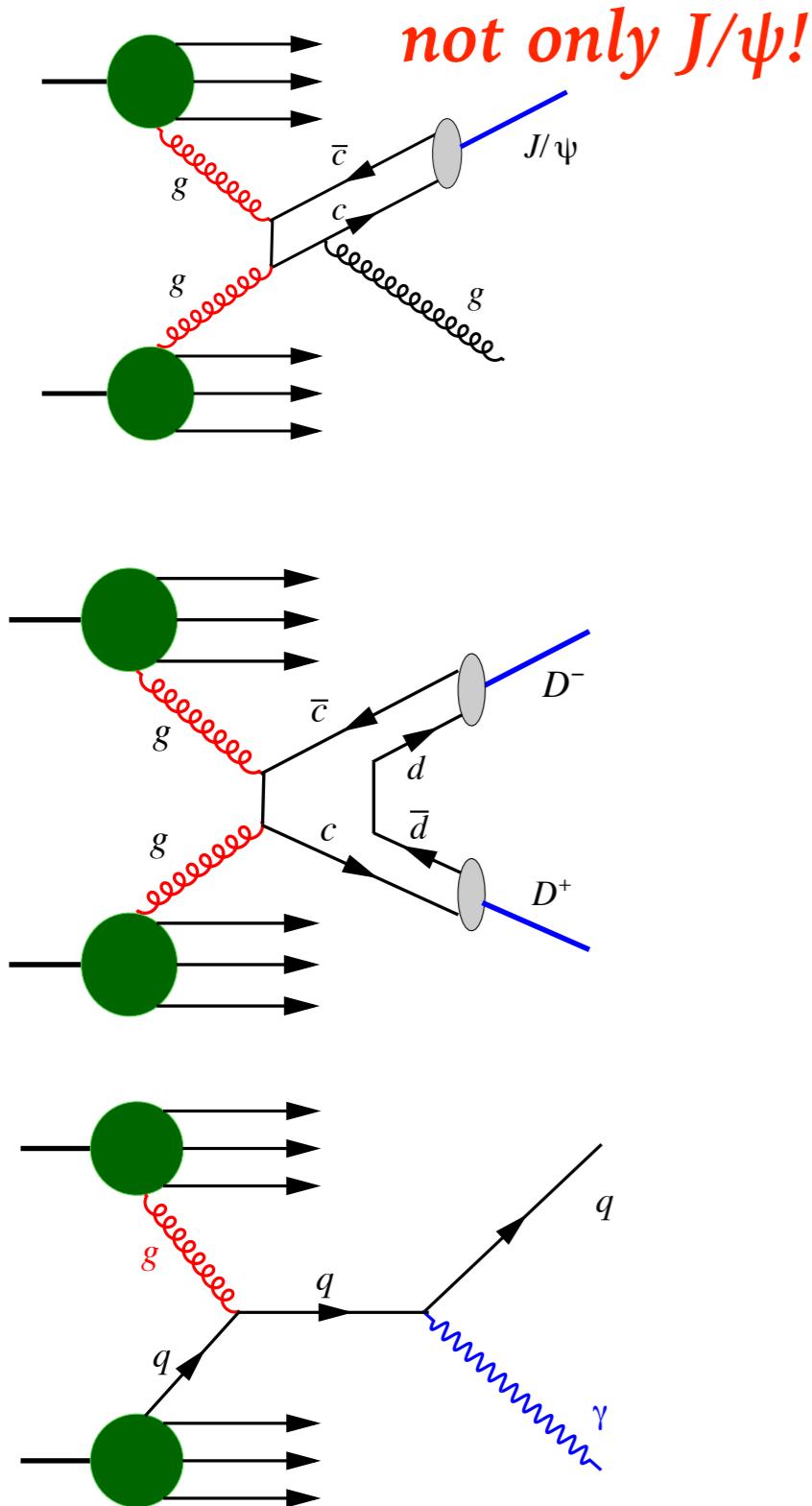
*Tensor structure of deuteron:*



- Spin effects in p-p, p-d and d-d elastic scattering
- Spin effects in hyperons production
- Multiquark correlations
- Dibaryon resonances
- Physics of light and intermediate nuclei collision
- Exclusive reactions
- Open charm and charmonia near threshold
- Auxiliary measurements for astrophysics

*arXiv:2102.08477*

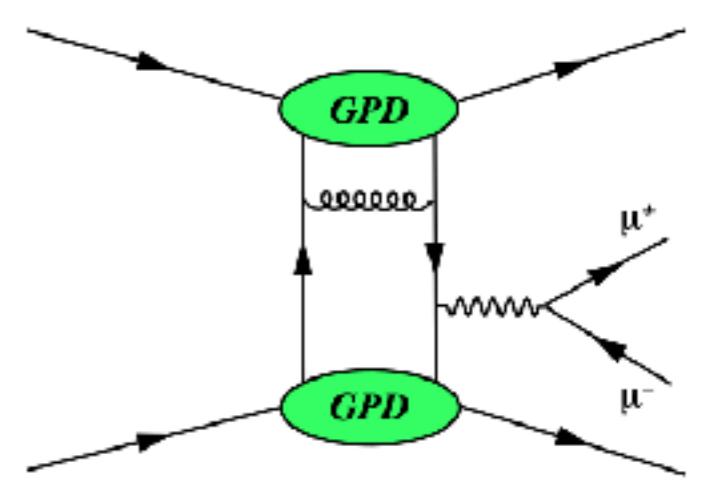
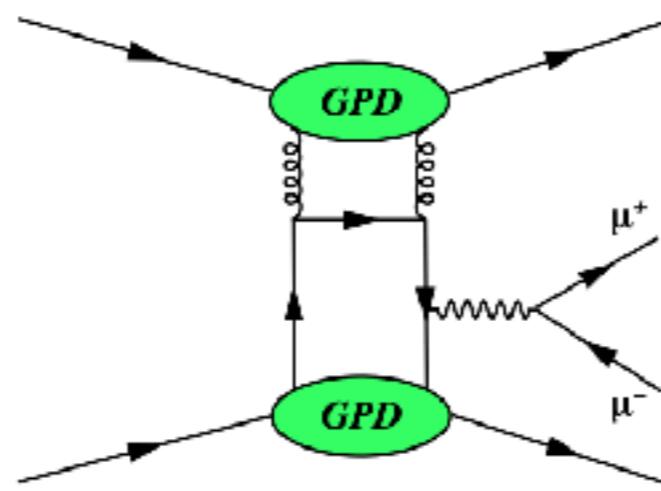
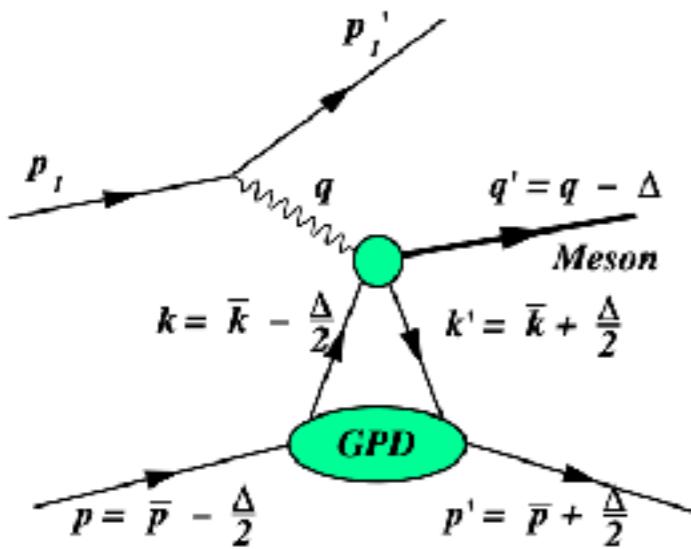
# GLUON PROBES AT SPD



# GPDs AT SPD

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*In principle, GPDs could also be accessed at SPD*

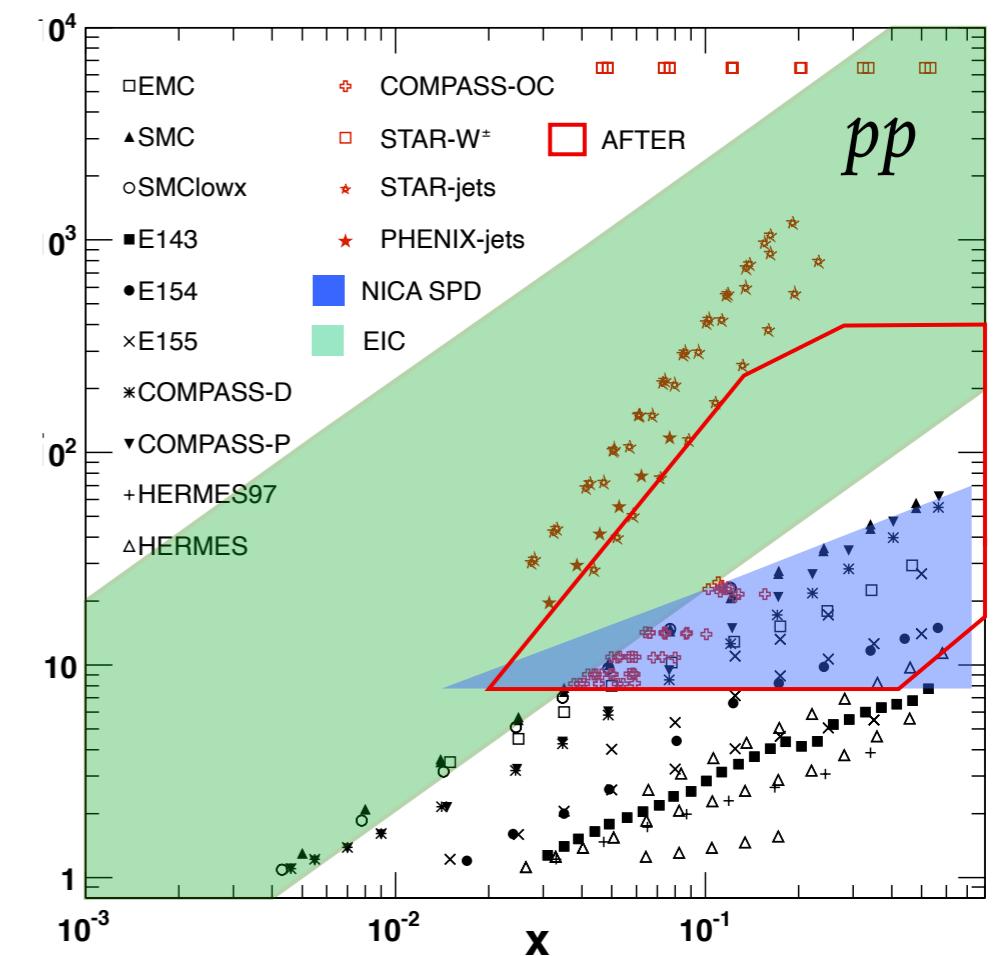
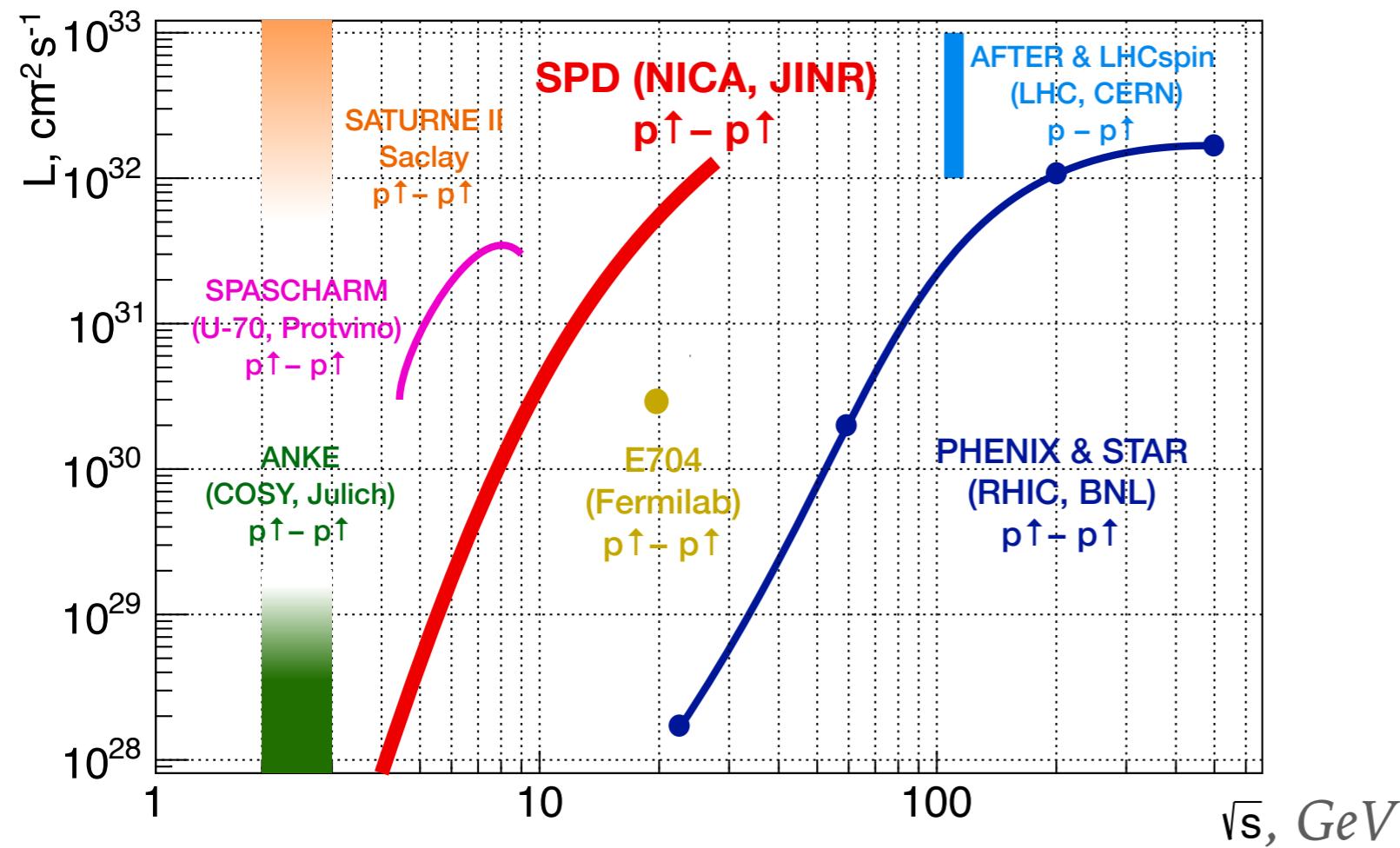


# SPD - VS OTHERS

*In the  $d^\dagger d^\dagger$  mode we are unique*

Experimental facility	SPD @NICA	RHIC	EIC	AFTER @LHC	LHCspin
Scientific center	JINR	BNL	BNL	CERN	CERN
Operation mode	collider	collider	collider	fixed target	fixed target
Colliding particles & polarization	$p^\dagger-p^\dagger$ $d^\dagger-d^\dagger$ $p^\dagger-d$ , $p-d^\dagger$	$p^\dagger-p^\dagger$	$e^\dagger-p^\dagger, d^\dagger, {}^3\text{He}^\dagger$	$p-p^\dagger, d^\dagger$	$p-p^\dagger$
Center-of-mass energy $\sqrt{s_{NN}}$ , GeV	$\leq 27$ ( $p-p$ ) $\leq 13.5$ ( $d-d$ ) $\leq 19$ ( $p-d$ )	63, 200, 500	20-140 ( $ep$ )	115	115
Max. luminosity, $10^{32} \text{ cm}^{-2} \text{ s}^{-1}$	$\sim 1$ ( $p-p$ ) $\sim 0.1$ ( $d-d$ )	2	1000	up to $\sim 10$ ( $p-p$ )	4.7
Physics run	>2025	running	>2030	>2025	>2025

