EIC 실험을 위한 μRWELL 검출기 소개

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Content

- Introduction to GEM & μRWELL

- ePIC detector plan and GEM+μRWELL tracker

- DAMSA experiment and μRWELL tracker

- μRWELL R&D plan

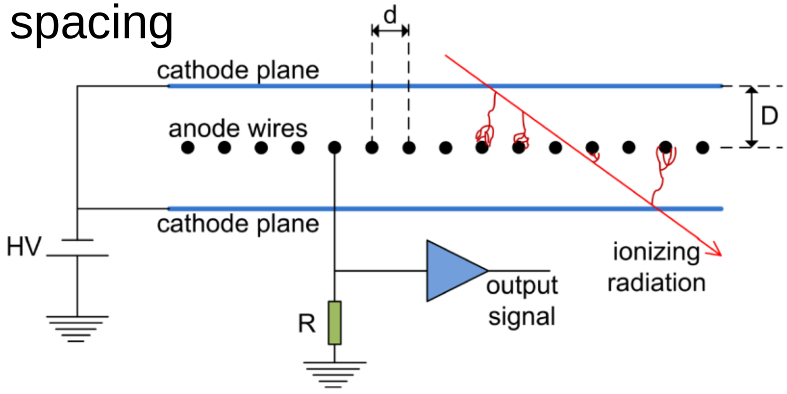
- μRWELL production processes
  - Low rate version
  - High rate version

Capacitive sharing RO

1. Introduction to GEM & μRWELL

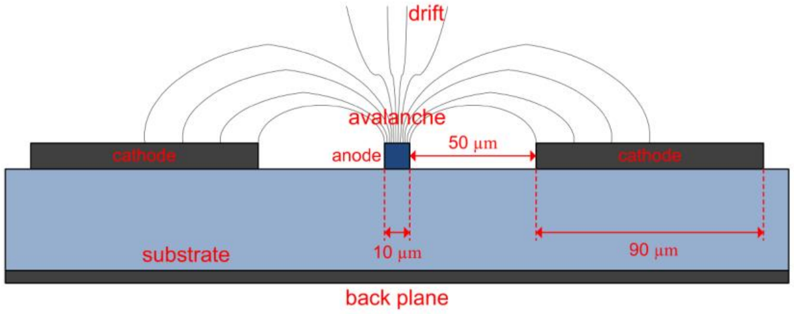
- Limitation of MWPC; impossible to reduce wire spacing

 ⇒ Limited multi-track resolution $\sim O(10mm)$



- Micro Strip Gaseous Counter

 - Susceptible to discharges



- Micro Pattern Gaseous Detector

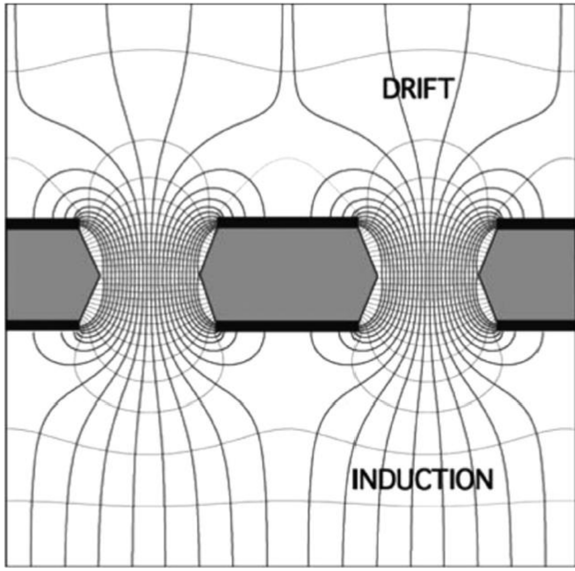
 - Key: suppressing discharges

 → Step-by-step amplification

& separation of RO and amplification region

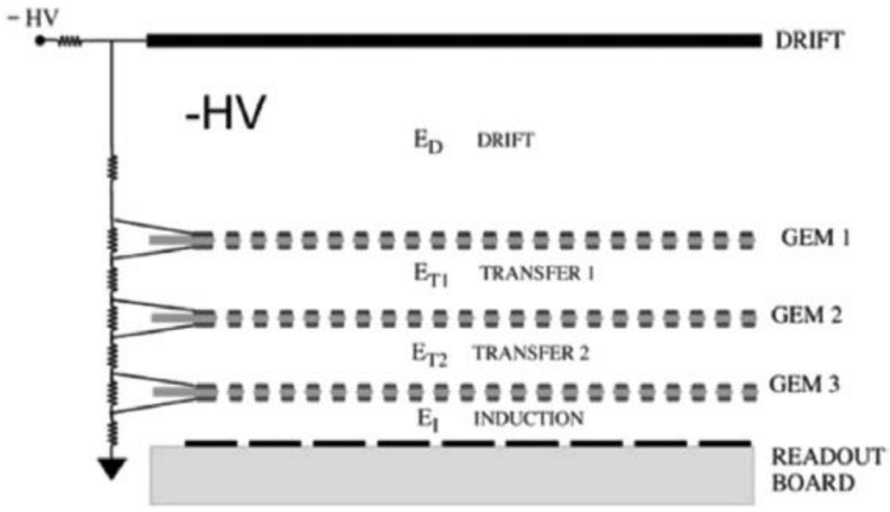
 → Resistive detector

1. Introduction to GEM & μRWELL

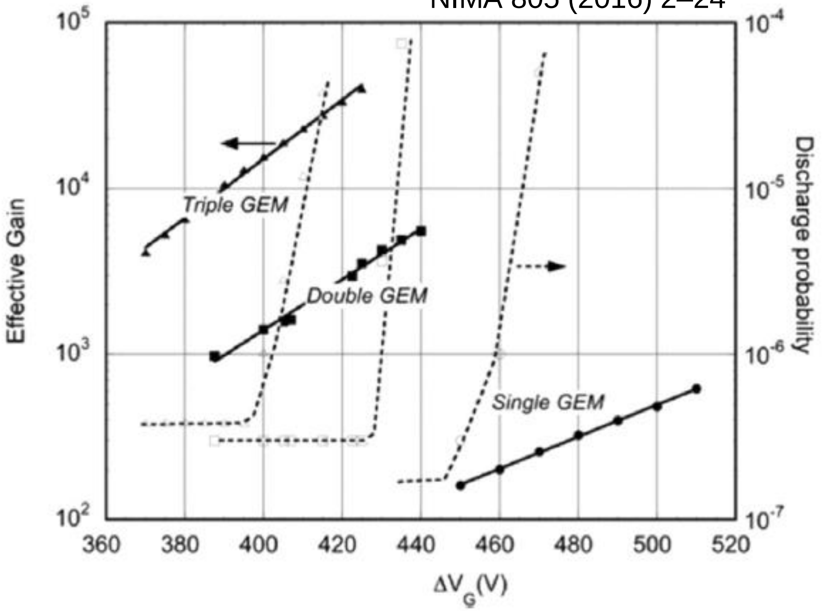


- Gas Electron Multiplier
  - Step-by-step amplification
  - Separation of RO and amplification region
  - Extremely high rate capability

- Only CERN and Korea can produce large-size GEM foils
  - GEM foils contribution of KCMS to CMS phase-2 upgrade

