



SRC Overview and workshop goals

we don't need an hour long "SRC Overview" - this is an audience of experts.

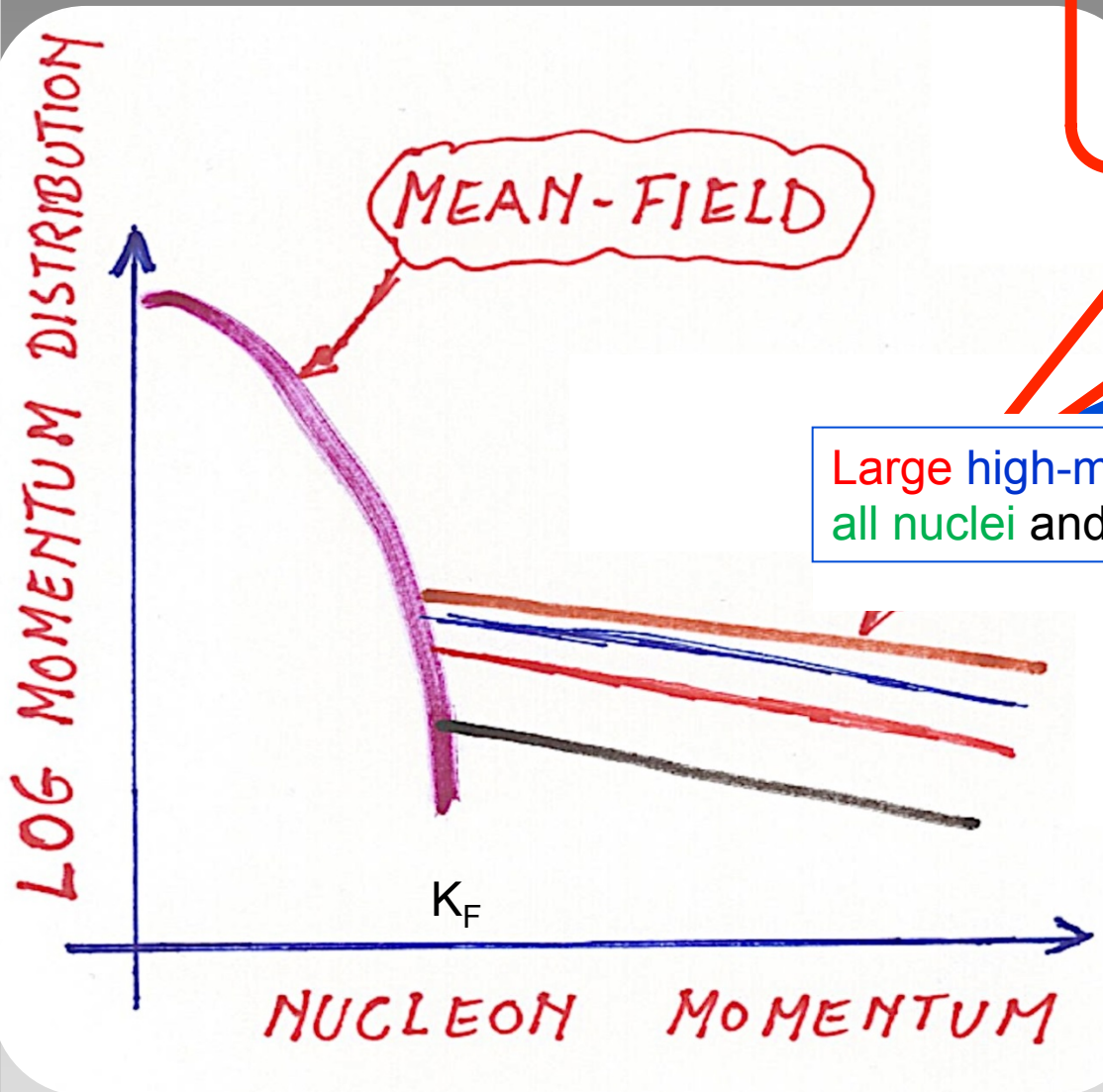
From: "Fomin, Nadia"

Q: Do all the experts share the same conception on the ground state of nuclei ?