*In the  $p^\dagger p^\dagger$  mode:*



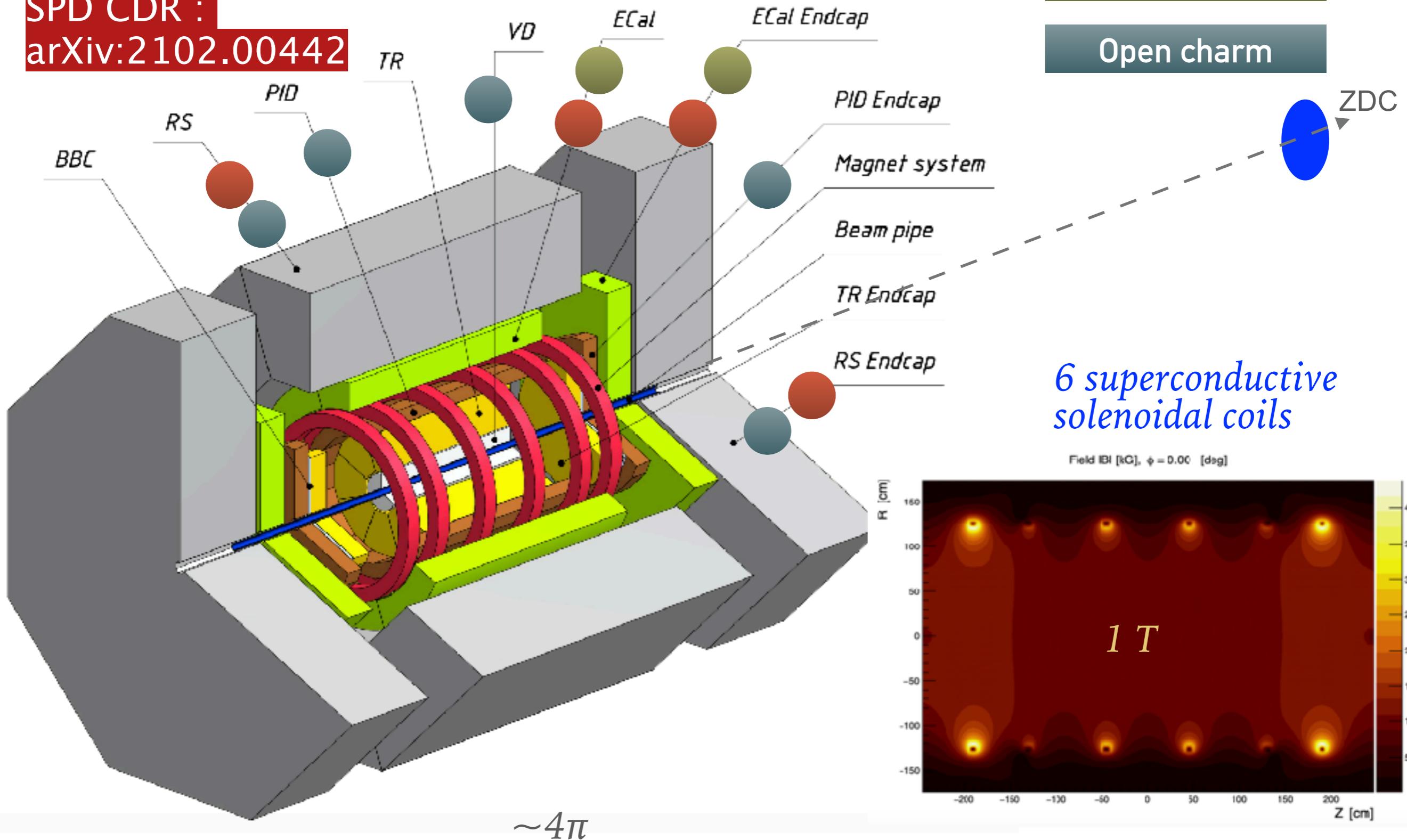
# DETECTOR: GENERAL OVERVIEW

Charmonia

SPD CDR :  
arXiv:2102.00442

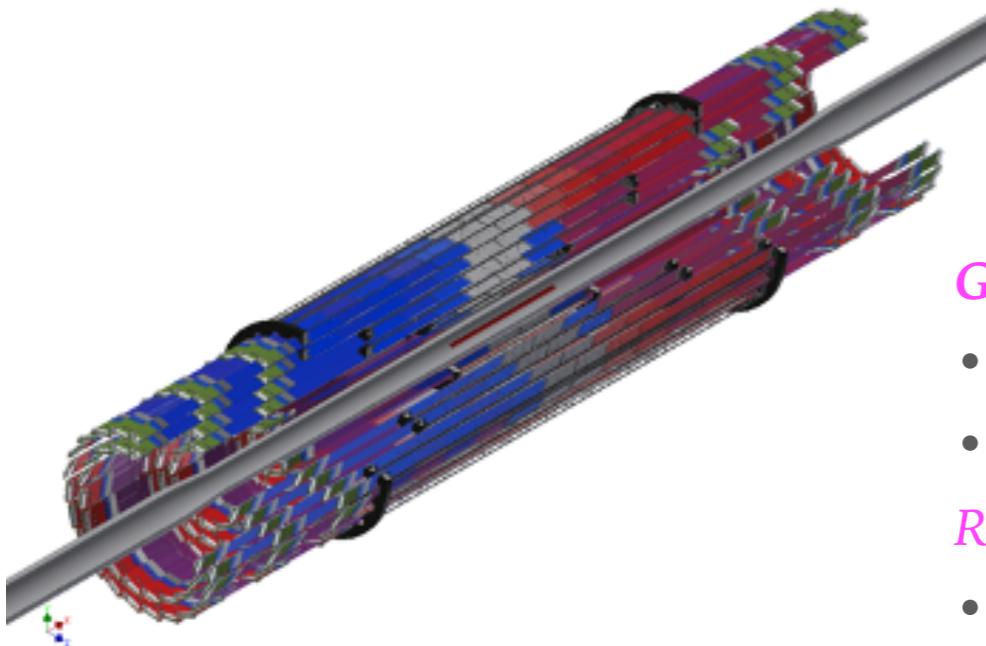
Prompt photons

Open charm



# TRACKING SYSTEM

5 layers of DSSD

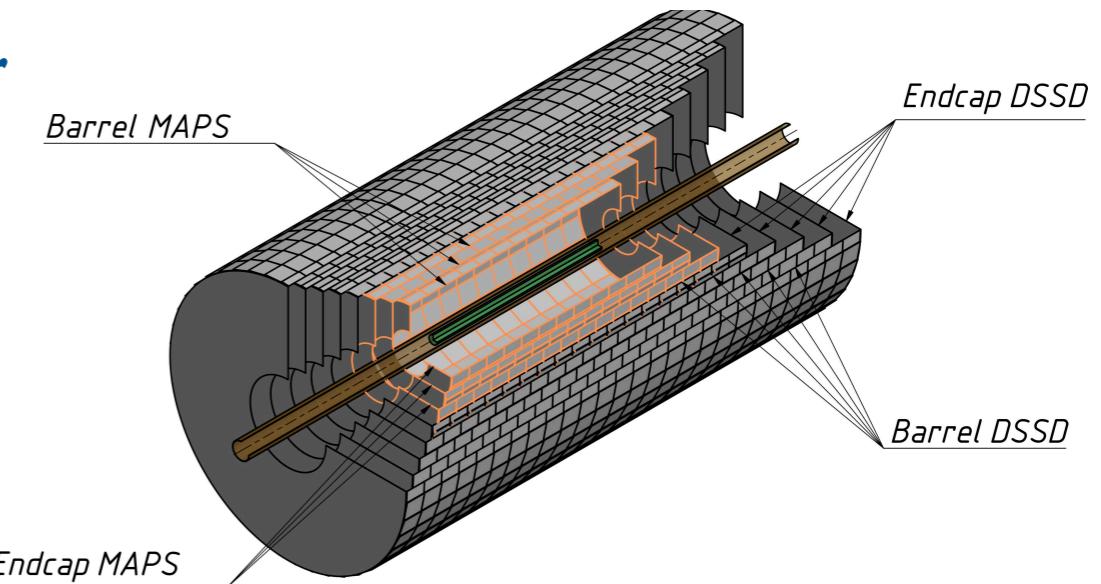


## Straw tracker

3 internal layers in barrel replaced by MAPS

## Vertex Detector

Two variants:



### Goals:

- Reconstruction of secondary vertices for D-mesons decay
- Participation in track reconstruction and momentum measurement

### Requirements:

- Spatial resolution  $< 100 \mu\text{m}$
- Low material budget
- Has to be installed as close as possible to the IP

### Goals:

- Track reconstruction and momentum measurement
- Participation in PID via  $dE/dx$  measurement

### Requirements:

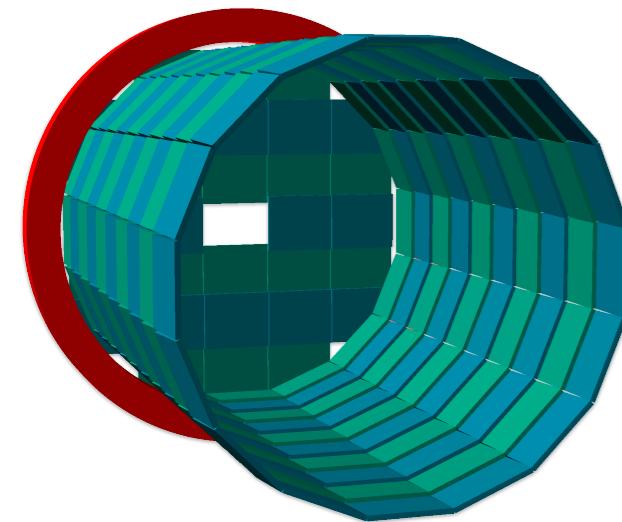
- Spatial resolution  $\sim 150 \mu\text{m}$
- Low material budget
- Operation in magnetic field of about 1 T

some R&D is still needed

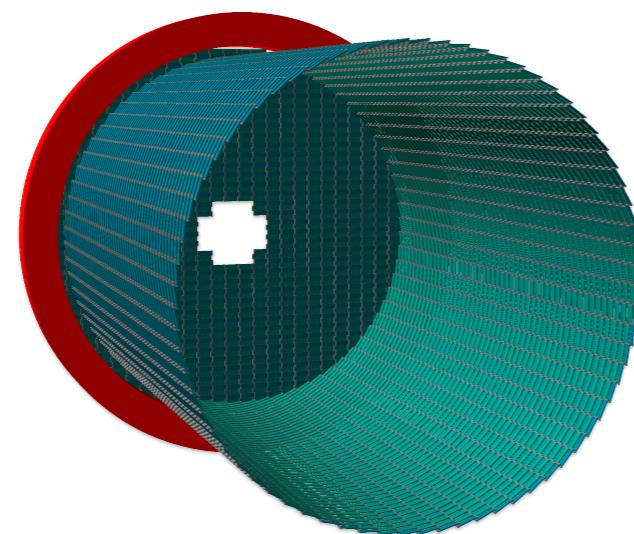
# PARTICLE IDENTIFICATION SYSTEM

TOF system

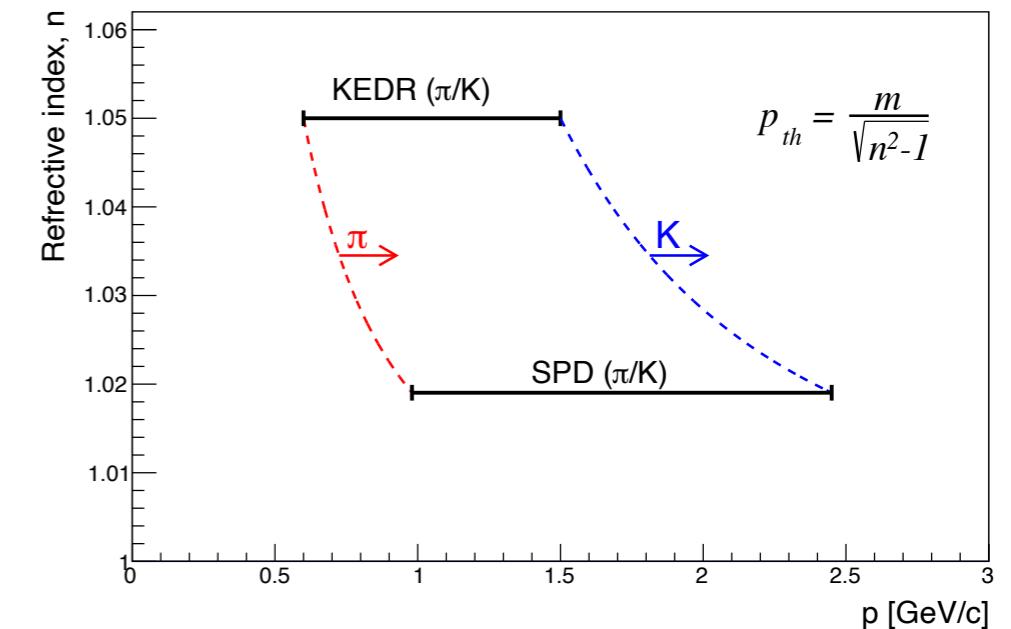
mRPC-based



Scintillator-based



Aerogel-based PID

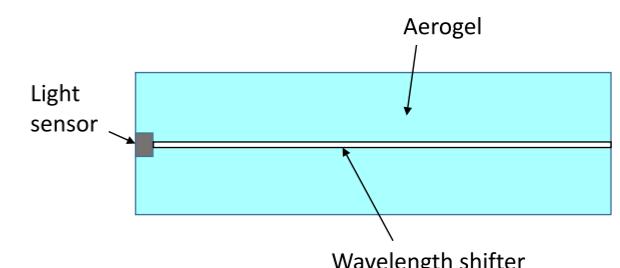
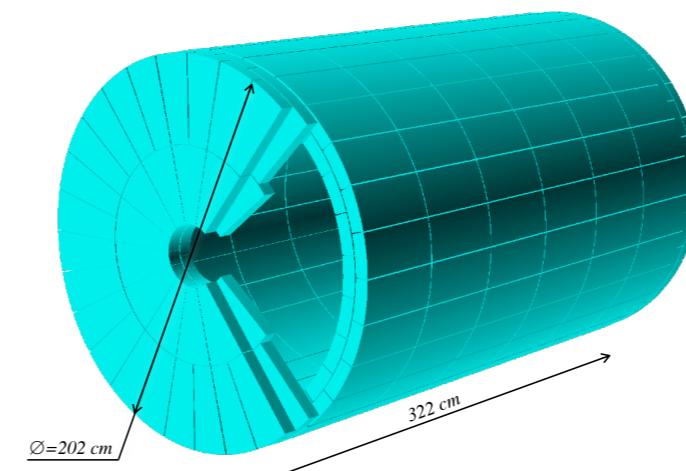


Goals:

- $\pi/K$  separation up to  $\sim 1.5 \text{ GeV}$
- $K/p$  separation
- $t_0$  determination

Requirements:

- Time resolution  $\sim 60-70 \text{ ps}$



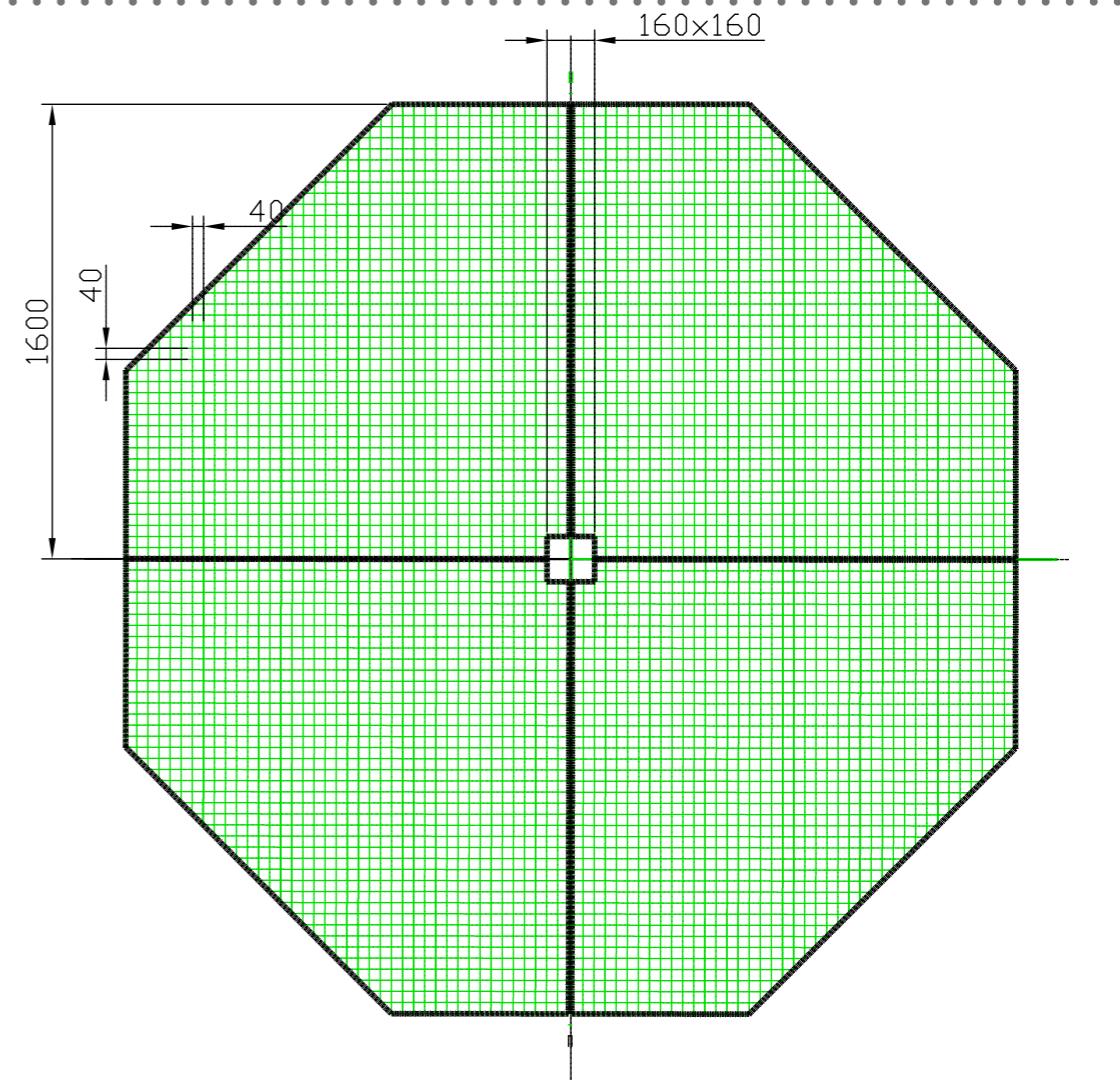
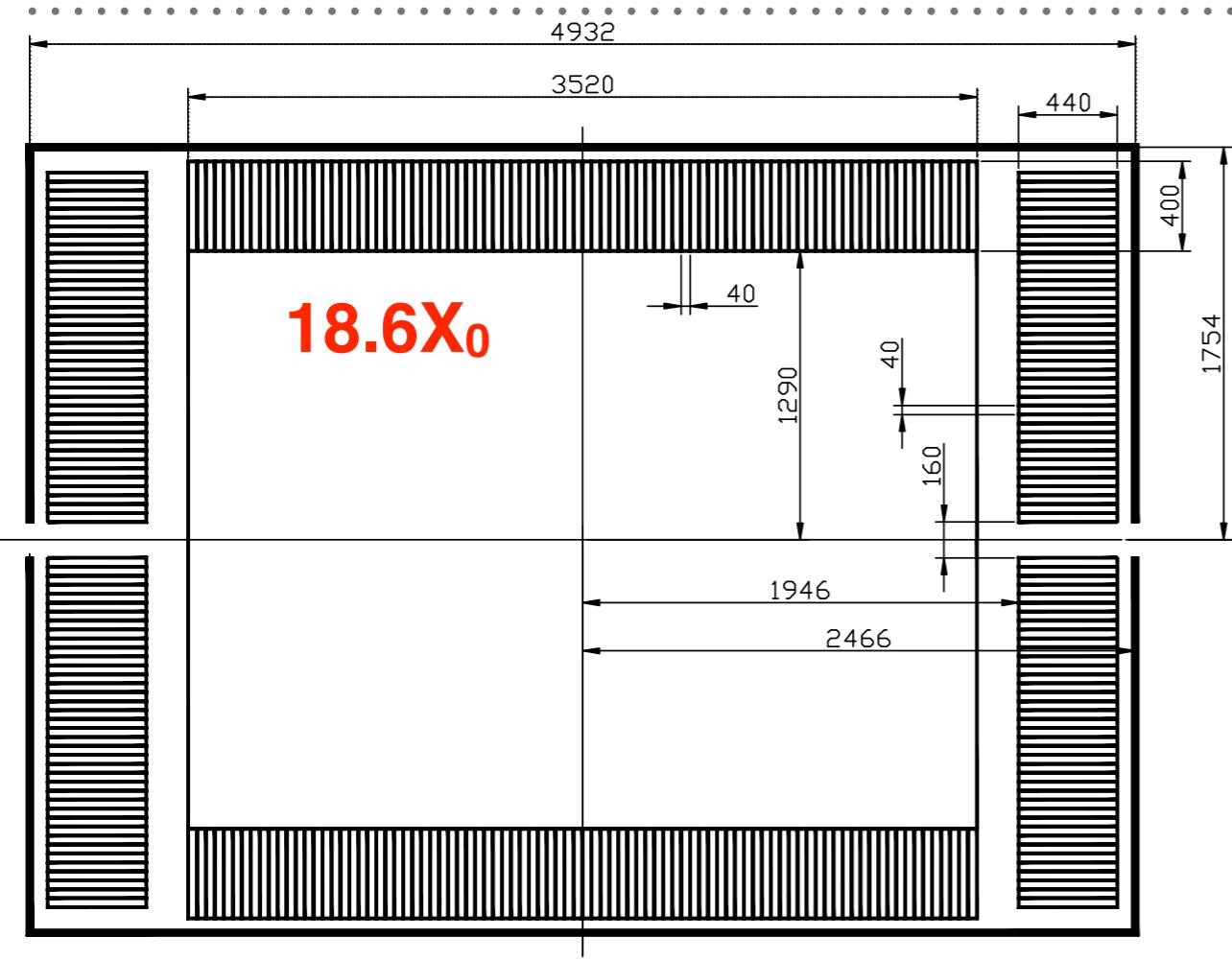
Goals:

- $\pi/K$  separation up to  $2.5 \text{ GeV}$  range

Requirements:

- We should have enough light!