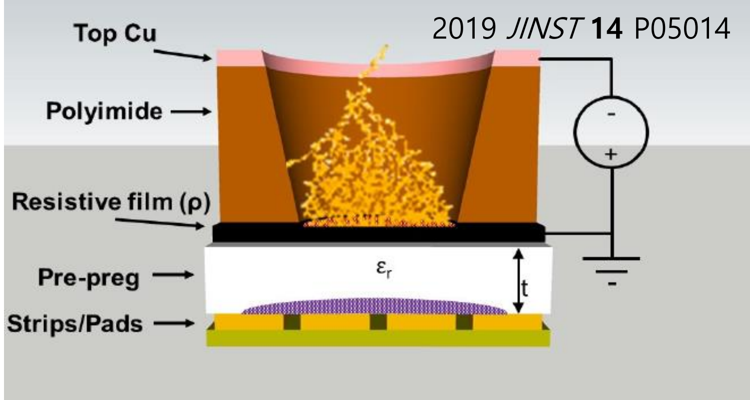


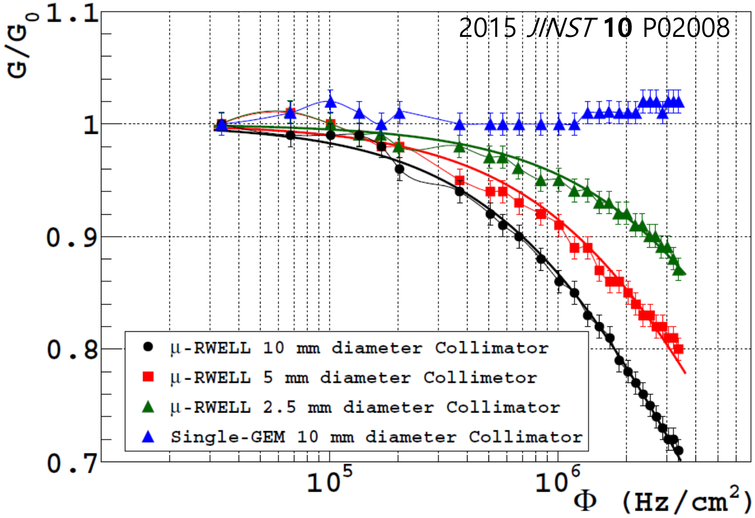
NIMA 805 (2016) 2–24



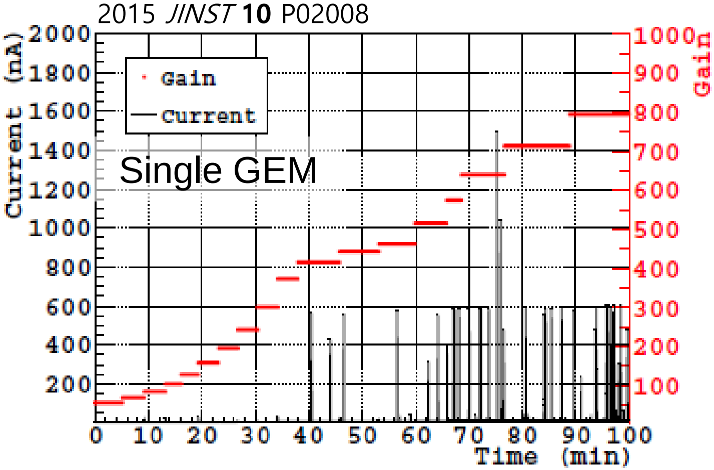
1. Introduction to GEM & μRWELL

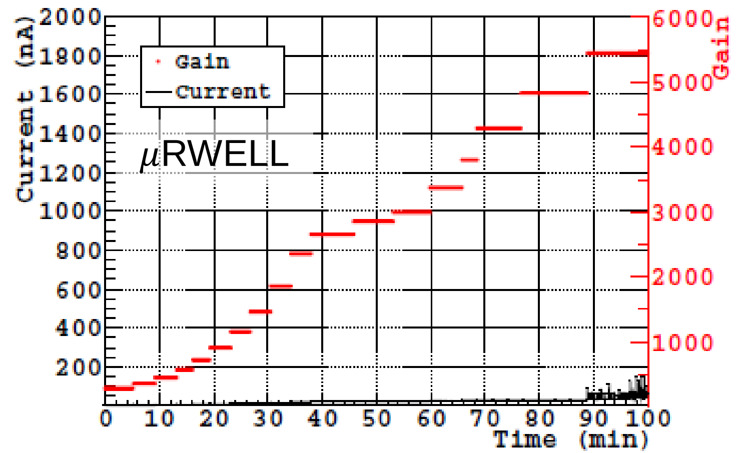
- Micro Resistive Well, the resistive version of GEM
  - Resistive layer, DLC, prevents streamer from evolving discharge
  - Self rigidity due to RO
  - ⇒ Simpler structure and easier assembly
  - ⇒ Cheap



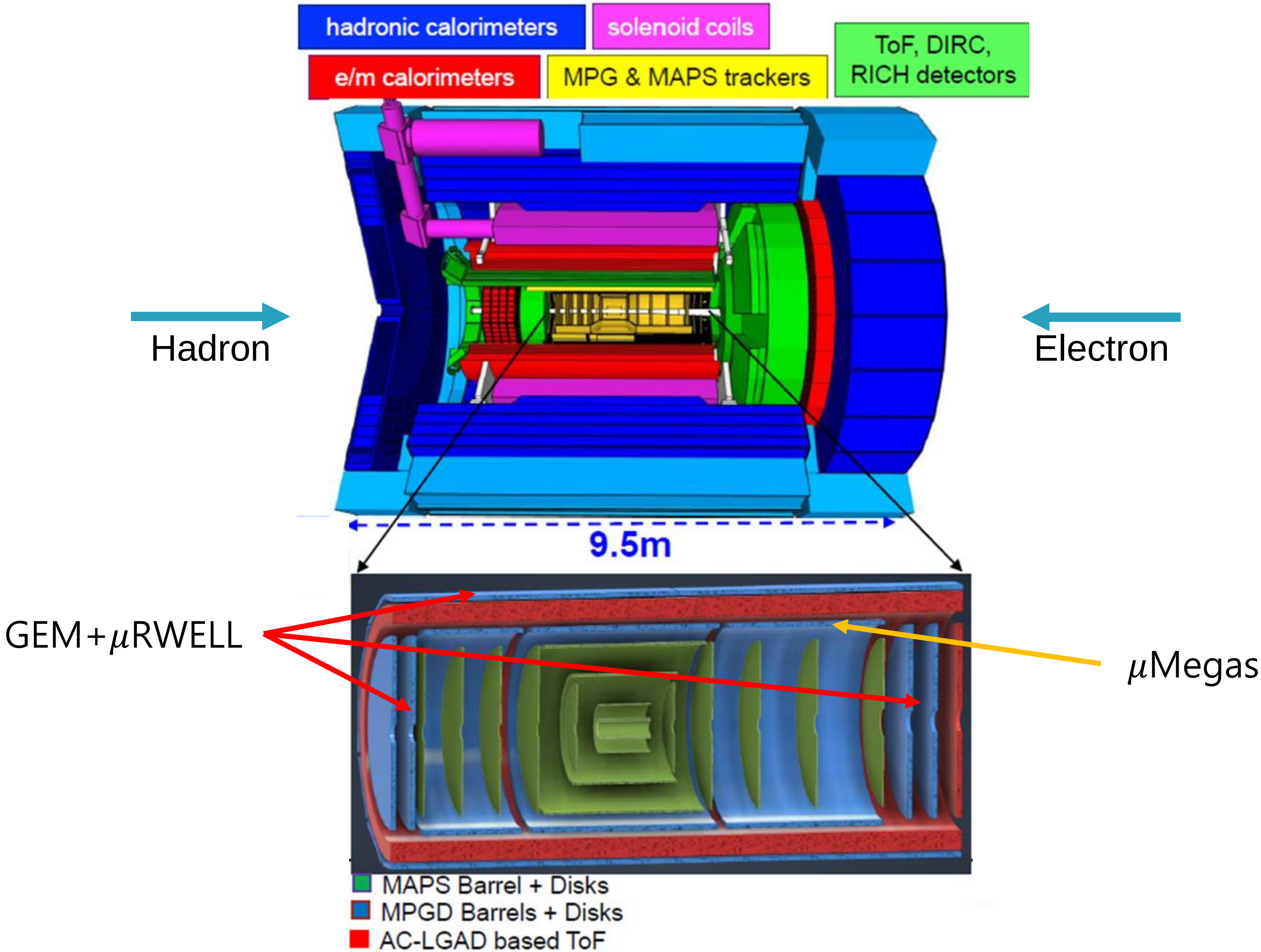


- Experiments using (planning to use) μRWELL
  - LHCb
  - CLAS12
  - ePIC
  - DAMSA
  - FCC-ee