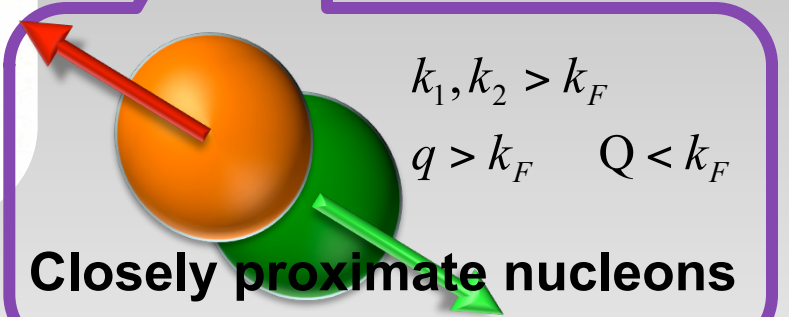
Small: MEAN FIELD <5%  
 Large : 10 - 30%

300 - 1000 MeV/c  
 1.5 - 5 fm<sup>-1</sup>

Large high-momentum tail similar in shape to all nuclei and dominated by 2N-SRC pairs



$$\sum n_{pairs} \cdot n_{pair}(k)$$



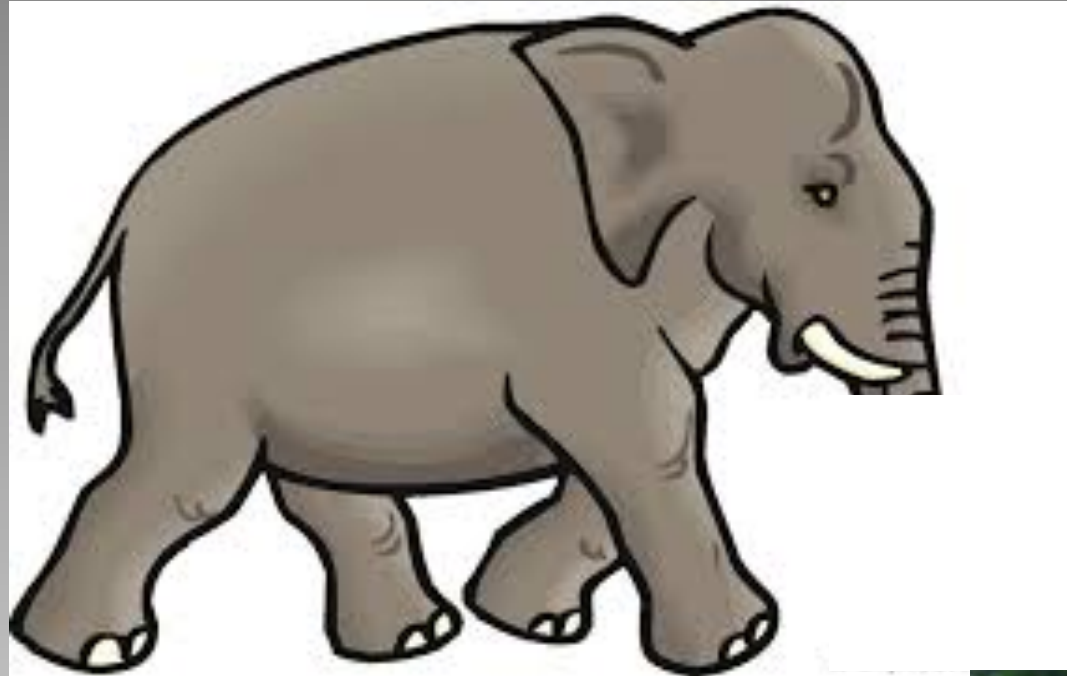
Adapted from Jan Ryckebusch



TEL AVIV UNIVERSITY

If the experts agree

NP with no SRC =  
elephant with no  
trunk



We are Otolaryngologists

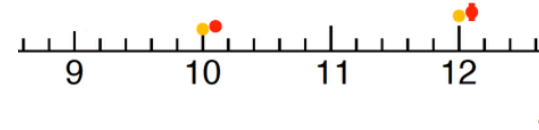
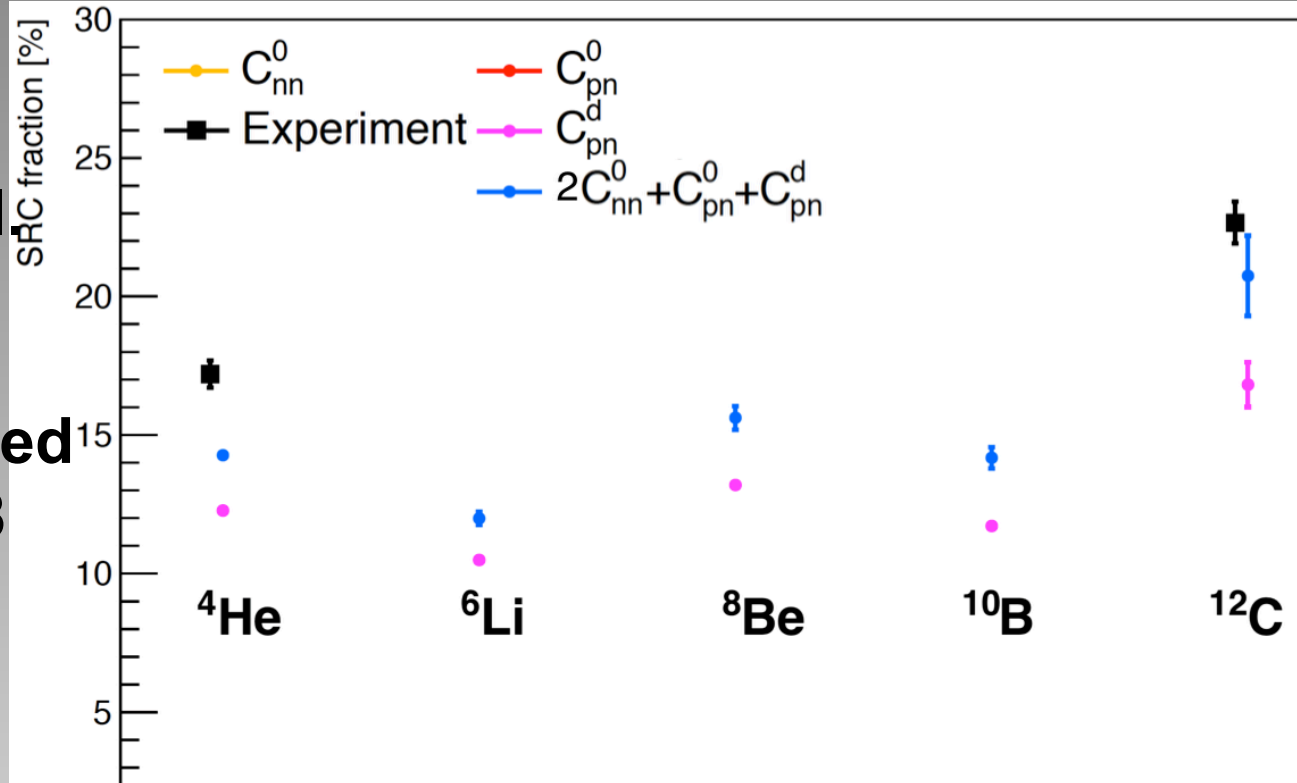




# Large high-momentum tail similar in shape to all nuclei and dominated by 2N-SRC pairs

Data:  
a2(A,Z) Fomin et al

Calc: contacts based  
on VMC with AV18  