# ELECTROMAGNETIC CALORIMETER



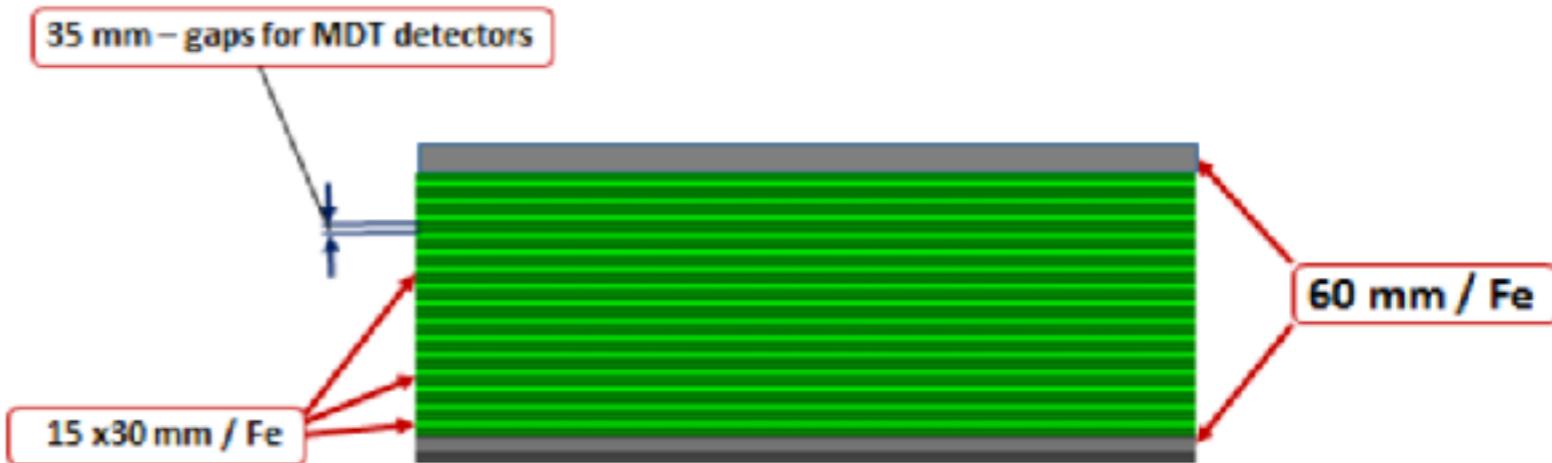
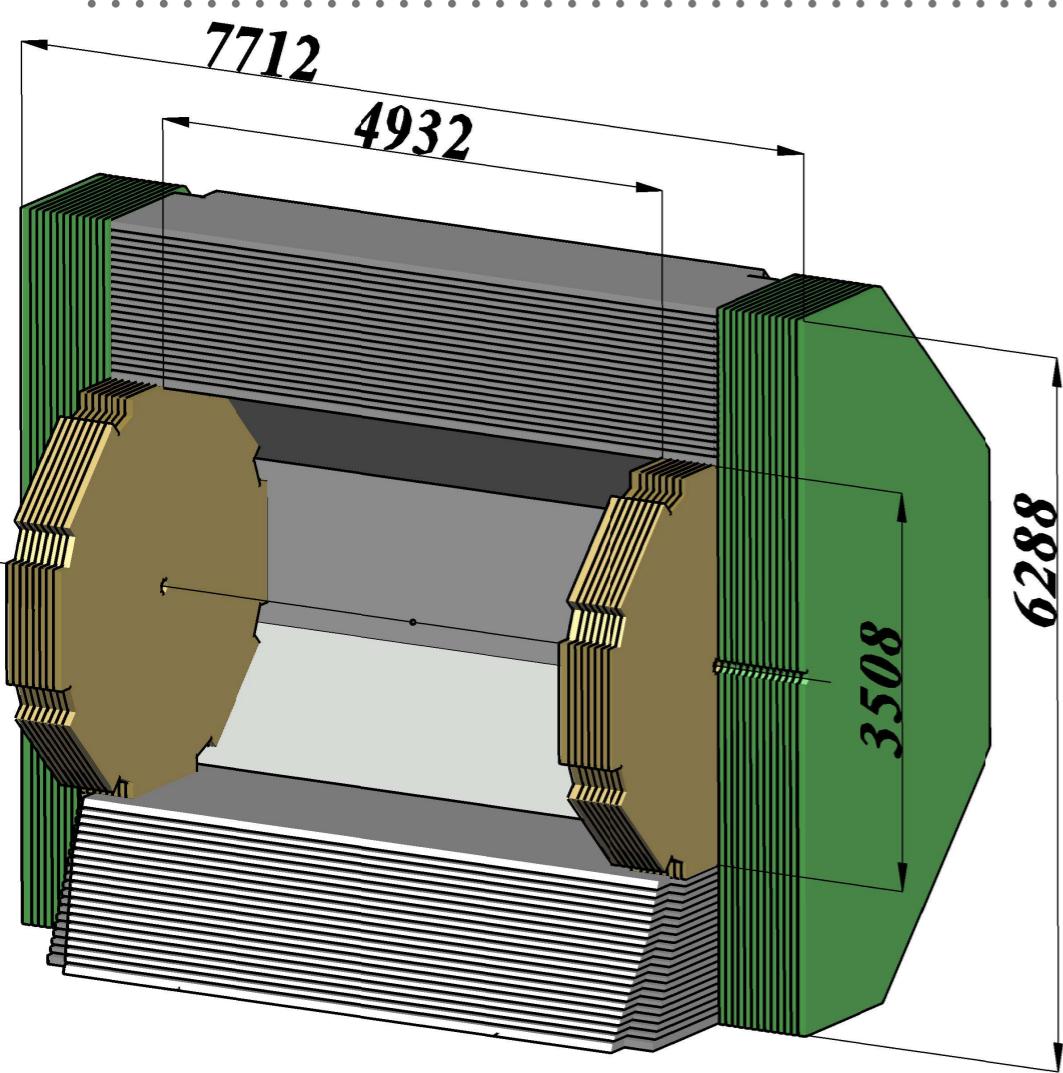
## Goals:

- Detection of prompt photons, photons from  $\pi^0$ ,  $\eta$  and  $\chi_c$  decays
- Identification of electrons and positrons, participation in muon identification

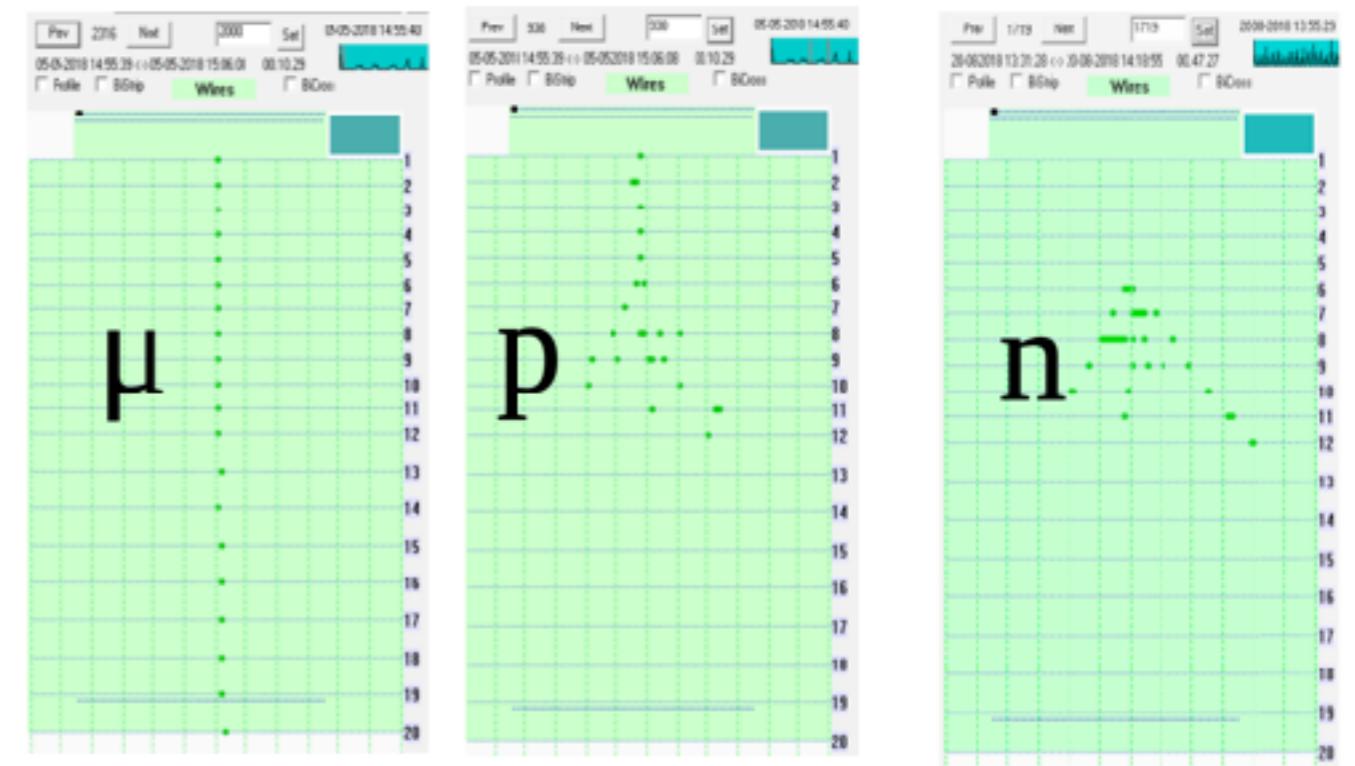
## Requirements:

- Granularity  $\sim 4$  cm
- Low energy threshold ( $\sim 50$  MeV)
- Energy resolution  $\sim 5\% / \sqrt{E}$

# RANGE (MUON) SYSTEM



Event examples at 5 GeV/c



## Goals:

- Muon identification
- Rough hadron calorimetry

## Requirements:

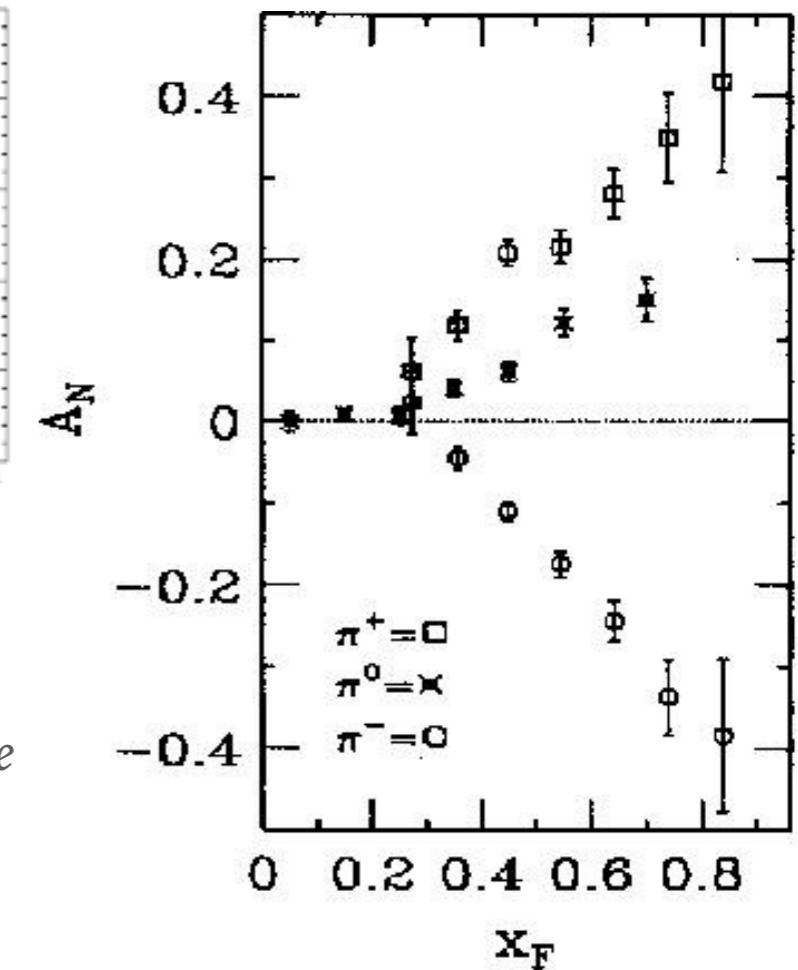
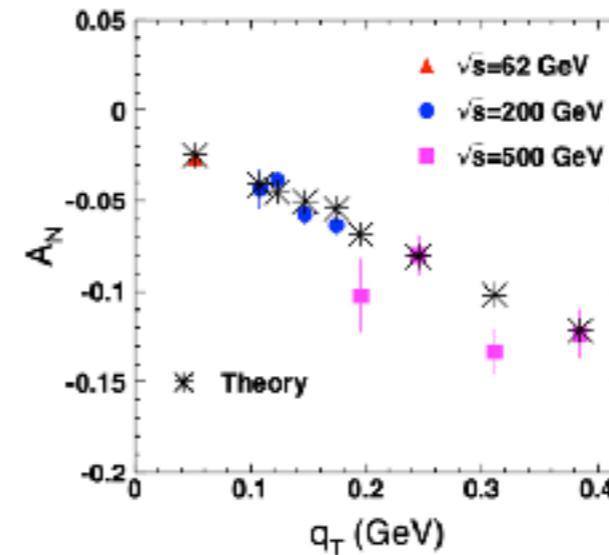
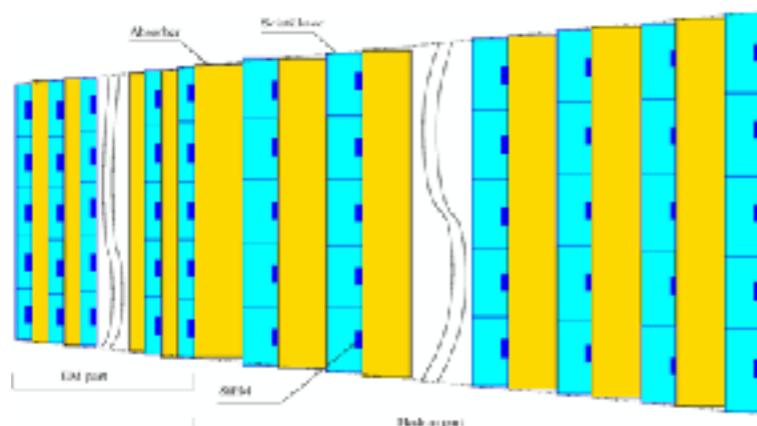
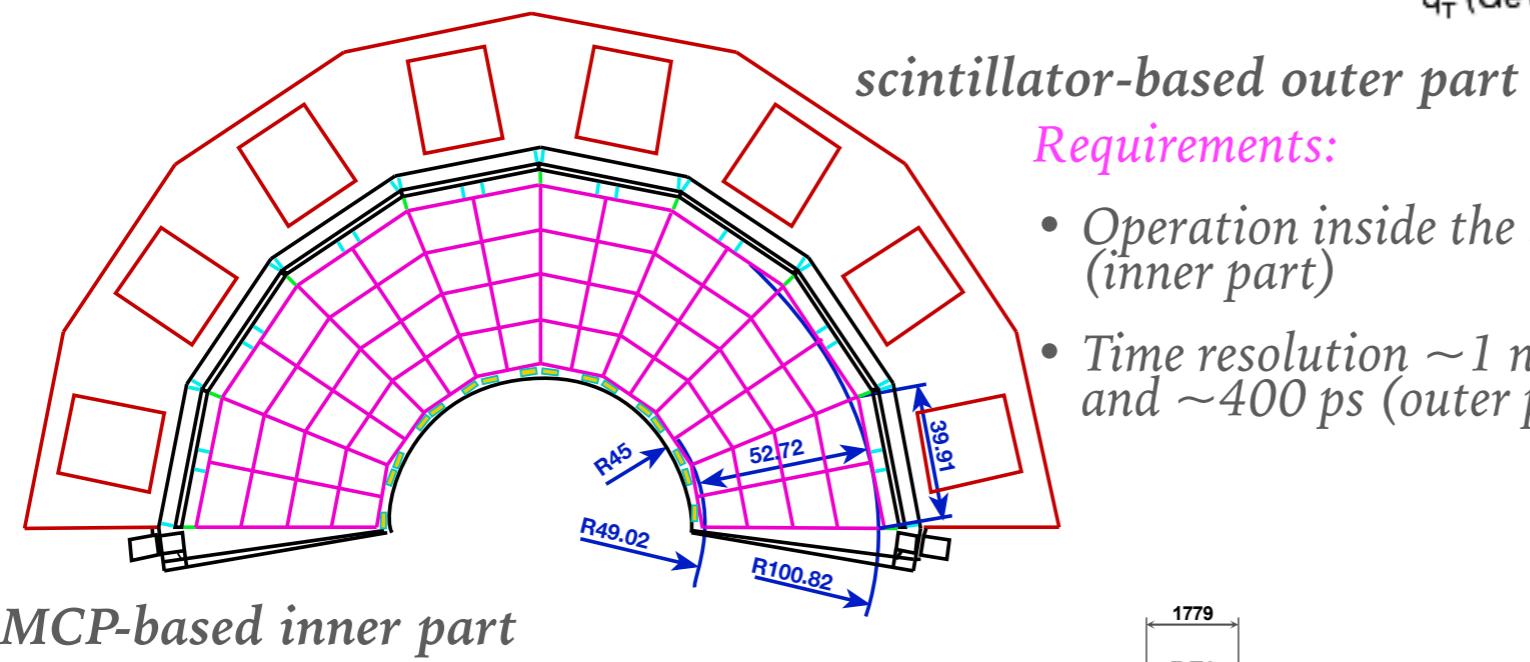
- should have at least  $4\lambda_I$