2. ePIC Detector Plan



2. ePIC Detector Plan – ECT

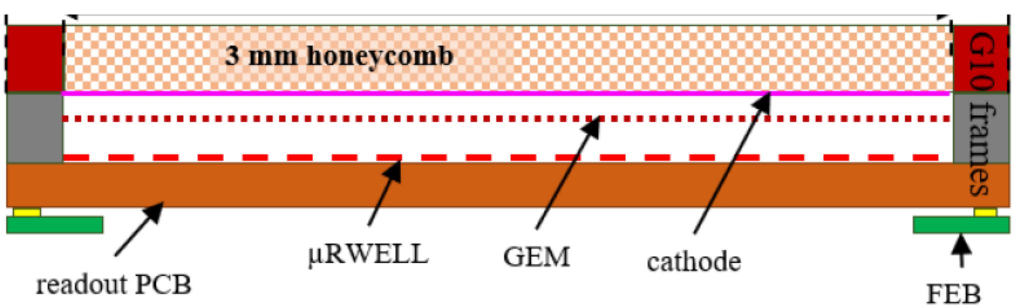
- GEM+μRWELL hybrid detector

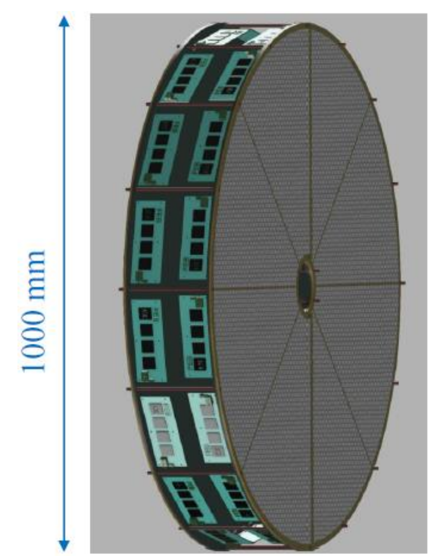
- ePIC (spokesperson, technical coordination and MPGD DSC) has requested Korea participate in the ECT prototyping that will take place next year
  - Concerns about CERN's production capacity

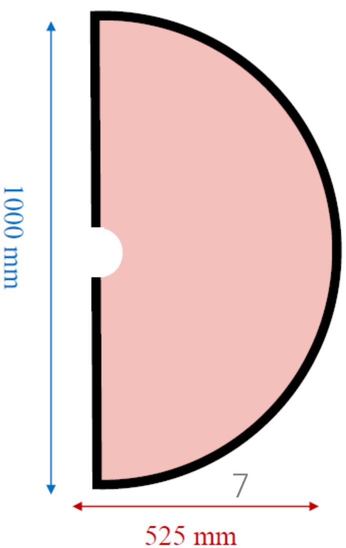
- To take the lead in ePIC and very charming next-generation detector
  - Due to the nature of μRWELL, producer will lead the whole project

- To secure the utilization of GEM production facilities after the KCMS project

- ECT is fit Korean MPGD production capability
  - BOT is too long and out of capability

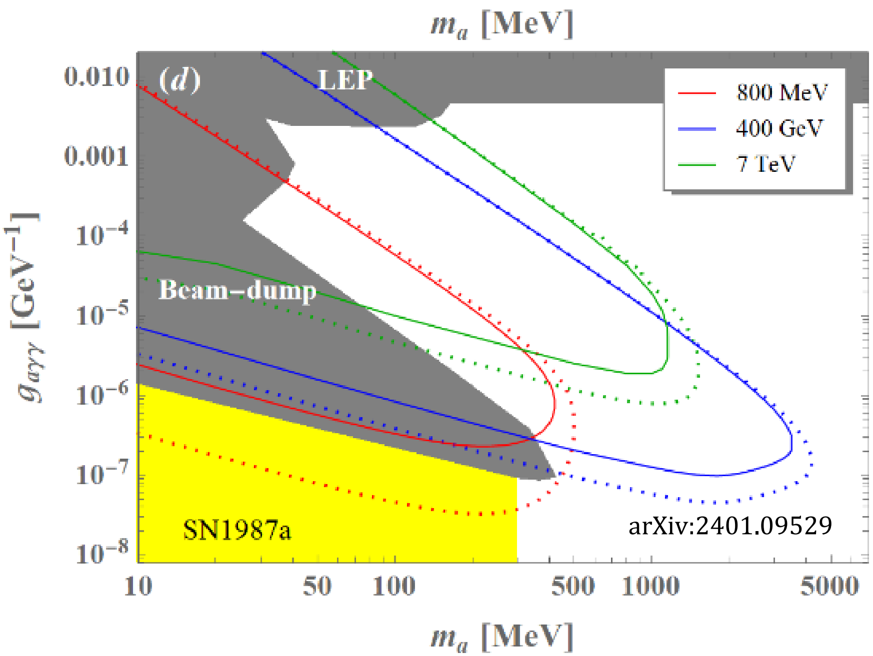


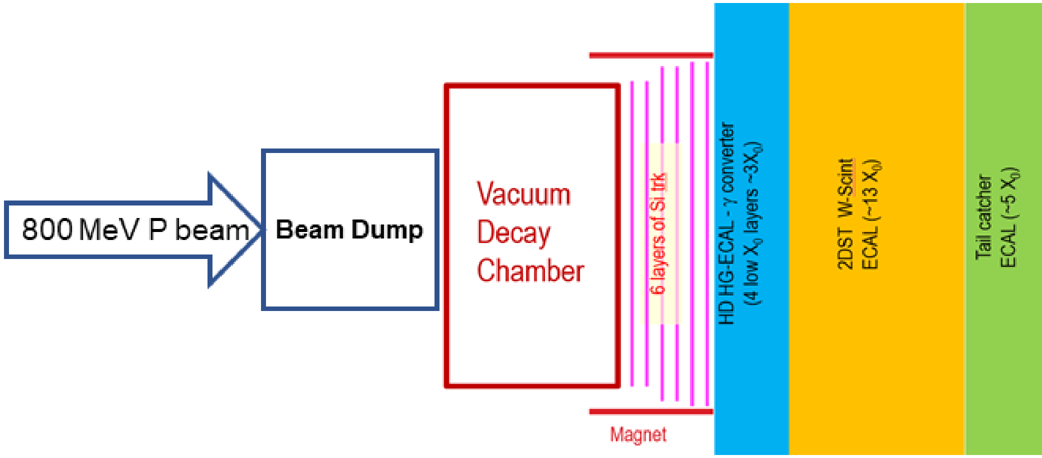




3. DAMSA Experiment

- Search for $a \to \gamma\gamma$ and $A' \to e^+e^-$ using beam dump of Fermi Lab PIP II
  - To veto Bkg. and to detect $A' \to e^+e^-$, tracker is needed
  - μRWELL would be nice option
    ∵ it's cheaper and harder to neutron Bkg. than Si





4. μRWELL R&D Plan

- Timeline

MPGD Timeline			DURATION (years)
START DATE	END DATE	DESCRIPTION	
3/1/24	12/31/24	Detectors Overall Design	<1
1/1/25	12/31/26	Pre - Production	2
1/1/27	31/12/29	Production & QA	3
1/1/30	6/1/30	Commissioning & Installation	0.5

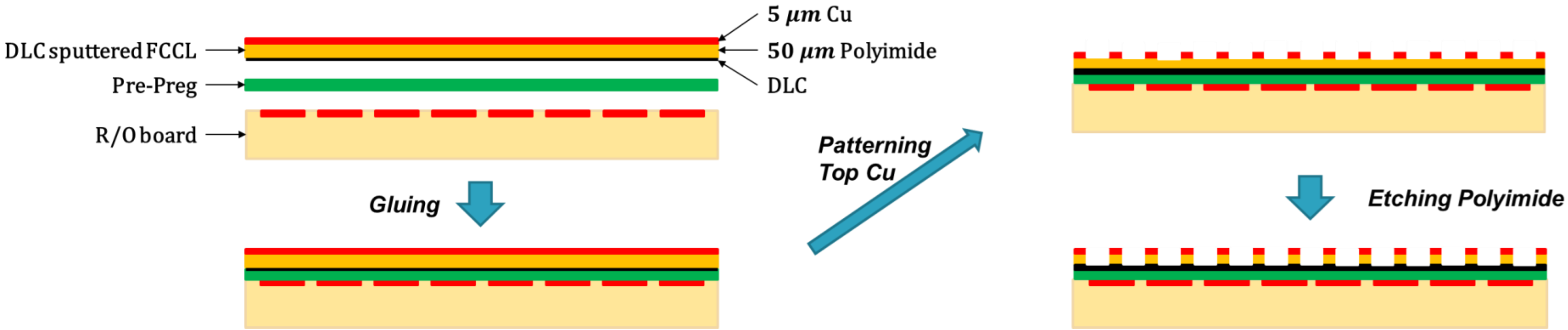
- Completion of Fermi Lab. PIP 2 ~ 2028
- Production of CMS GEM will end ~2025

- Checking production feasibility of μRWELL is the most urgent
  - Plan to attempt production of a $10 \times 10cm^2$ μRWELL in this year

- Design of production process: completed
  - Procurement of parts is ongoing

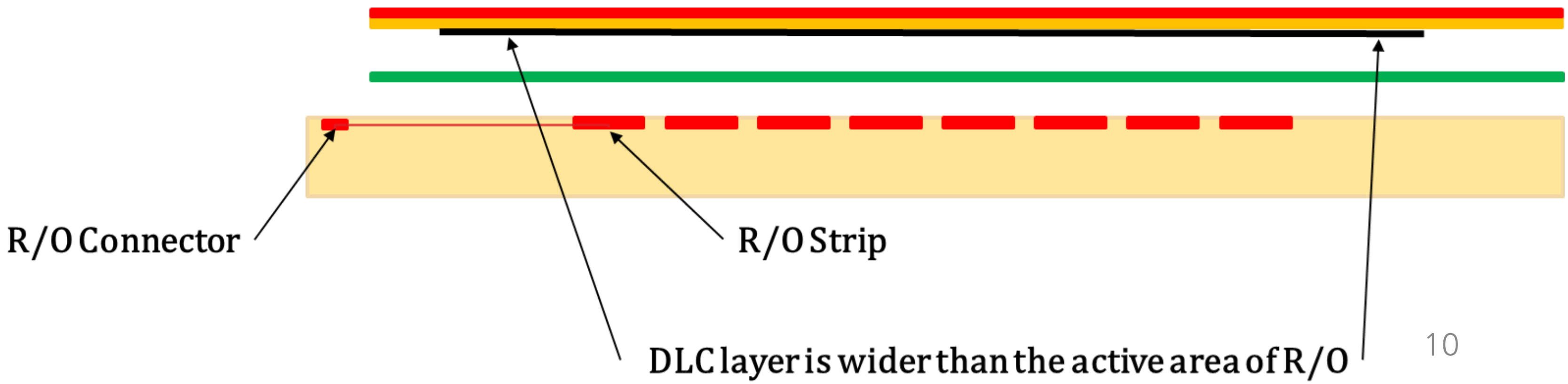
5. μRWELL Production – Overview and DLC Sputtering

- GEM and μRWELL share production processes

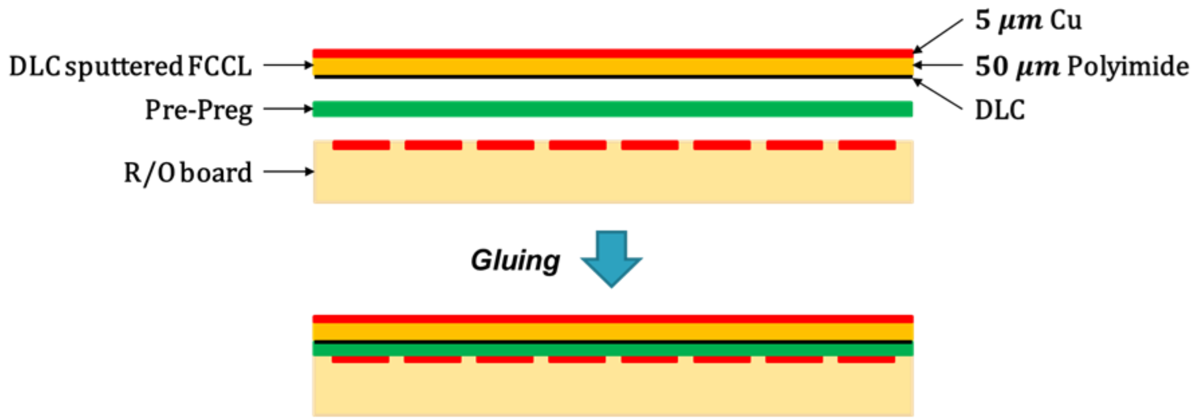


- The most challenging part is PI etching, which KCMS is doing well

- The DLC layer is formed by a sputtering process and are procured by ordering it from CERN or other suppliers (domestic, long-term)

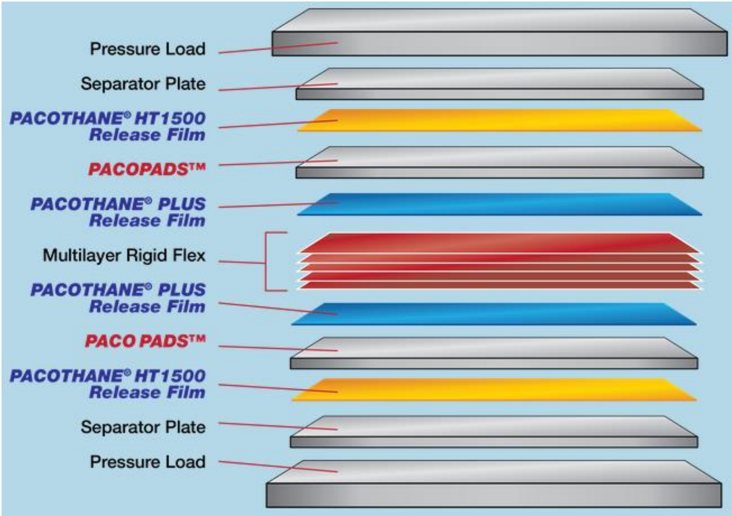


5. μRWELL Production – Gluing



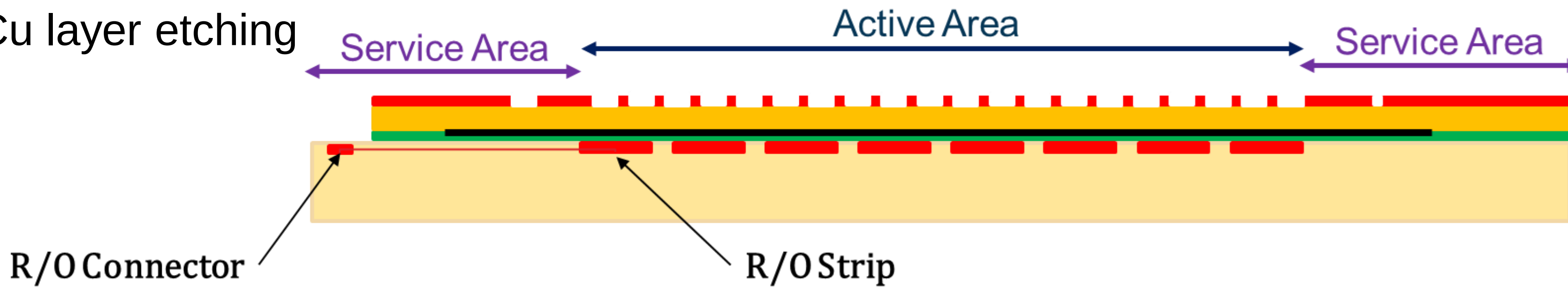
• Pressing DLC FCCL, pre-preg and RO PCB at high temperature in a vacuum chamber

- Will be done by PCB maker
- Common PCB pressing process, but requires know-how to construct "stack" and to define parameters
- Stack: to regularize pressure and to control heat transfer
- Pressure: 7-10 bar, defined by FCCL
- Temperature and duration: defined by choice of pre-preg