# LOCAL POLARIMETRY AND LUMINOSITY CONTROL

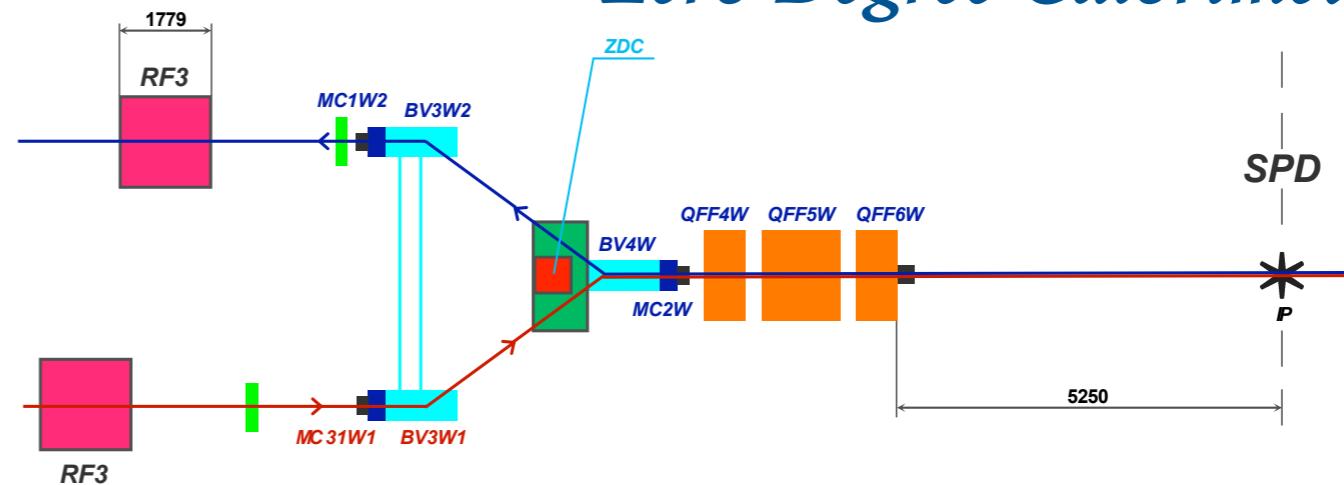
## Local polarimetry

- Charged particles in BBC
- $\pi^0$  in the end-cap part of ECAL
- Neutrons in ZDC

## Beam-Beam Counter

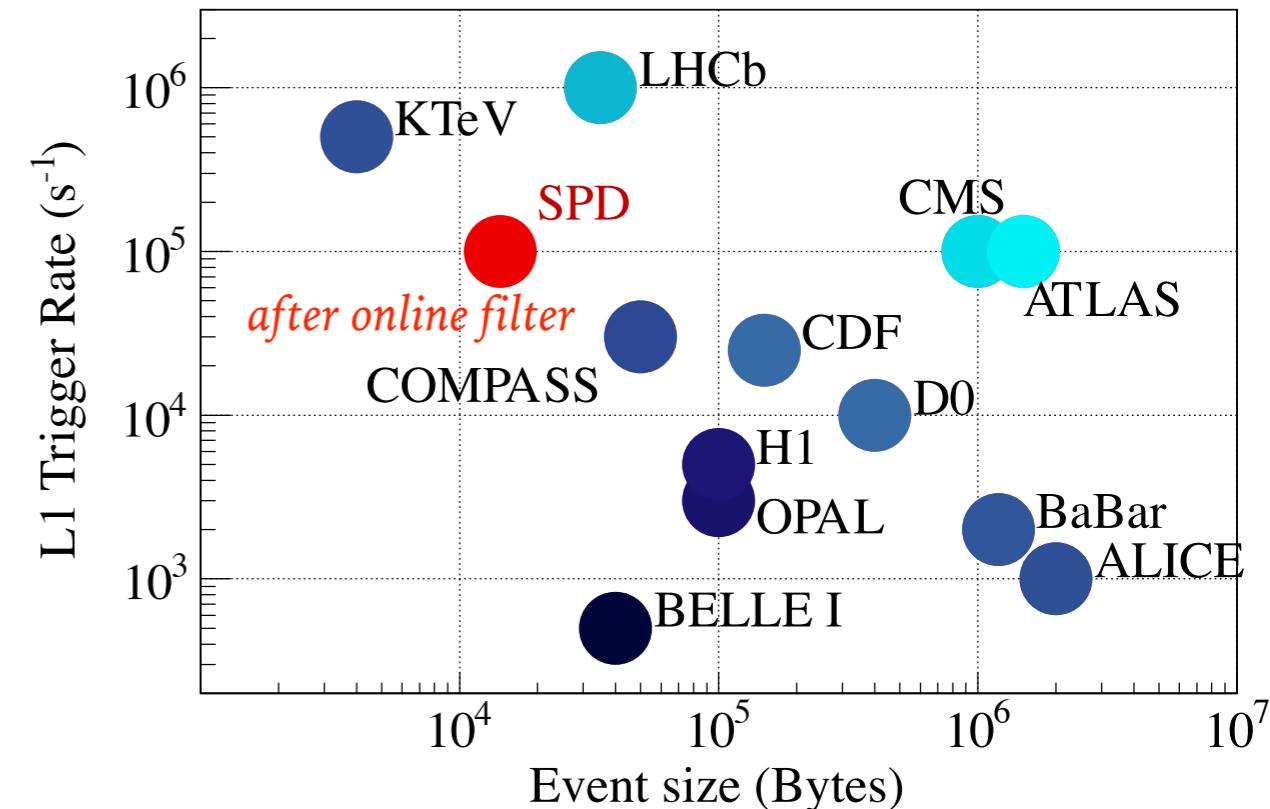
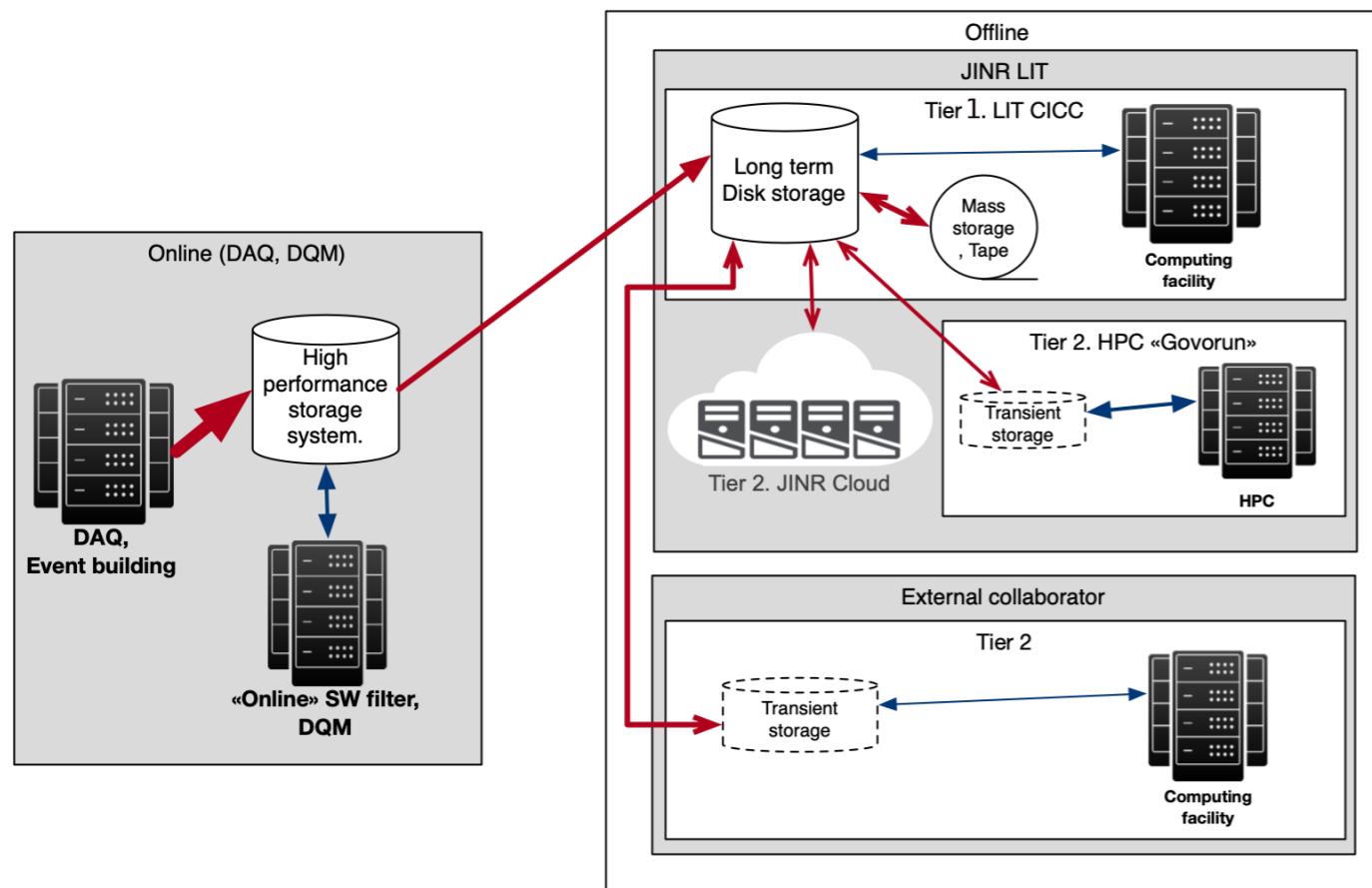


## Zero Degree Calorimeter



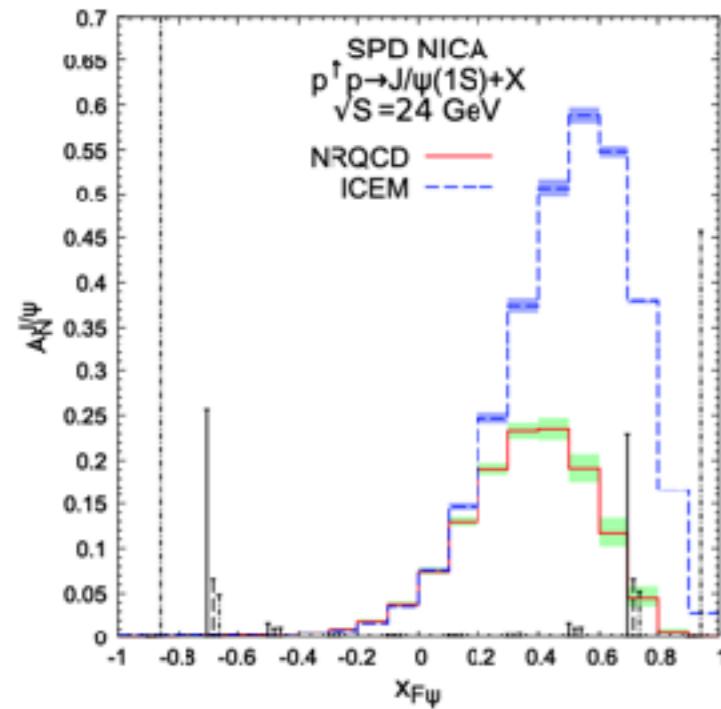
# DAQ & COMPUTING

*No hardware triggers to avoid possible bias!*

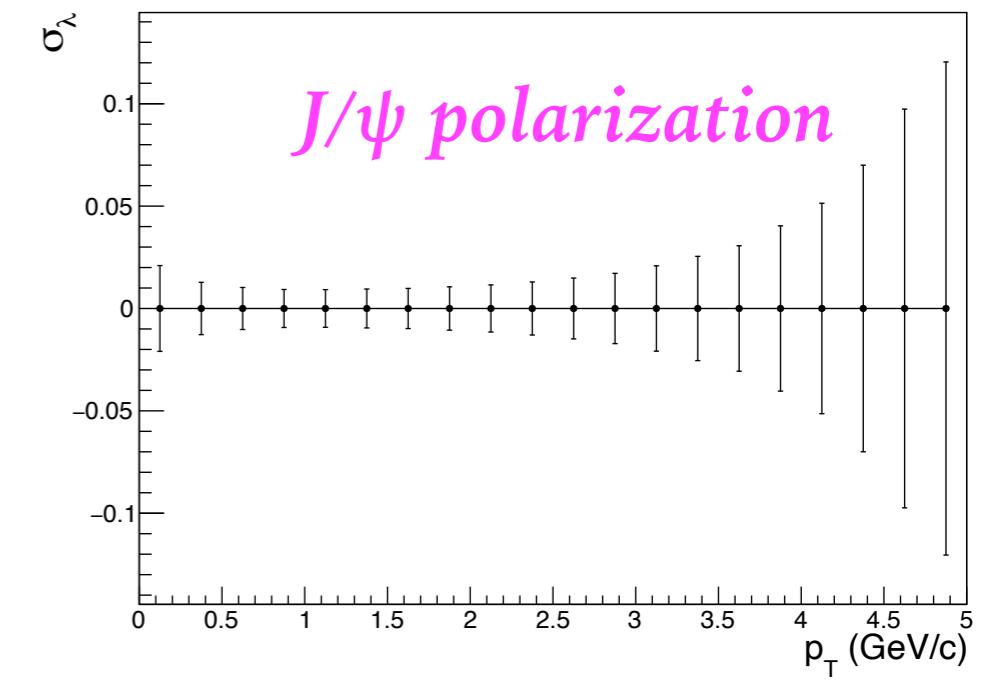
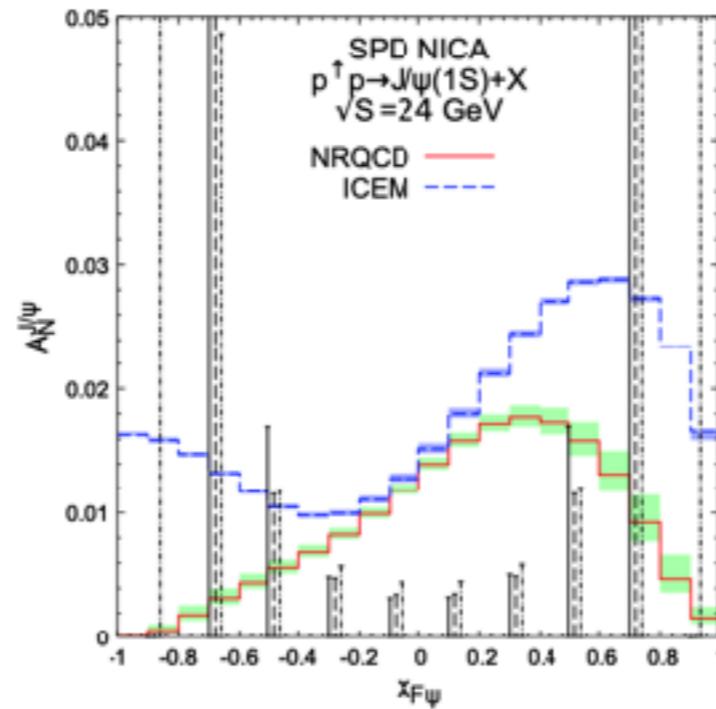


	CPU [cores]	Disk [PB]	Tape [PB]
Online filter	6000	2	none
Offline computing	30000	5	9 per year

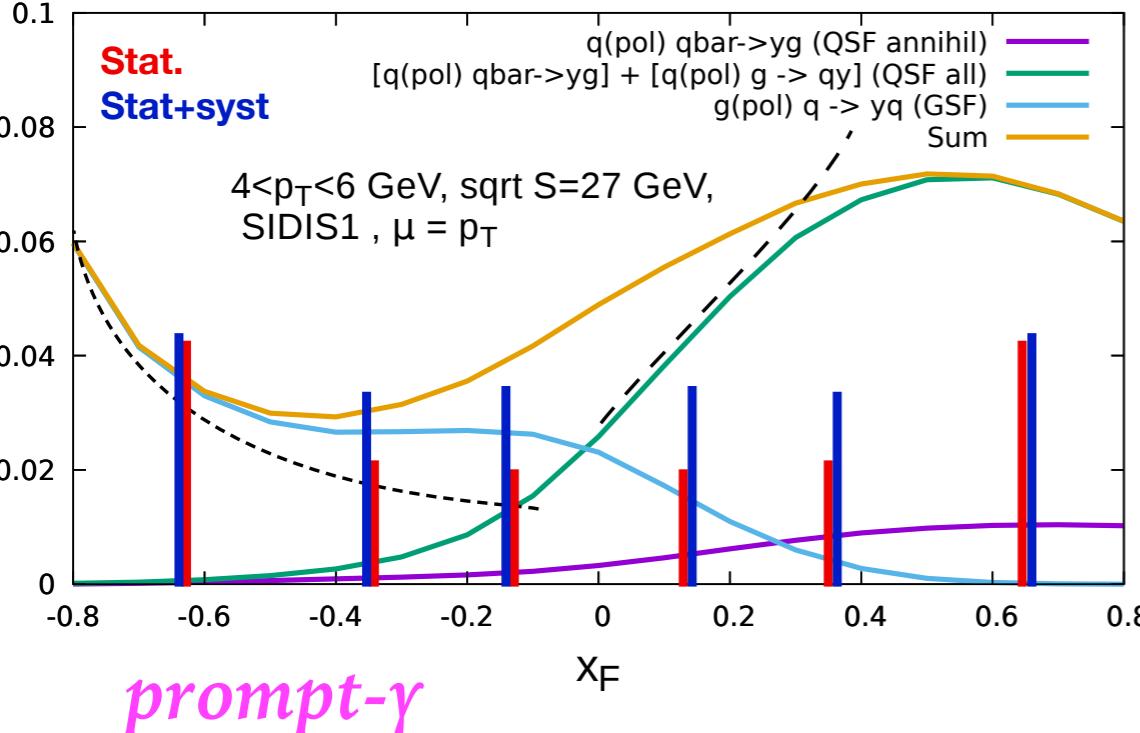
# PHYSICS PERFORMANCE: ACCURACIES



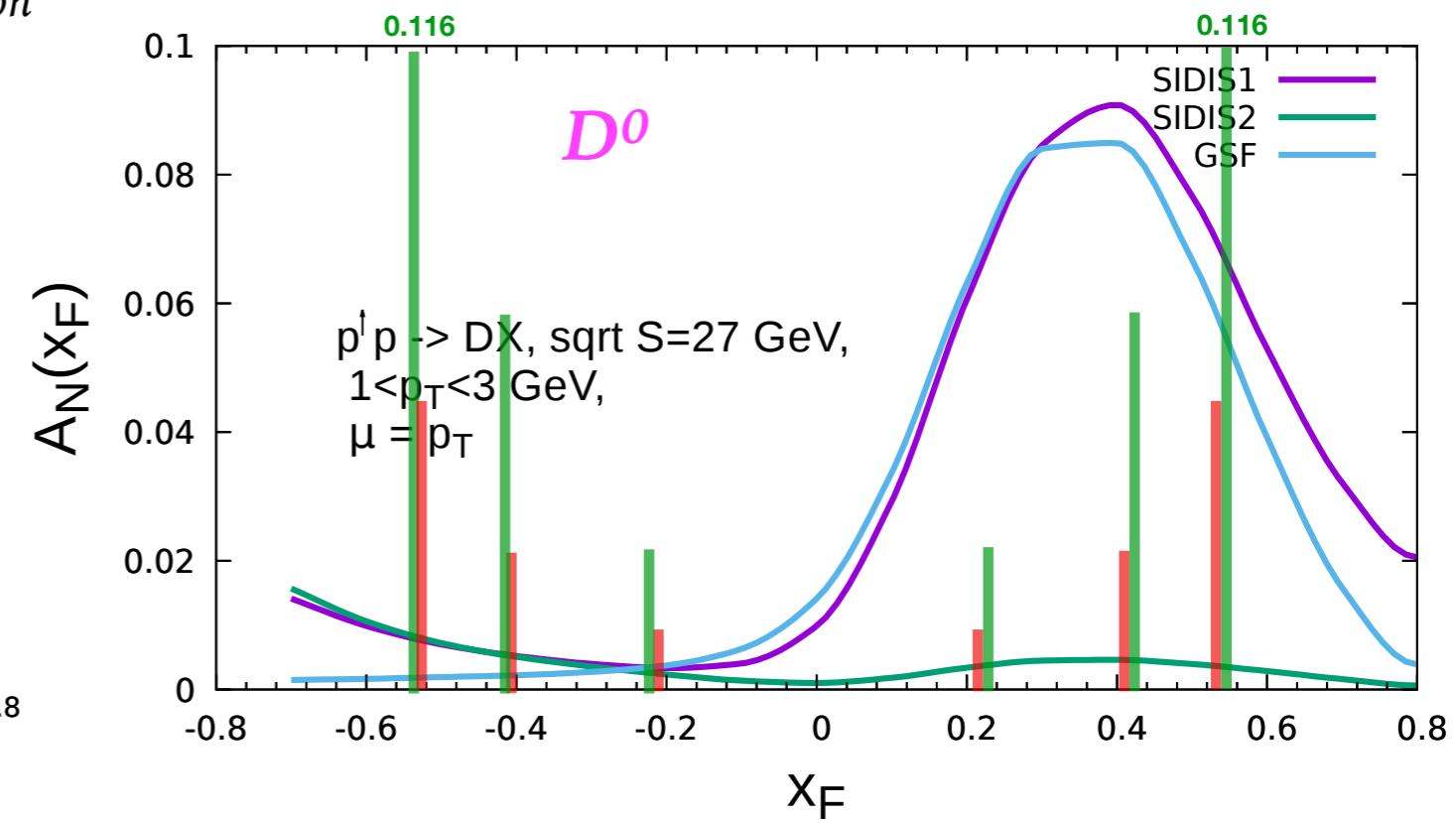
*J/ $\psi$*



*Different inputs for gluon Sivers function*



*prompt- $\gamma$*



# TENTATIVE RUNNING PLAN

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Physics goal	Required time	Experimental conditions
First stage		
Spin effects in $p$ - $p$ scattering dibaryon resonances	0.3 year	$p_{L,T}$ - $p_{L,T}$ , $\sqrt{s} < 7.5$ GeV
Spin effects in $p$ - $d$ scattering, non-nucleonic structure of deuteron, $\bar{p}$ yield	0.3 year	$d_{tensor}$ - $p$ , $\sqrt{s} < 7.5$ GeV
Spin effects in $d$ - $d$ scattering hypernuclei	0.3 year	$d_{tensor}$ - $d_{tensor}$ , $\sqrt{s} < 7.5$ GeV
Hyperon polarization, SRC, ... multiquarks	together with MPD	ions up to Ca
Second stage		
Gluon TMDs, SSA for light hadrons	1 year	$p_T$ - $p_T$ , $\sqrt{s} = 27$ GeV
TMD-factorization test, SSA, charm production near threshold, onset of deconfinement, $\bar{p}$ yield	1 year	$p_T$ - $p_T$ , $7 \text{ GeV} < \sqrt{s} < 27$ GeV (scan)
Gluon helicity, ...	1 year	$p_L$ - $p_L$ , $\sqrt{s} = 27$ GeV
Gluon transversity, non-nucleonic structure of deuteron, "Tensor polarized" PDFs	1 year	$d_{tensor}$ - $d_{tensor}$ , $\sqrt{s_{NN}} = 13.5$ GeV or/and? $d_{tensor}$ - $p_T$ , $\sqrt{s_{NN}} = 19$ GeV

$\geq 5$  years  
of data taking

# DIRECTIONS FOR COLLABORATION

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Physics

Detectors

Electronics

Software development

Machine  
learning  
algorithms

DAQ

Testing facilities

Computing and Big Data

Monte Carlo simulation

Slow control and  
monitoring

Magnet and  
magnetic  
measurements

...

# SUMMARY

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- The **Spin Physics Detector** at the NICA collider as **a universal facility** for comprehensive study of polarized and unpolarized **gluon content of proton and deuteron**, in polarized high-luminosity p-p (up to  $10^{32} \text{ cm}^{-2}\text{s}^{-1}$ ) and **d-d** collisions at  $\sqrt{s} \leq 27 \text{ GeV}$ . The wide physics program is also prepared for the first period of running with reduced energy and luminosity.
- SPD CDR could be found at [arXiv:2102.00442](https://arxiv.org/abs/2102.00442) for more details.
- It seems, we have huge potential for cooperation: spin physics, detectors (R&D and construction), DAQ, beam tests ...

# BACKUP

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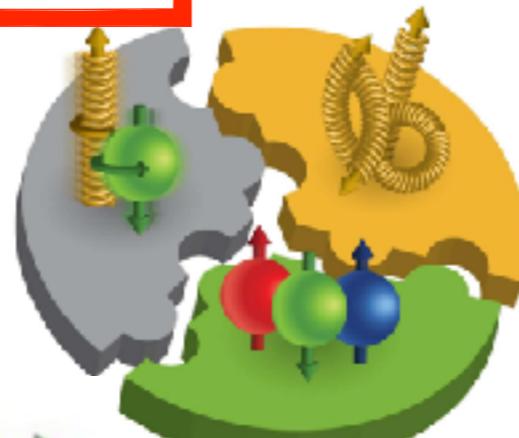
# PARTONIC STRUCTURE OF PROTON AND DEUTERON