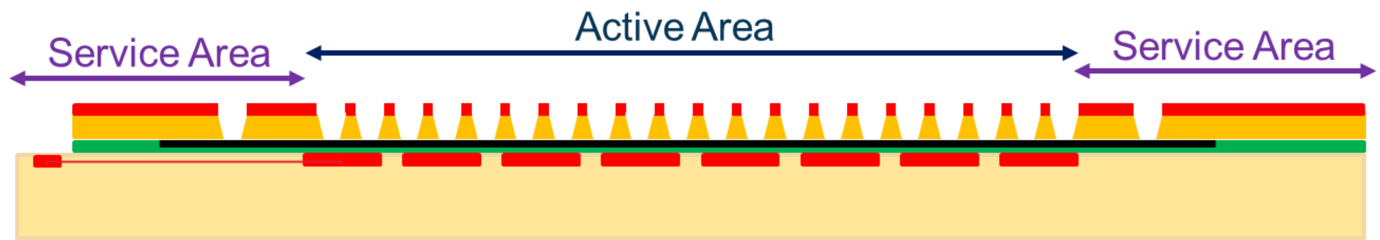


5. μRWELL Production – Photo & Etching

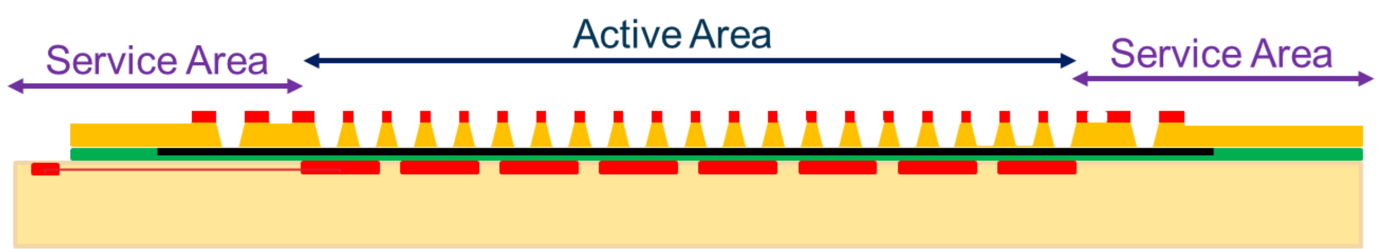
- 1st Cu layer etching



- PI layer etching
  - KOH, amine

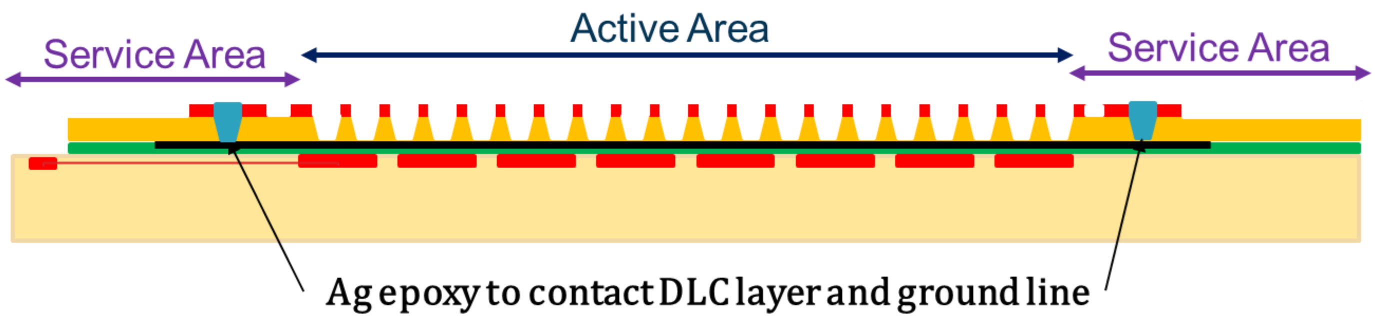


- 2nd Cu etching

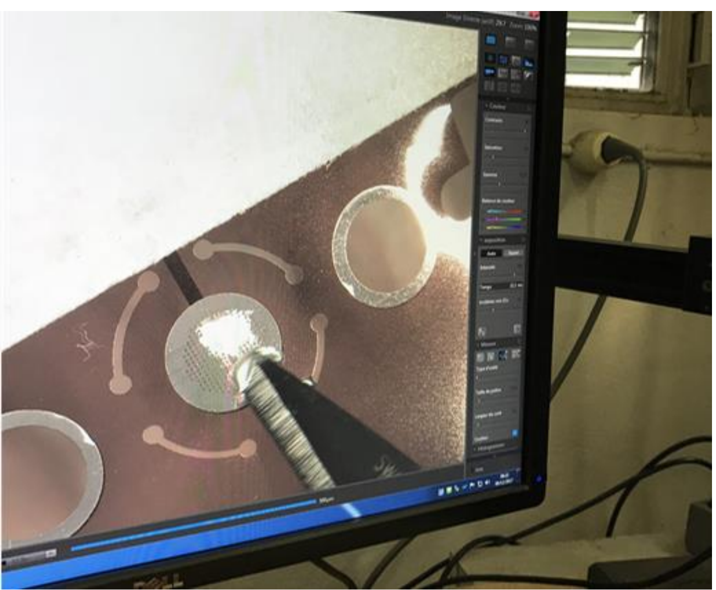


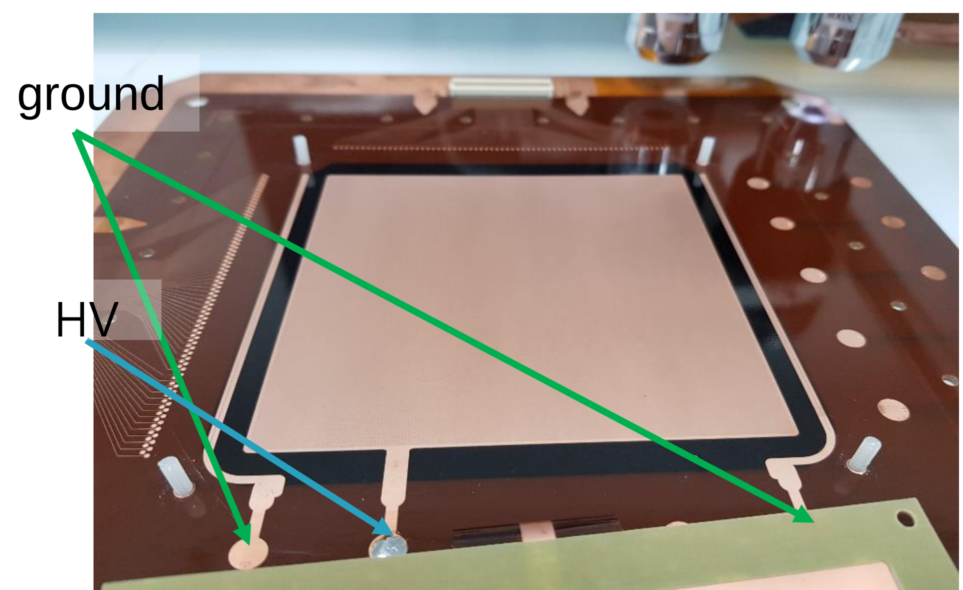
5. μRWELL Production – Post Process and Cleaning

- Ag epoxy pasting



- Soldering connectors and cleaning
  - C-cleaning & E-cleaning needs lots of know-how
  - We have the know-how through KCMS GEM production