$\sigma(x_F, p_T)$   $A_{LL}(x_F, p_T)$

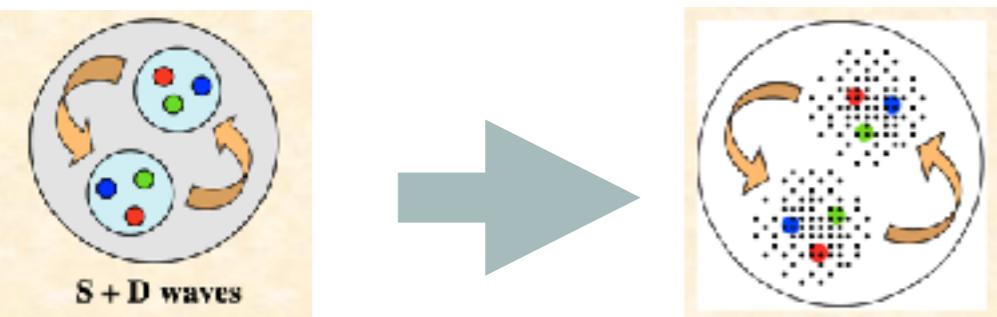
$A_{TT}(x_F, p_T)$   $A_N(x_F, p_T)$

*Spin crisis:*

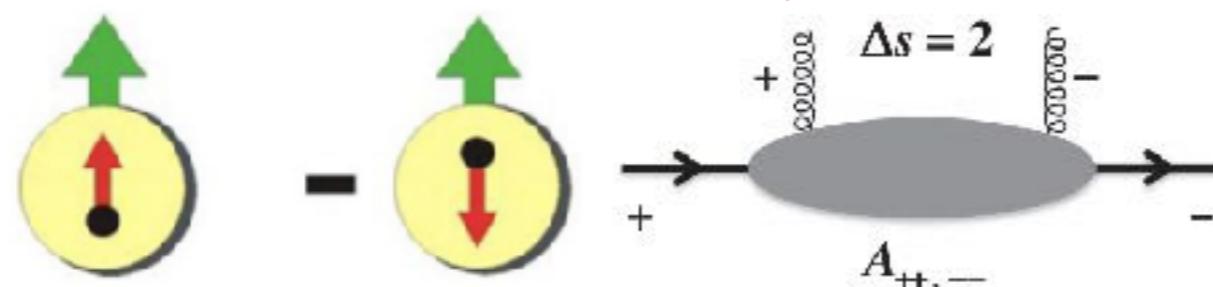
*Gluon helicity*



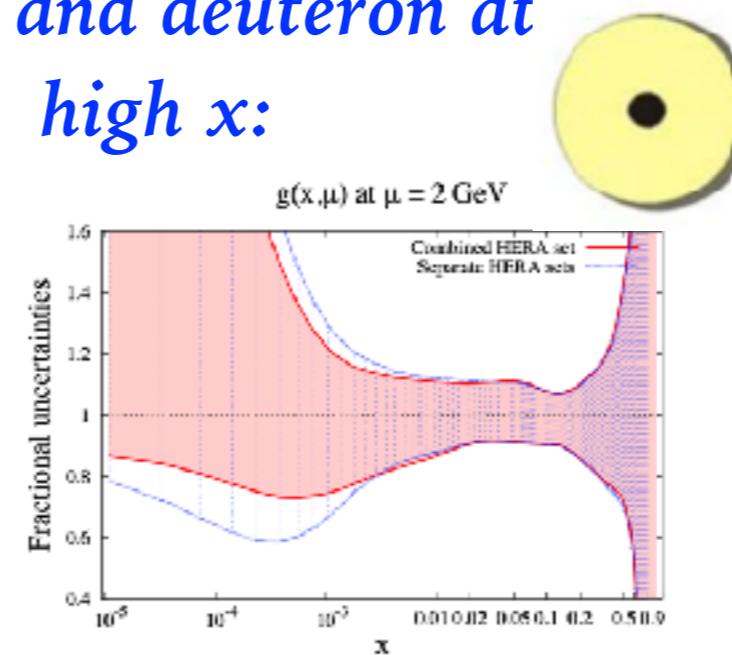
*Nonbaryonic content of deuteron:*



*Gluon transversity*



*Unpolarized gluons in proton and deuteron at high  $x$ :*



*Tensor structure of deuteron:*

Spin-1 System

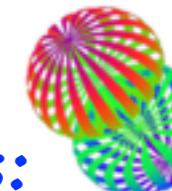
$m = +1$



$m = 0$

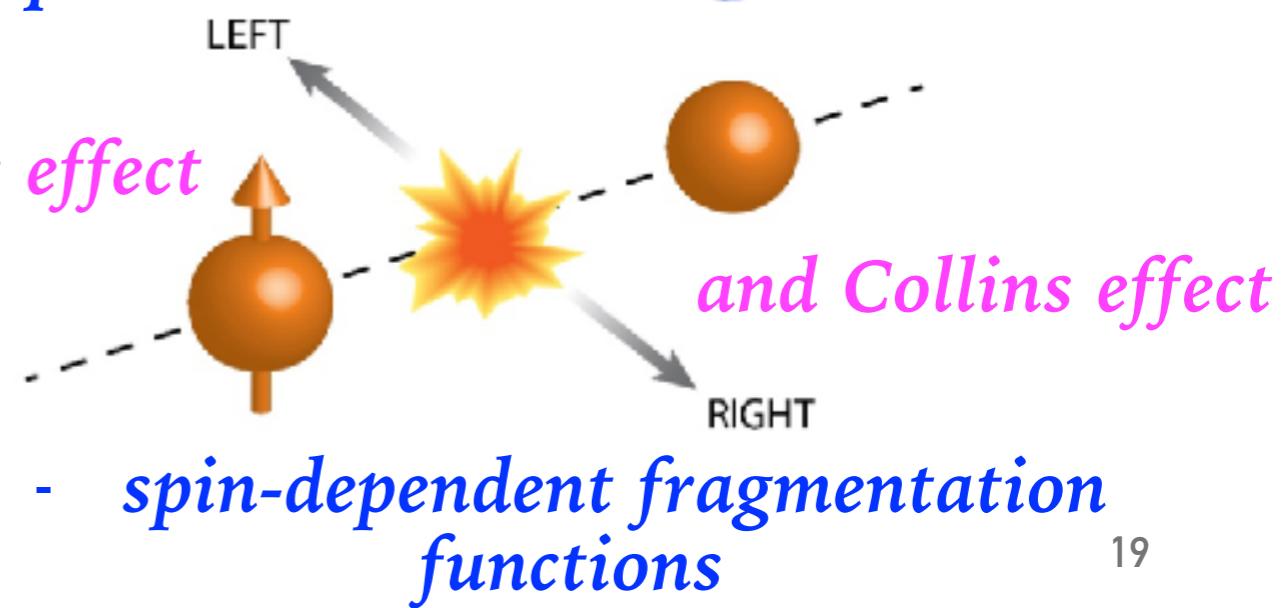


$m = -1$



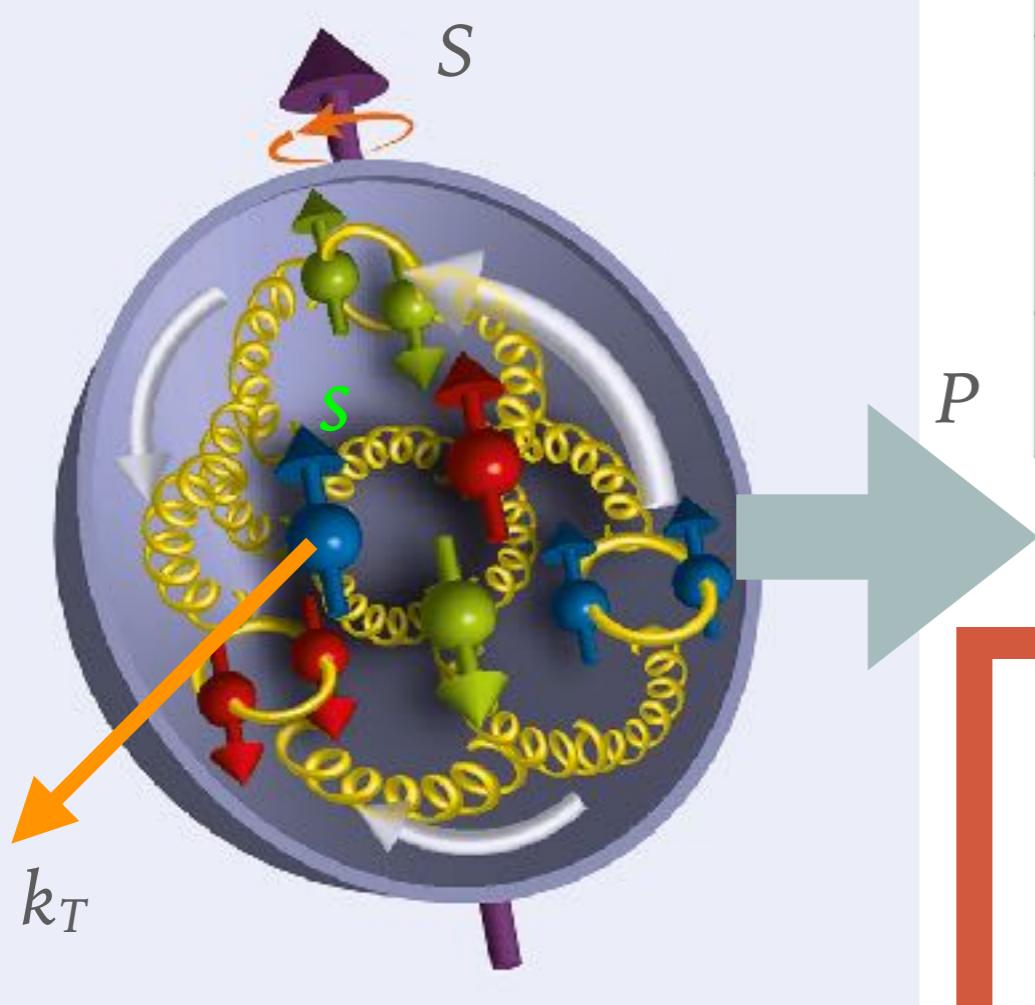
*Gluon and quark TMD PDFs:*

*Sivers effect*



- *spin-dependent fragmentation functions*

# SPIN STRUCTURE OF NUCLEON



*Momentum of proton*

*Spin of proton*

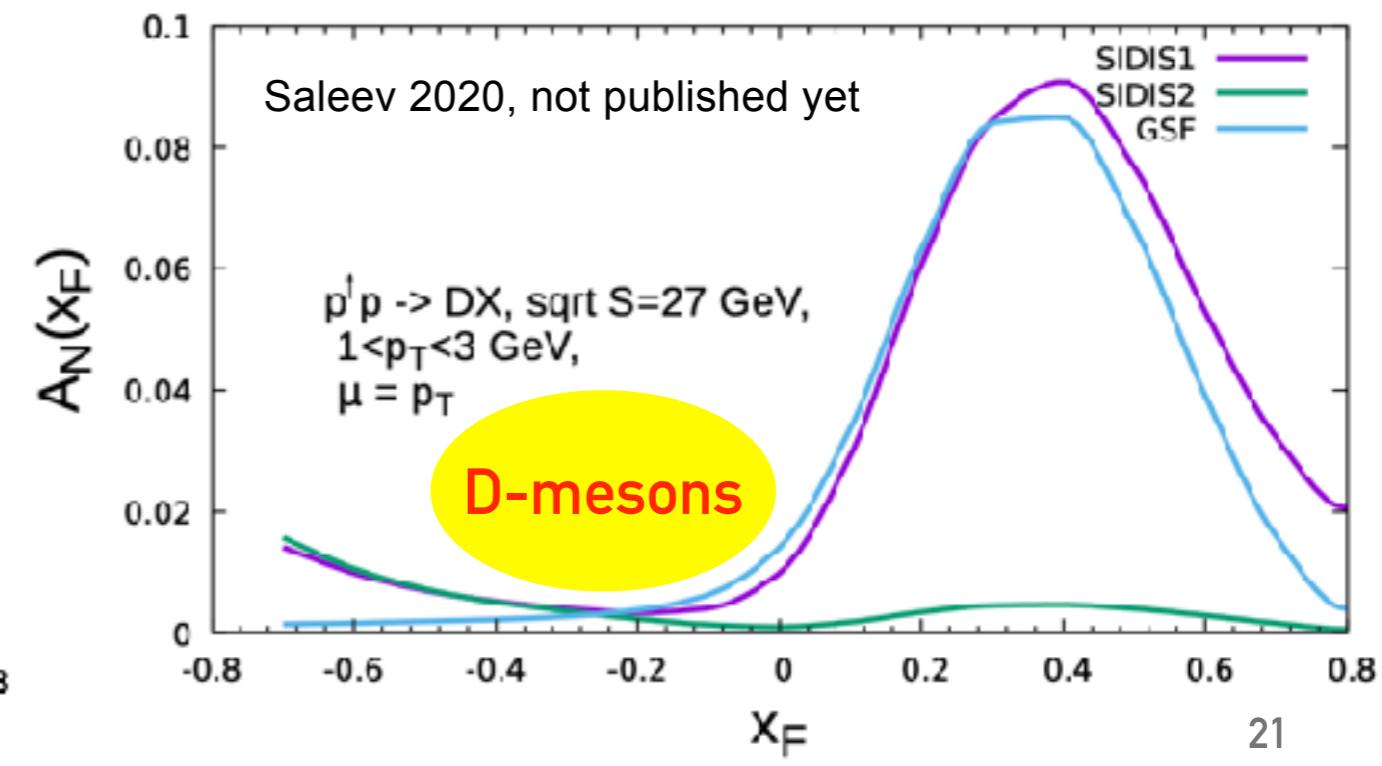
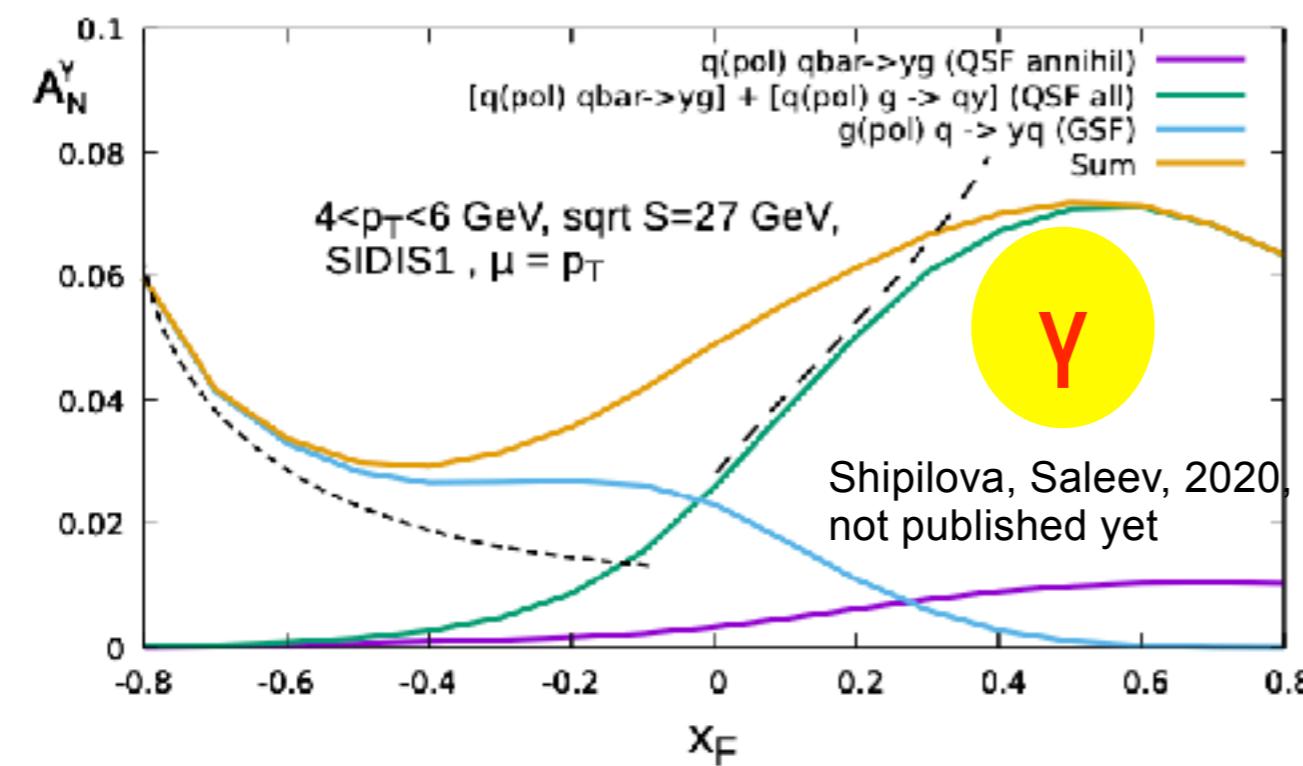
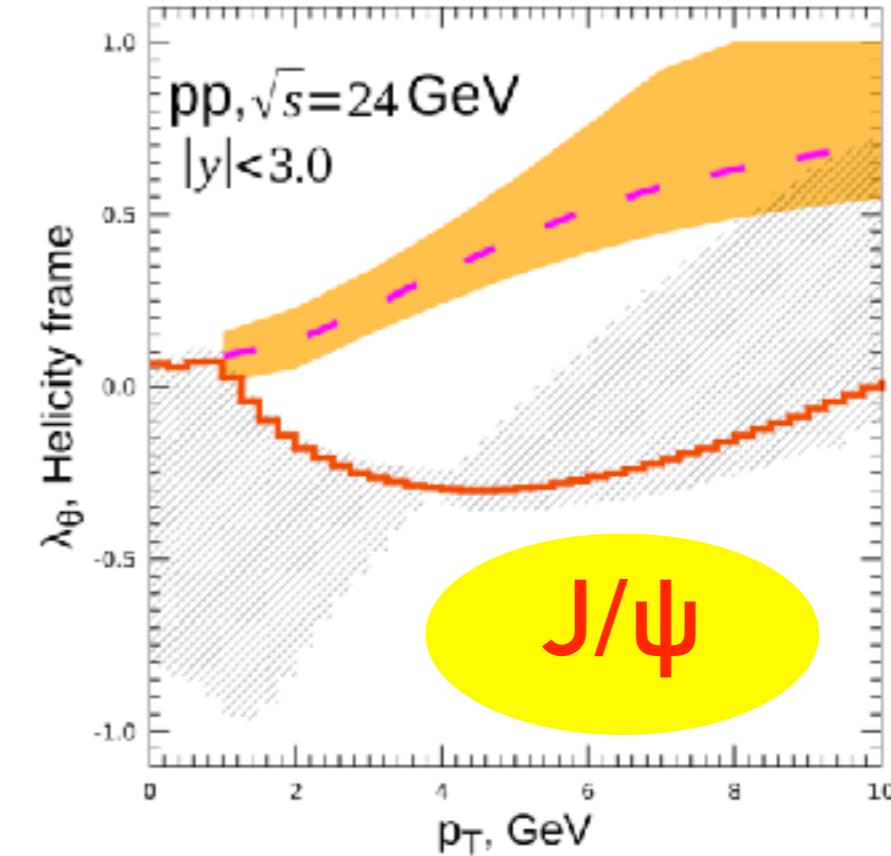
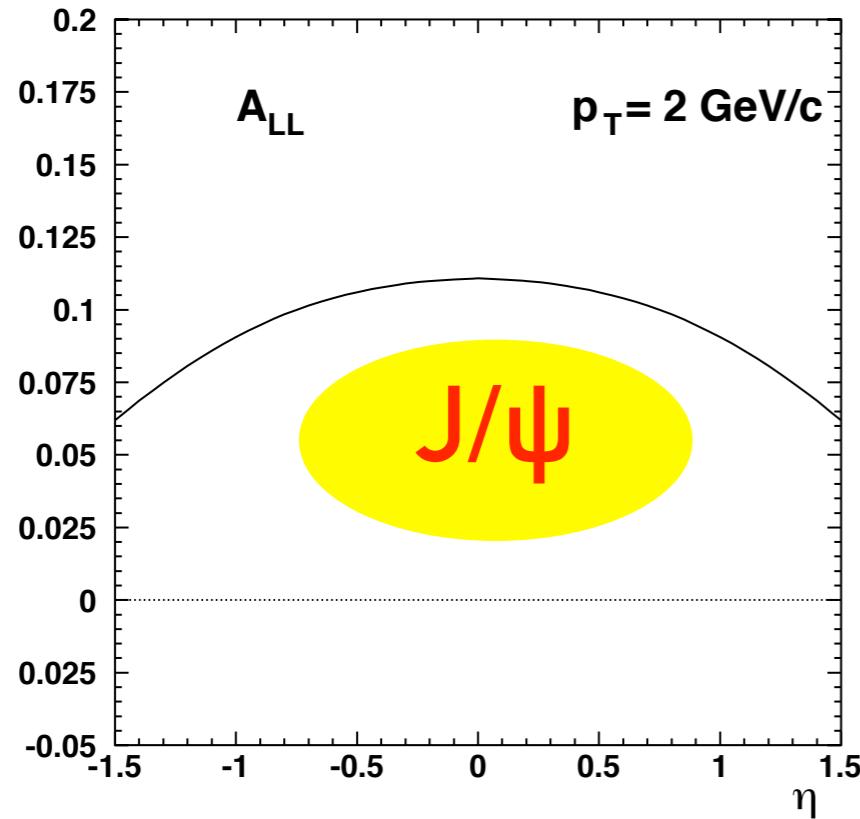
*Spin of parton*

*Transverse momentum of parton*

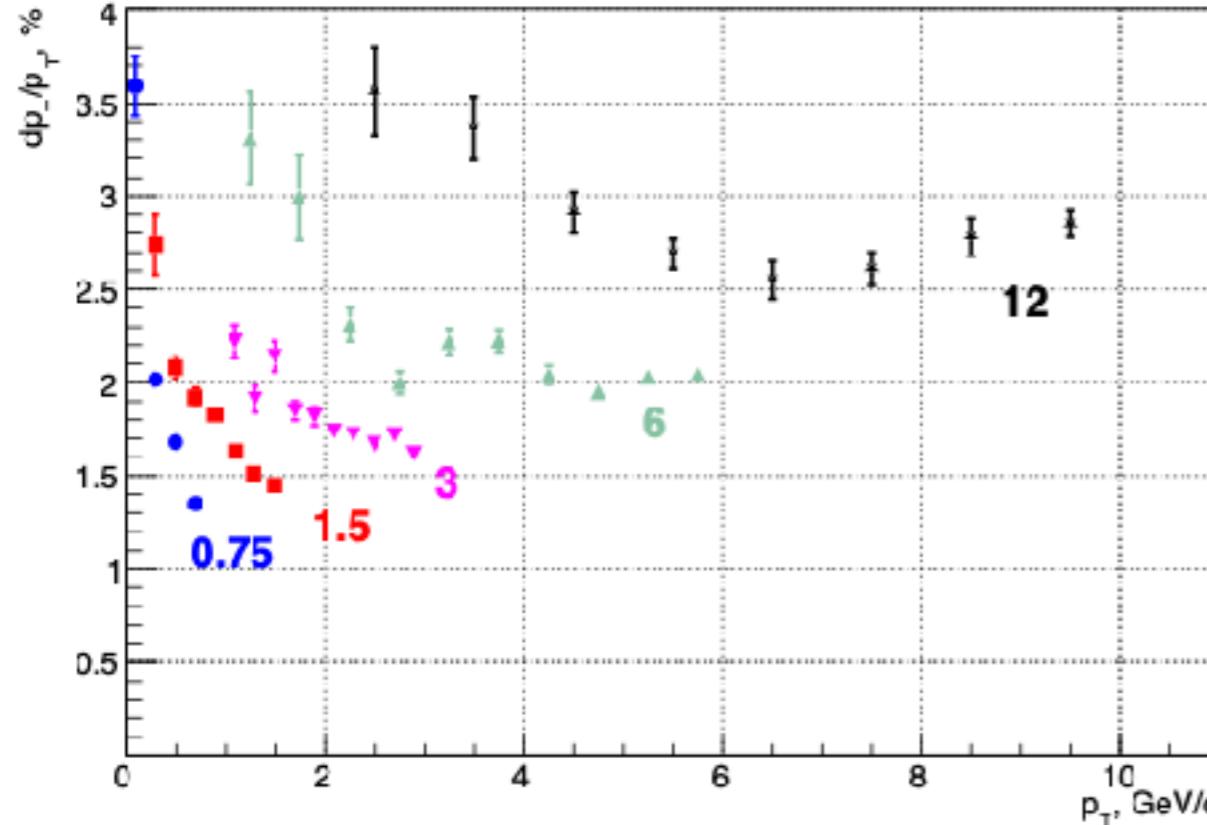
QUARKS	<i>unpolarized</i>	<i>chiral</i>	<i>transverse</i>
U	$f_1$		$h_1^\perp$
L		$g_{1L}$	$h_{1L}^\perp$
T	$f_{1T}^\perp$	$g_{1T}$	$h_{1T}, h_{1T}^\perp$

GLUONS	<i>unpolarized</i>	<i>circular</i>	<i>linear</i>
U	$f_1^g$		$h_1^{\perp g}$
L		$g_{1L}^g$	$h_{1L}^{\perp g}$
T	$f_{1T}^{\perp g}$	$g_{1T}^g$	$h_{1T}^g, h_{1T}^{\perp g}$