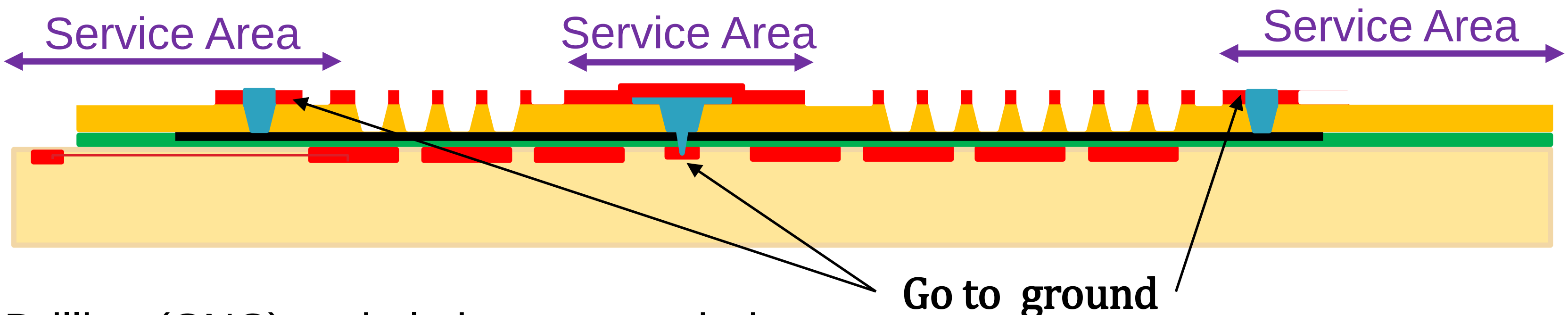


5. μRWELL Production – High rate version

- Rate capability of μRWELL is limited by voltage drop due to charge drain

⇒ Grounds can be added to increase rate capability

- PEP type high rate μRWELL



- Drilling (CNC) and plating are needed

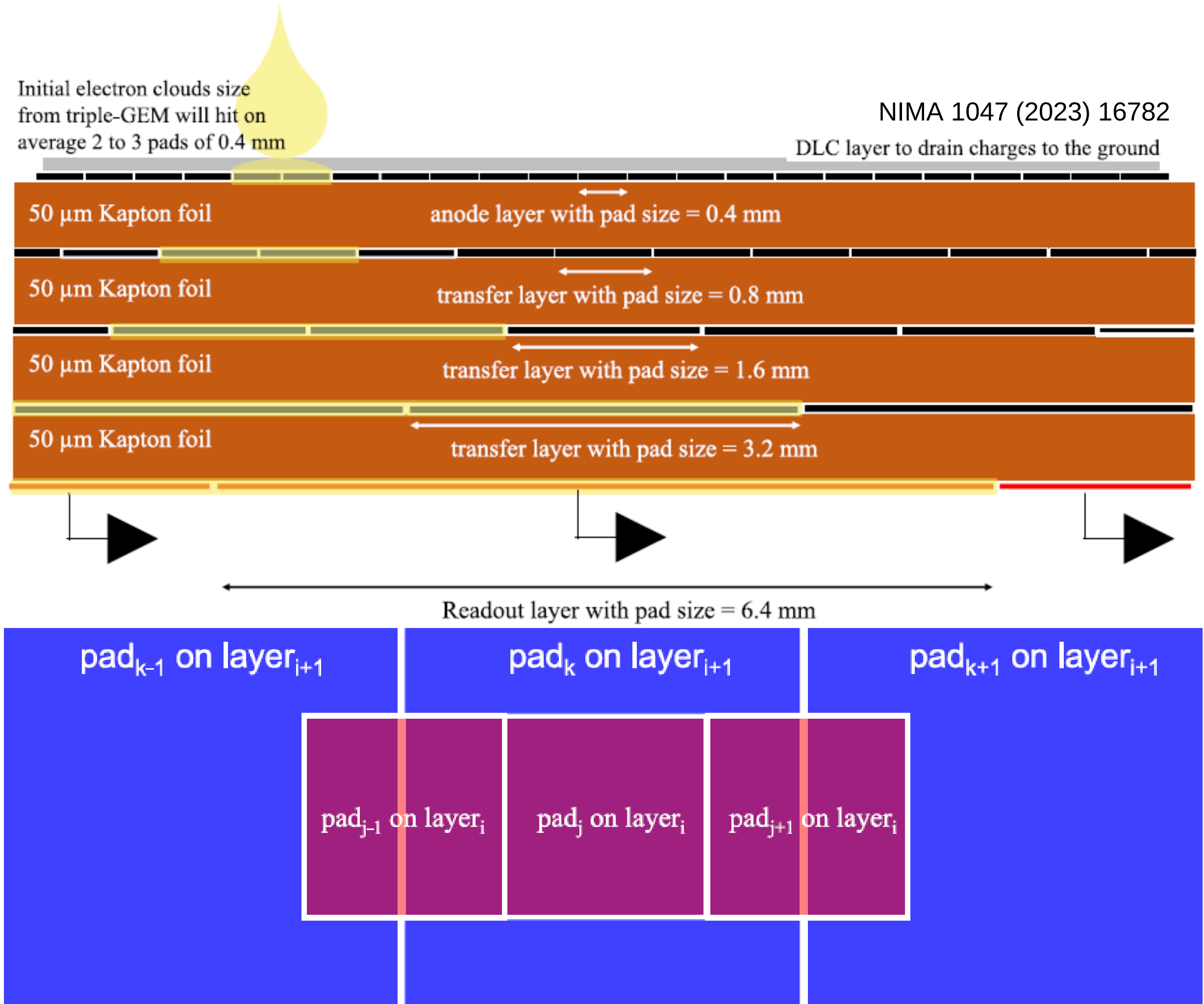
→ Long-term challenges beyond current production capability

- FCC-ee may need this type

- For ePIC and DAMSA, low rate version is more than enough

6. The Capacitive Sharing Readout

- Spreading signal laterally using the capacitive sharing layer, $\sim 60\ \mu m$ resolution is achievable even with $800\ \mu m$ pitch strip RO
  - Very nice timing property
  - Versatile
  - NIMA 1047 (2023) 16782



Summary

- μRWELL, the resistive version of GEM, is very charming
  - Simple structure and cheap
  - ePIC, DAMSA, and FCC-ee

- ePIC has requested Korea participate ECT prototyping due to concern of CERN's production capacity
  - It will be win-win game for Korea as well

- Studying production process has been done

$\rightarrow$ μRWELL production is feasible using the technology we already have

- $10 \times 10cm^2$ μRWELL will be produced in this year
  - Procurement is ongoing

Back Up

Physics programs – spin structure of proton

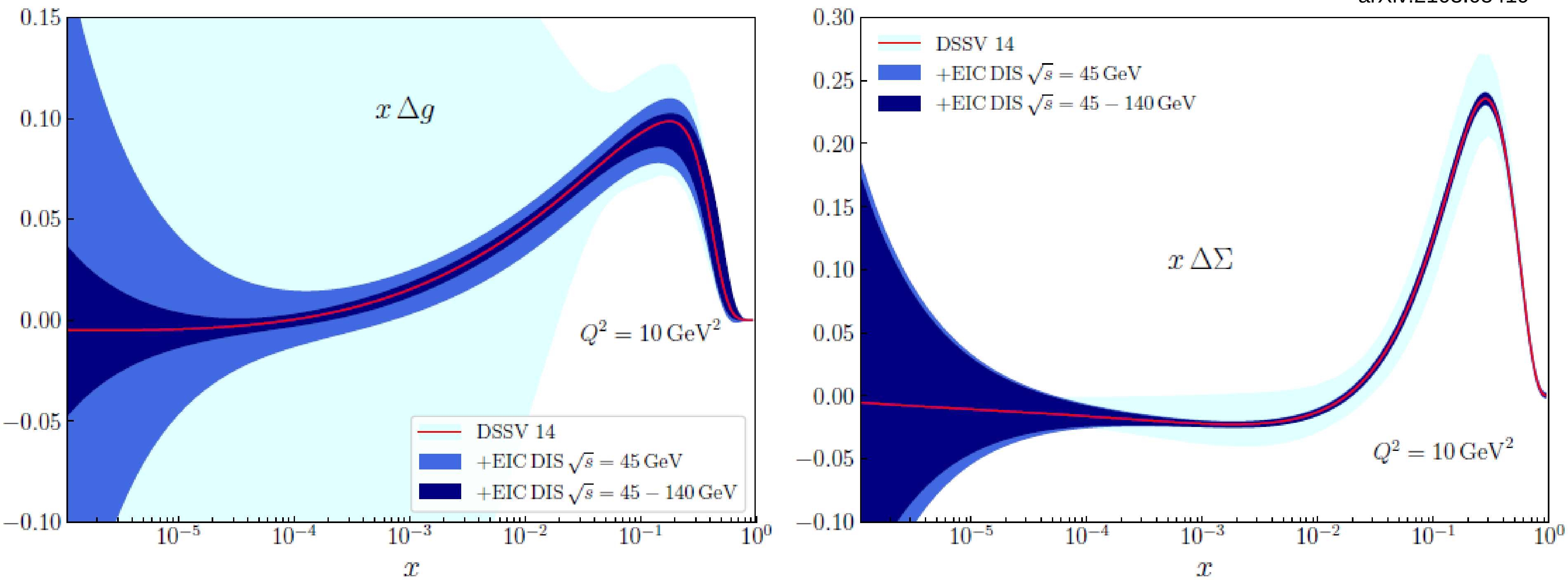
- Inclusive A_{LL}

$$\frac{1}{2}\left[\frac{d^2\sigma^{\leftrightarrows}}{dxdQ^2} - \frac{d^2\sigma^{\rightrightarrows}}{dxdQ^2}\right] \cong \frac{4\pi\alpha^2}{Q^4} y(2-y) g_1(x, Q^2)$$

, where $g_1(x,Q^2) = \frac{1}{2}\sum e_q^2[\Delta q(x,Q^2) + \Delta\bar{q}(x,Q^2)]$.

- Δg is encoded in scale violation of g_1

arXiv:2103.05419



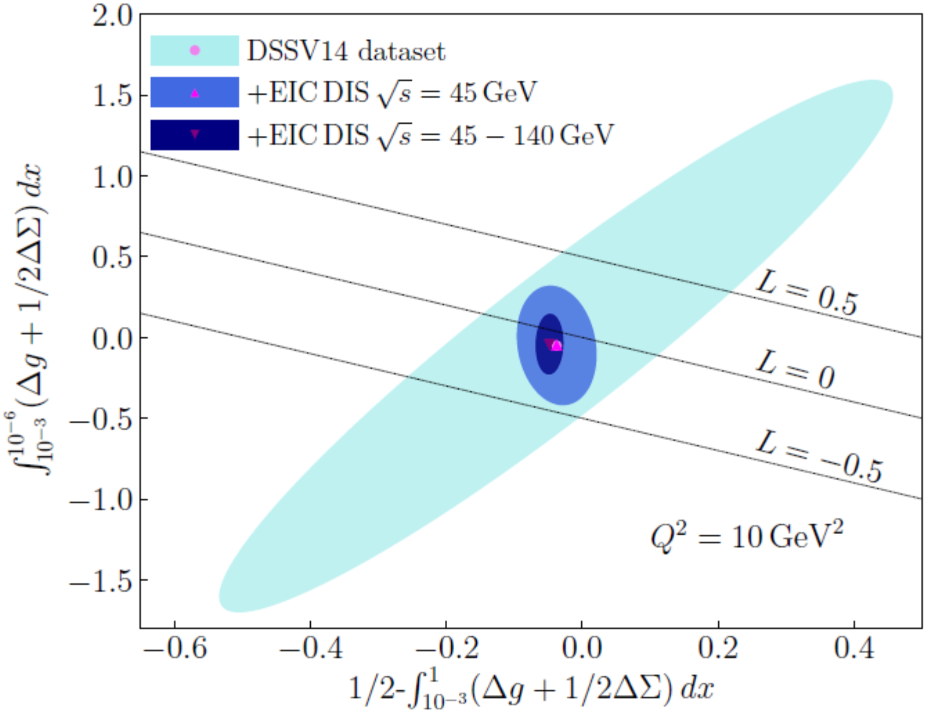
Physics programs – spin structure of proton

- OAM
  - As S_q and S_g are expected to be precise, OAM will be constrained
  - $J^q = \frac{1}{2} - J^g = \frac{1}{2}\int dx x[H^q(x, \xi = 0, t = 0) + E^q(x, \xi = 0, t = 0)]$, where H and E are GPD

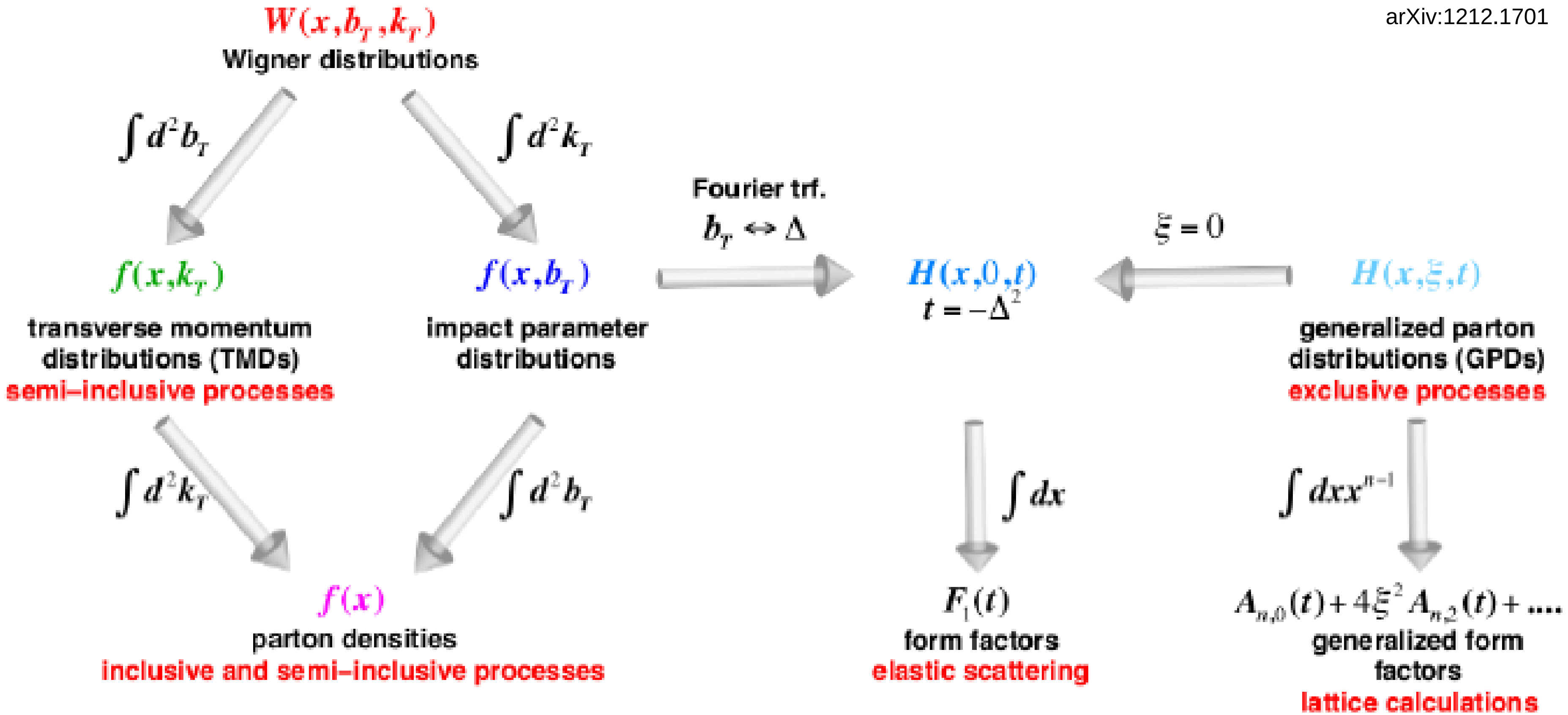
$$OAM_q = J^q - S_q \text{ and } OAM_g = J^g - S_g$$

  - H and E are accessible at EIC and JLab via DVCS and DVMP

arXiv:2103.05419



Physics programs – Multi. D. imaging of proton



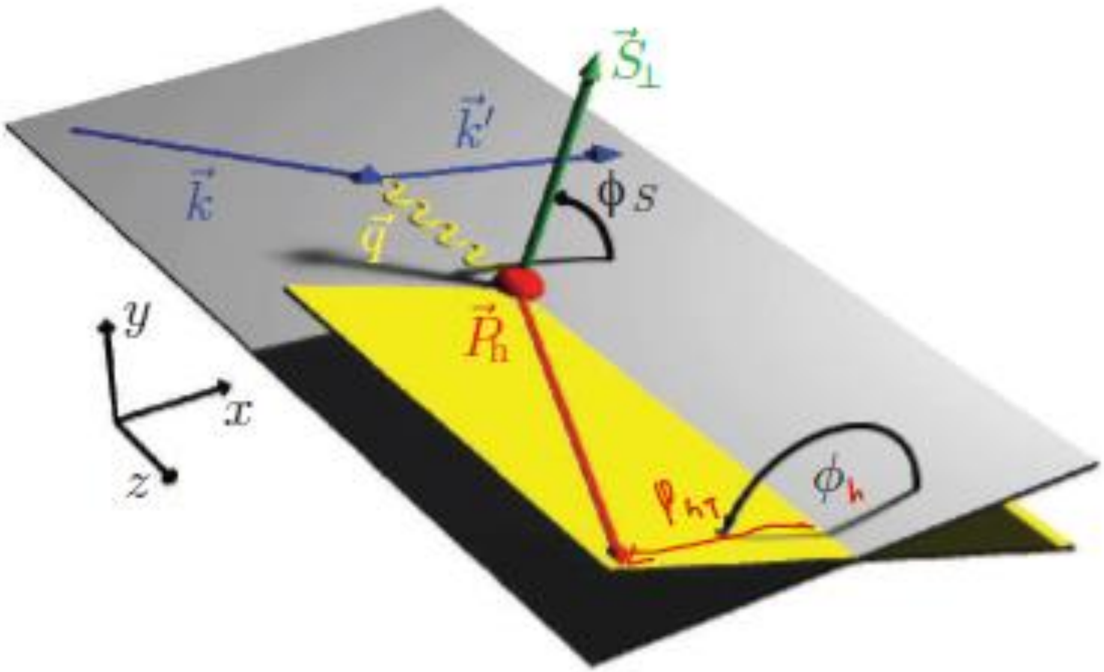
arXiv:1212.1701

Physics programs – TMDs

- $\frac{d\sigma}{dxdyd\phi_S dzd\phi_h dP_{hT}^z} \propto F_{UU} + |S_\perp| \sin(\phi_h - \phi_S) F_{UT}^{\sin(\phi_h - \phi_S)} + \cdots$