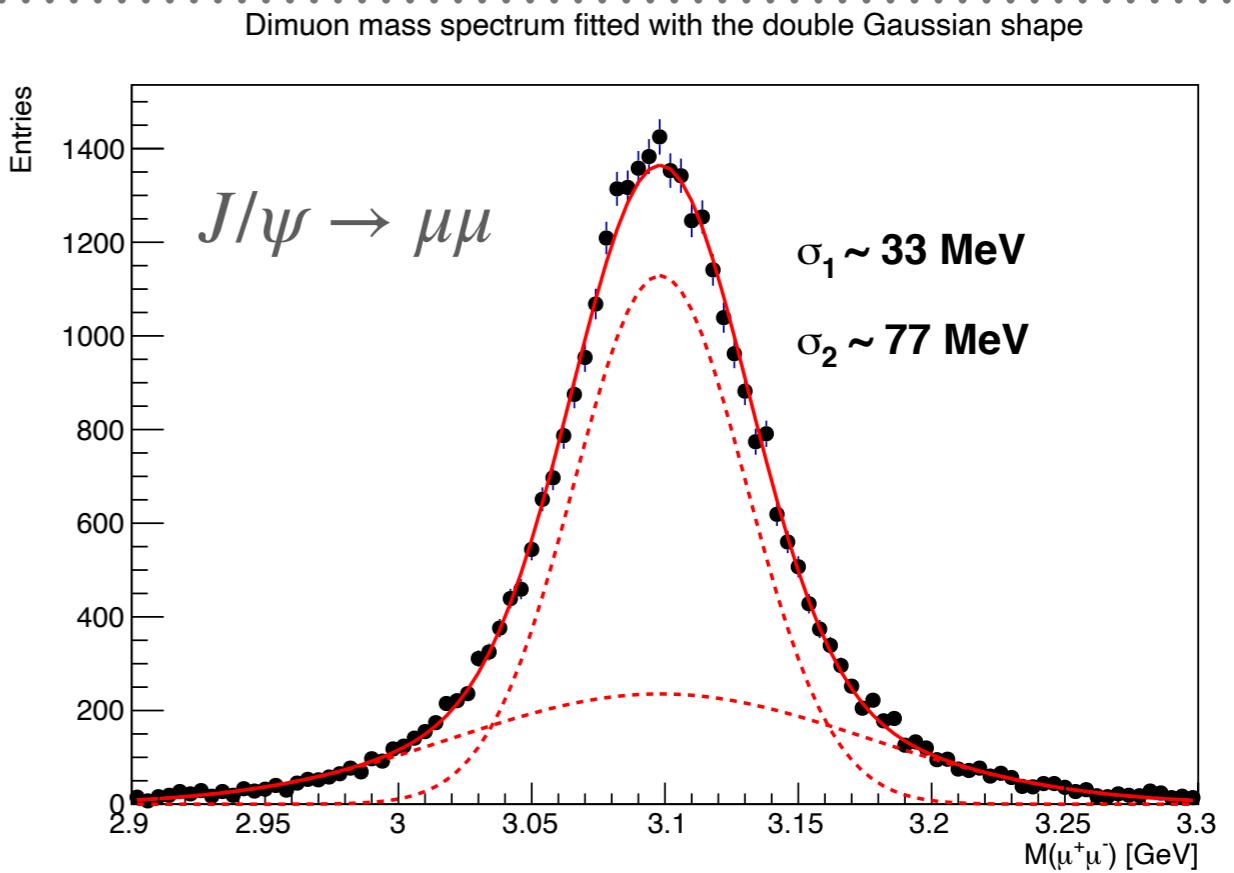
# EXPECTATIONS FOR SPD ENERGIES



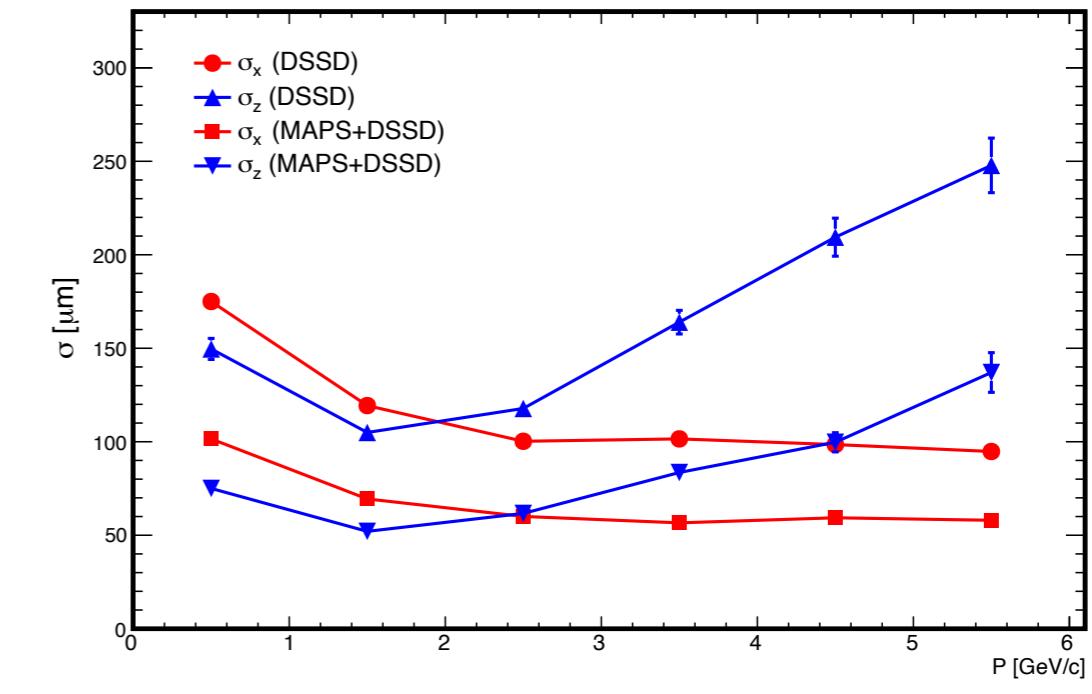
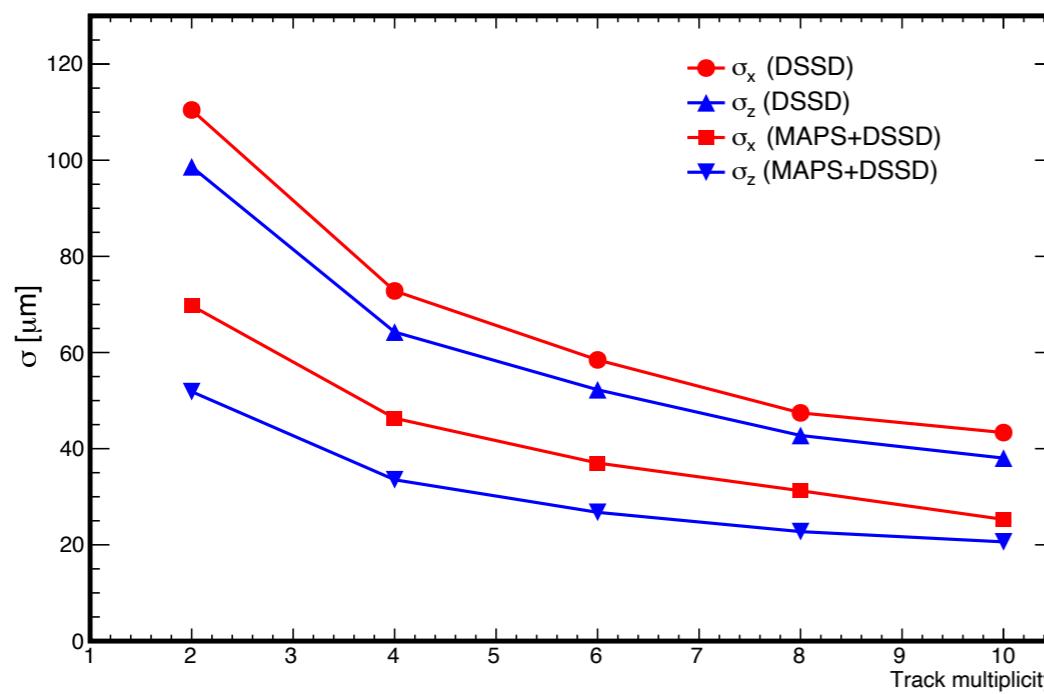
# PHYSICS PERFORMANCE: TRACKING AND VERTEXING



Spatial resolution for primary vertices

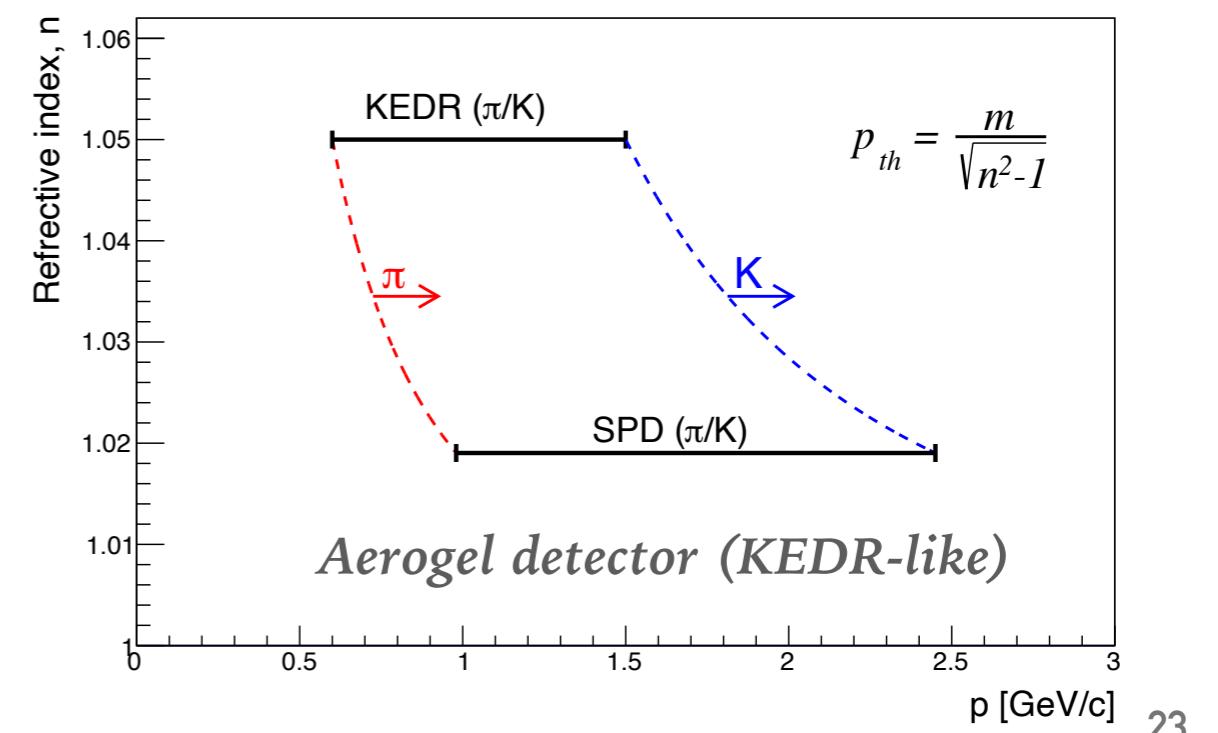
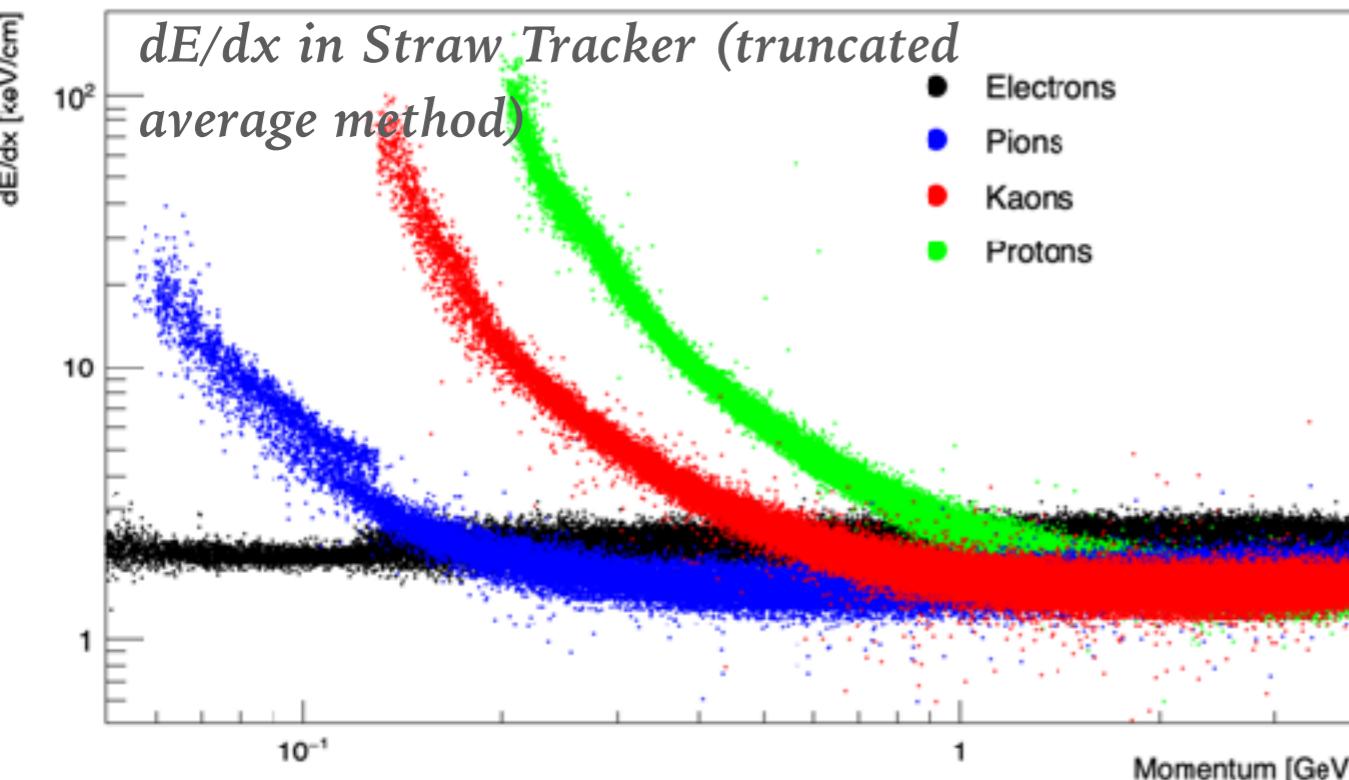
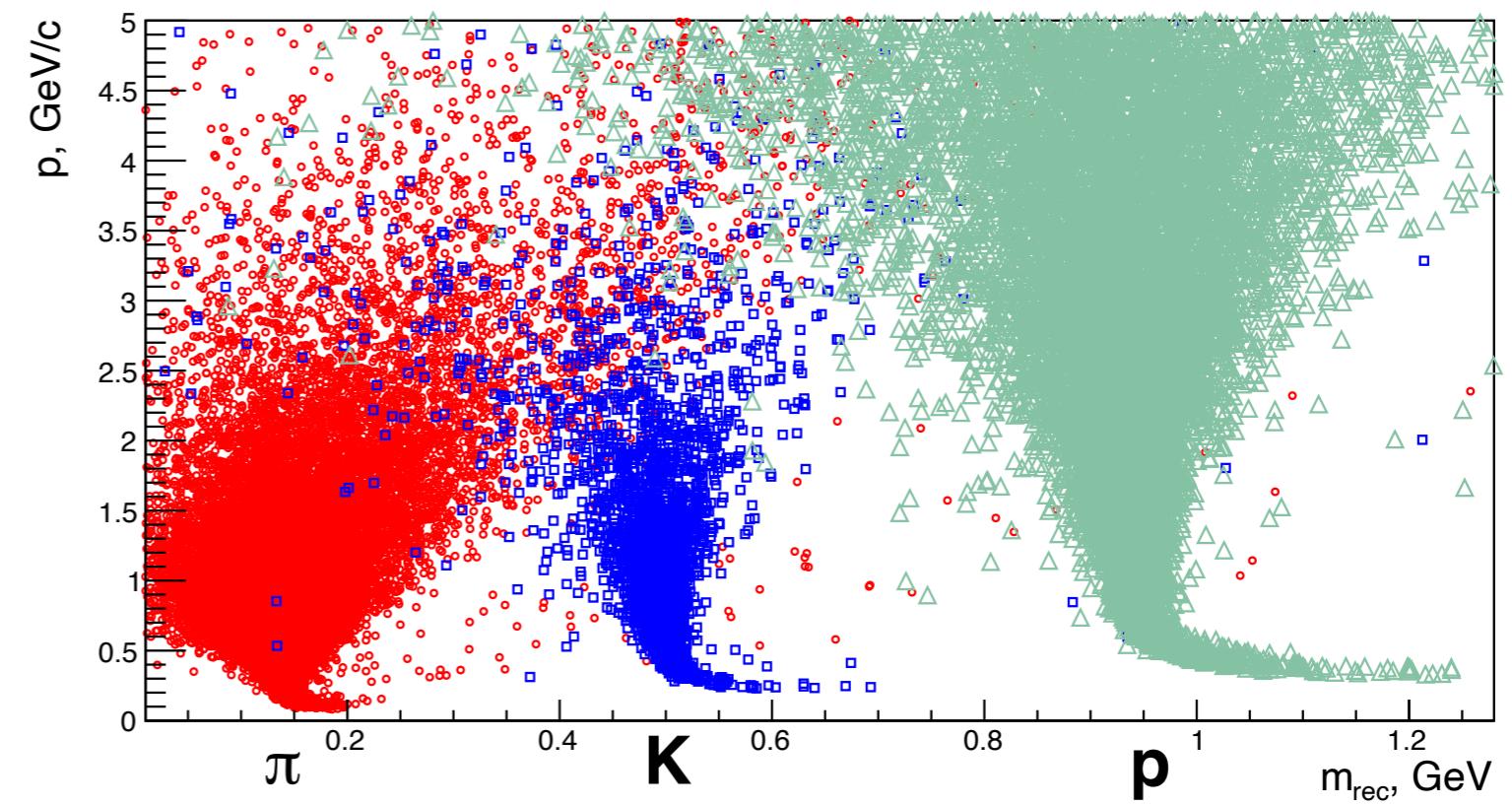
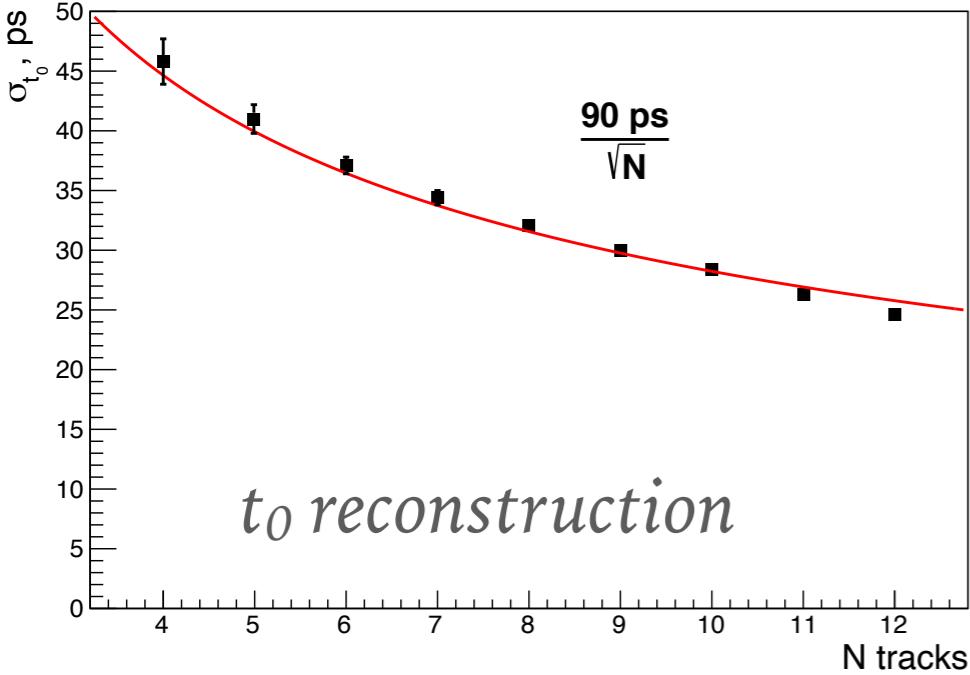