  , where $F_{UT}^{\sin(\phi_h-\phi_S)} = \sum_q e_q^2 |C_V\ (Q)|^2 [R(Q;\mu_0) \otimes f_{1T}^{\perp q}(x;\mu_0) \otimes D_1^q\ (z;\mu_0)](P_T)$

  , where $|C_V\ (Q)|^2$ perturbative coefficient, $R(Q;\mu_0)$ evolution factor, $f_{1T}^{\perp q}(x;\mu_0)$ Sivers TDM, and $D_1^q\ (z;\mu_0)$ unpolarized TMD FF

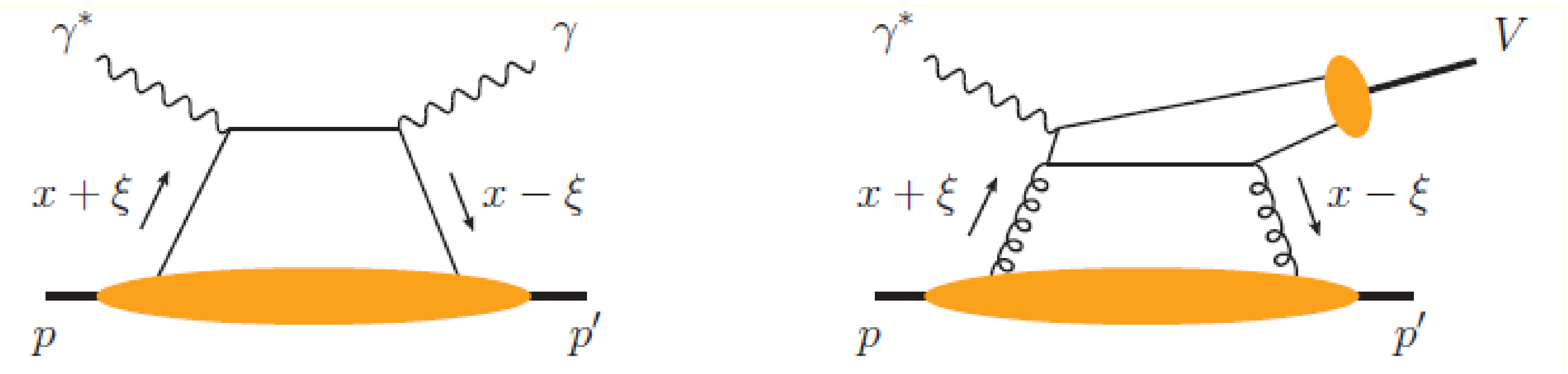


Physics programs – GPDs

- GPDs provide a connection between PDFs and form factors

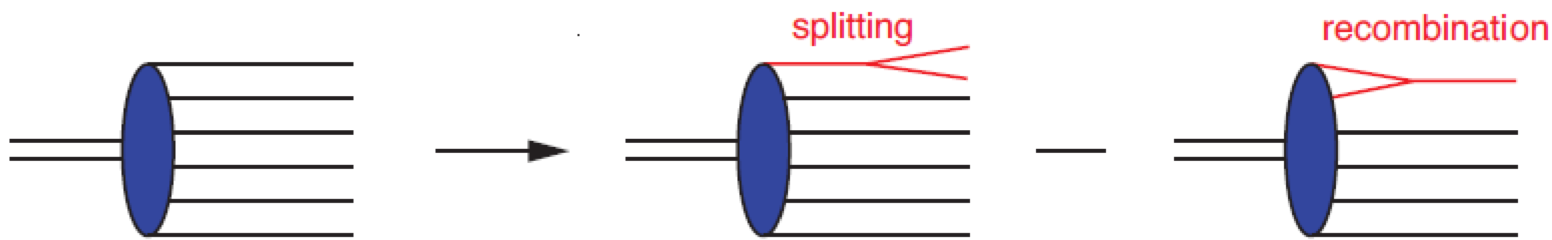
- The cleanest channels to access GPDs are DVCS and DVMP

  \- $x + \xi$ and $x - \xi$ are longitudinal parton momentum fractions with respect to the average proton momentum $\frac{p+p'}{2}$ before and after scattering



Physics programs – Gluon saturation

- Will gluon density continue to increase in low enough x region?
  - Probably not

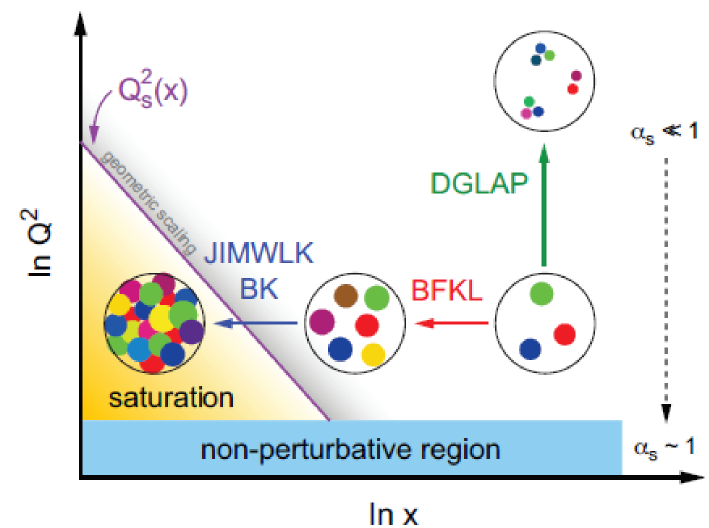


- BFKL evolution
  - The evolution eq. that allows one to construct the PDF at low-x
  - $\frac{\partial N(x,r_T)}{\partial \ln(1/x)} = \alpha_s K_{BFKL} \otimes N(x,r_T)$, where $r_T \sim 1/Q$ (transverse distance) and Fourier Tr.

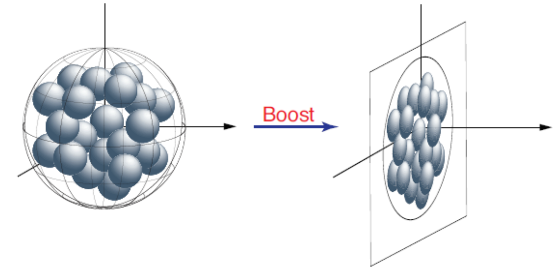
of $N(x,r_T)$ is related to gluon TMD

- BK evolution
  - $\frac{\partial N(x,r_T)}{\partial \ln(1/x)} = \alpha_s K_{BFKL} \otimes N(x,r_T) - \alpha_s [N(x,r_T)]^2$

- HERA implied the existence of CGC



Physics programs – Gluon saturation



- Nuclear "Oomph" factor
  - To access CGC, we need higher beam energy or heavy ion collision
  - Gluon fields are overlapped by Lorentz contraction and higher density gluon field can be probed wo/ increasing beam energy
  - $Q_s^2(x) \sim A^{1/3}(\frac{1}{x})^{\lambda}$ where $\lambda = 0.2 - 0.3$

- Observables
  - Nuclear structure function
  - Di-hadron correlations
  - Diffractive events

arXiv:1212.1701