$J/\psi \rightarrow \mu\mu$



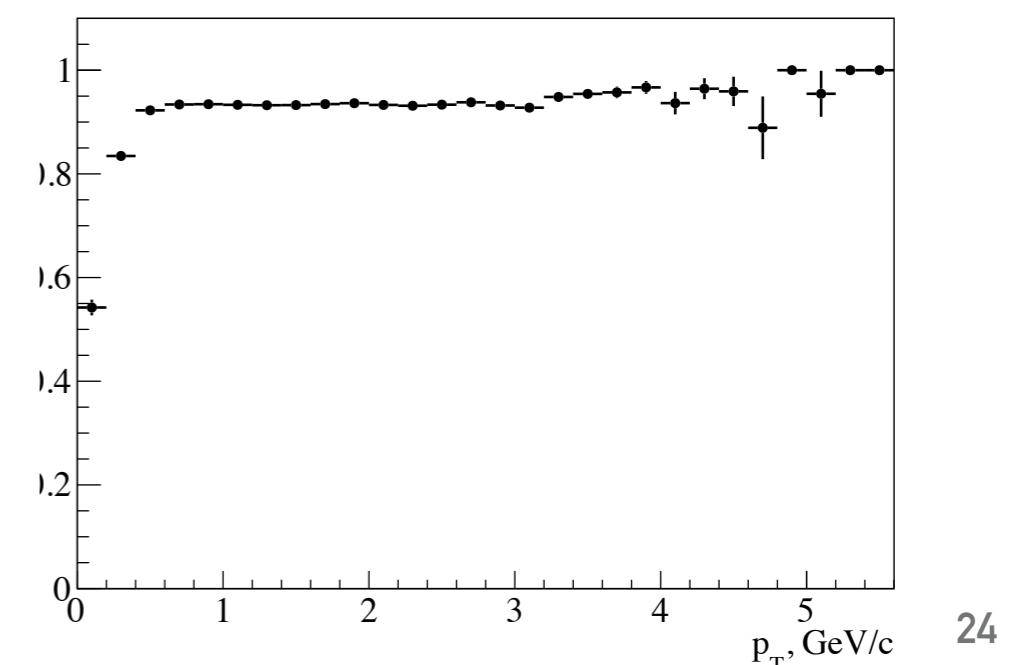
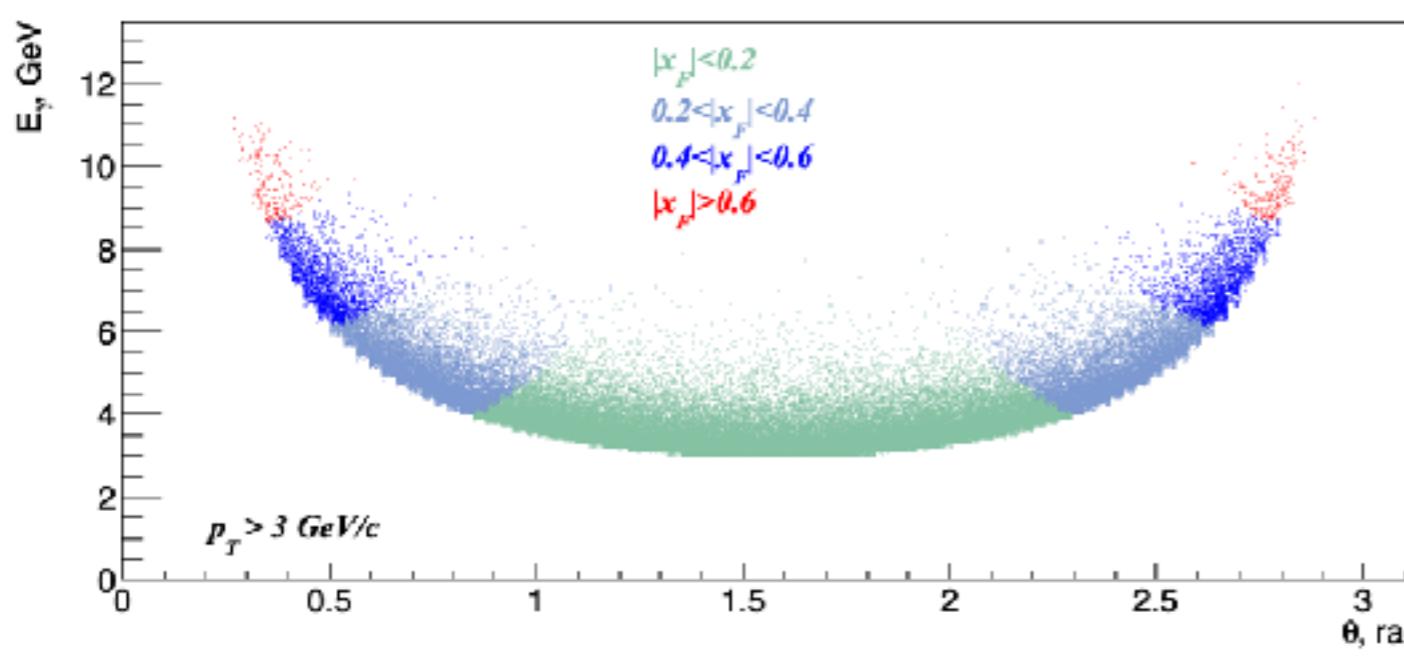
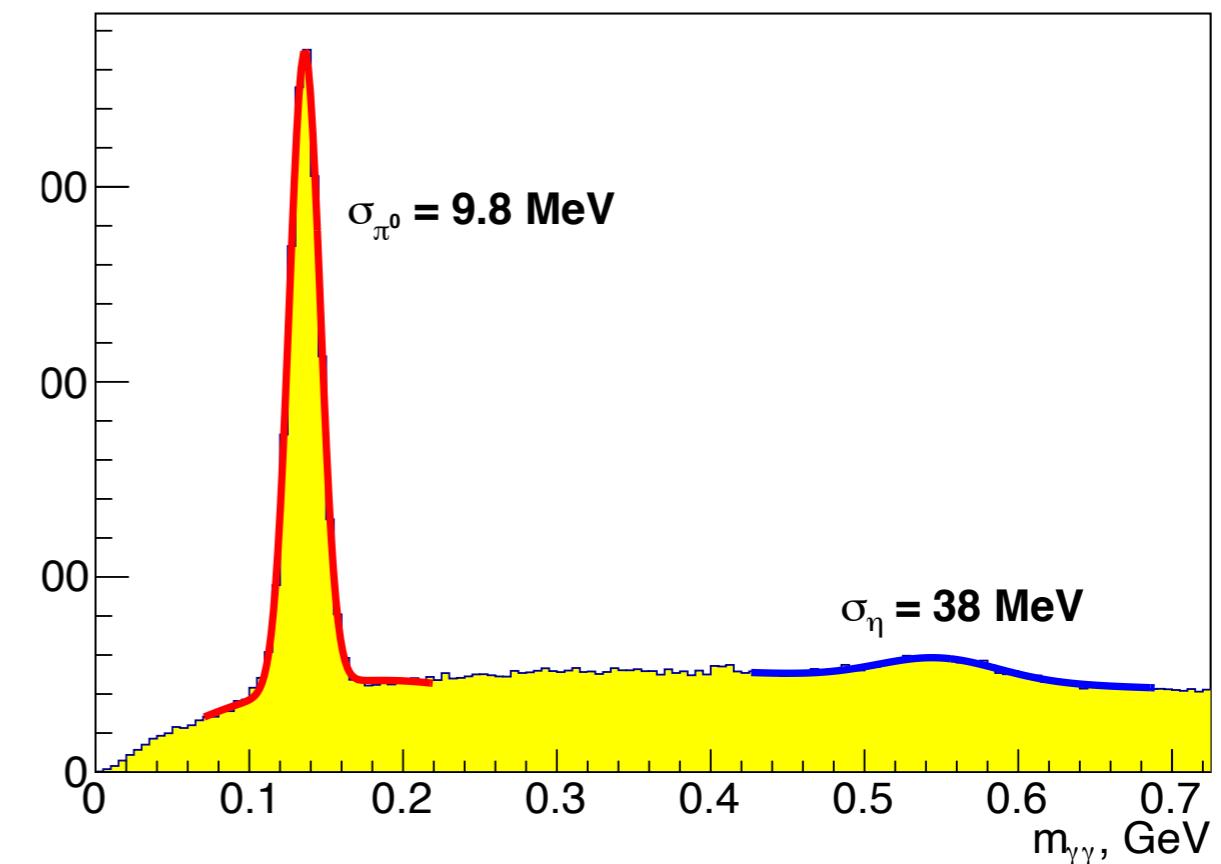
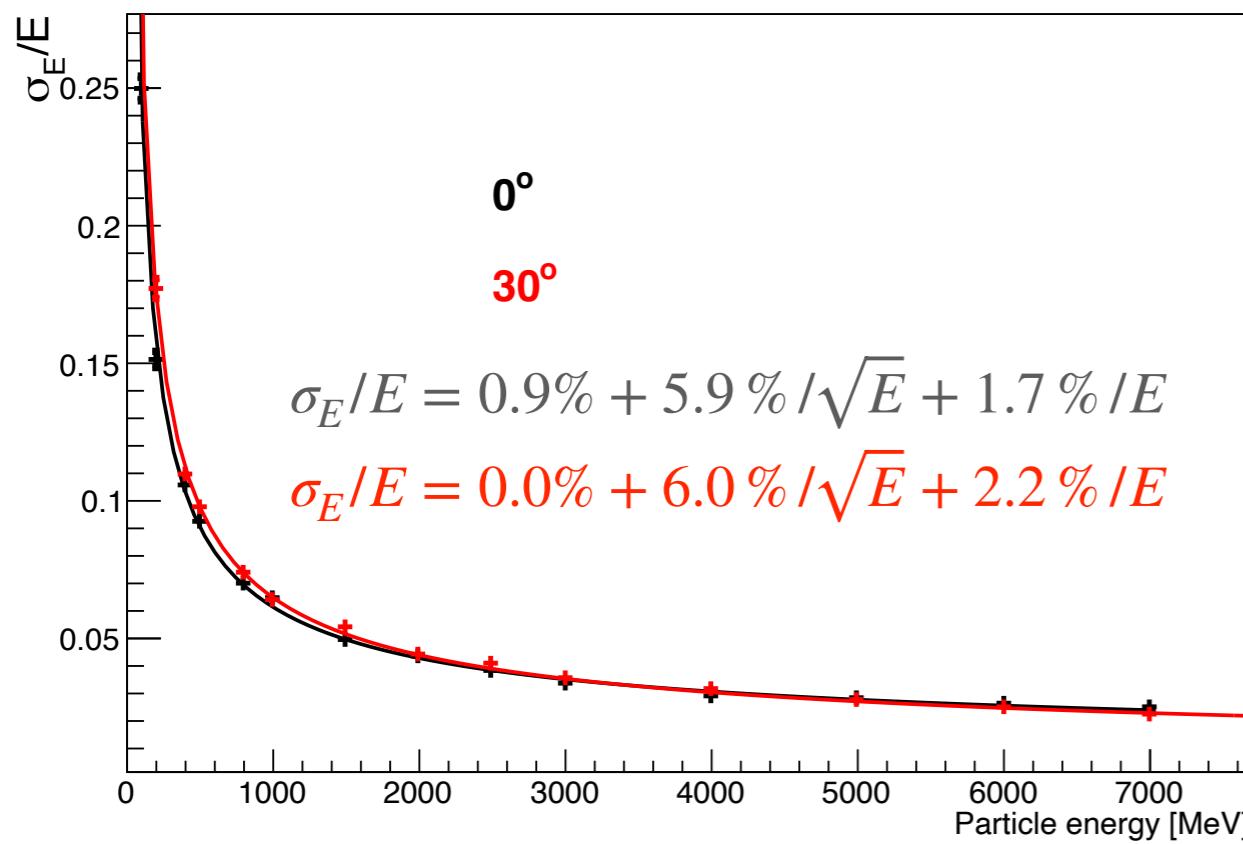
# PHYSICS PERFORMANCE: PID

*TOF ( $\sigma_T=70$  ps)*

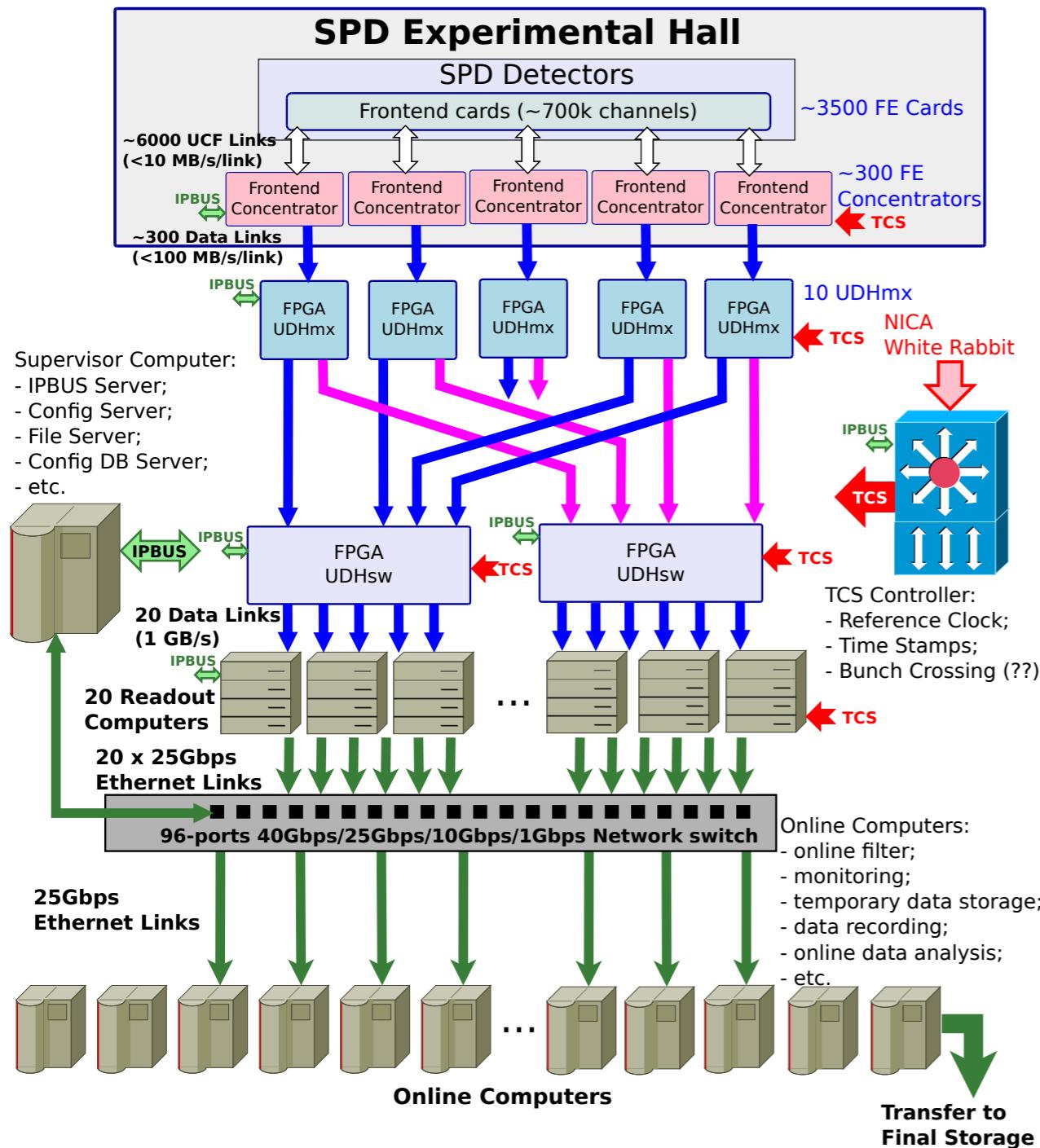


# PHYSICS PERFORMANCE: CALORIMETRY

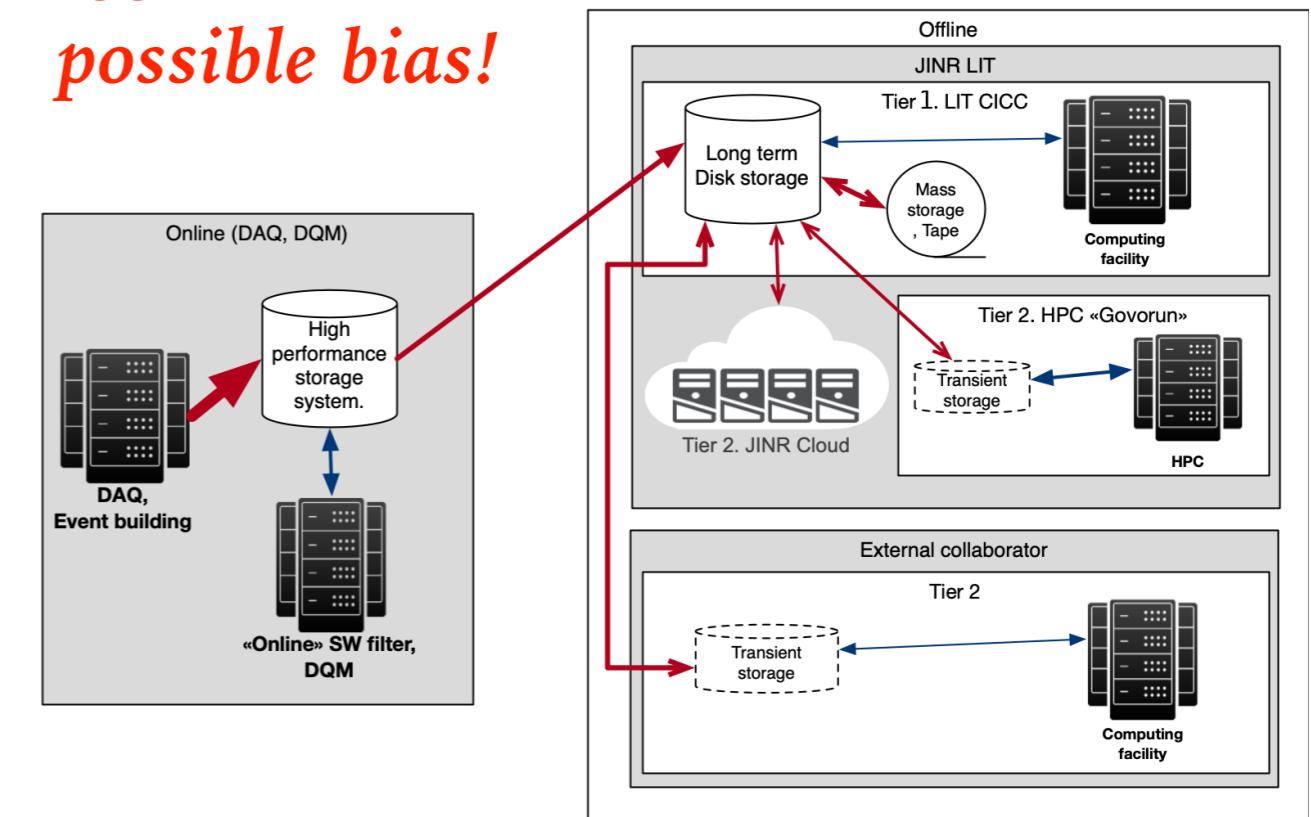
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# DAQ & COMPUTING



*No hardware triggers to avoid possible bias!*



	CPU [cores]	Disk [PB]	Tape [PB]
Online filter	6000	2	none
Offline computing	30000	5	9 per year