and UIX

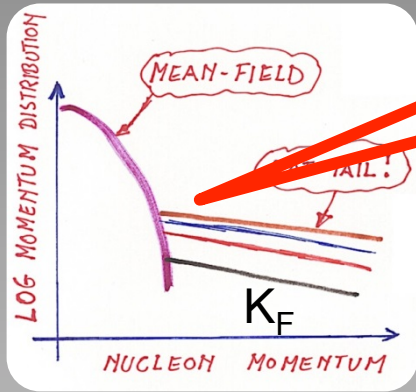


Factorization and Universality	Nir Barnea and Or Hen (30 min) Ronen Weiss (15 min) Will Detmold (15 min)
--------------------------------	---

Two body densities in coordinate and momentum space	Stefano Gandolfi (20 min) Reynier Cruz Torres (10 min) ← Joel Lynn (15 min) Maximilian Alvioly (15 min)
---	--



**Large** high-momentum tail similar in shape to all nuclei and dominated by 2N-SRC pairs



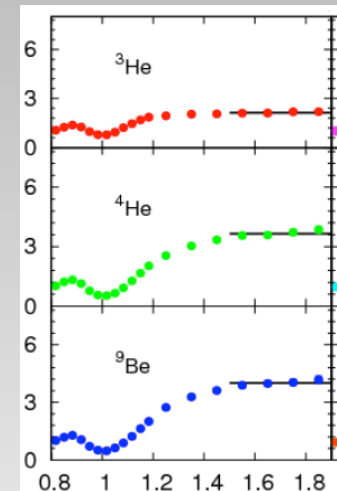
Small: MEAN FIELD <5%  
 Large : 10 - 30%

**Q: If one calculate 10% and the data show 20% how bad is it ?:**

*A(e,e')*  
ratios

**Q: How well we know to extract the strength from the data ?:**

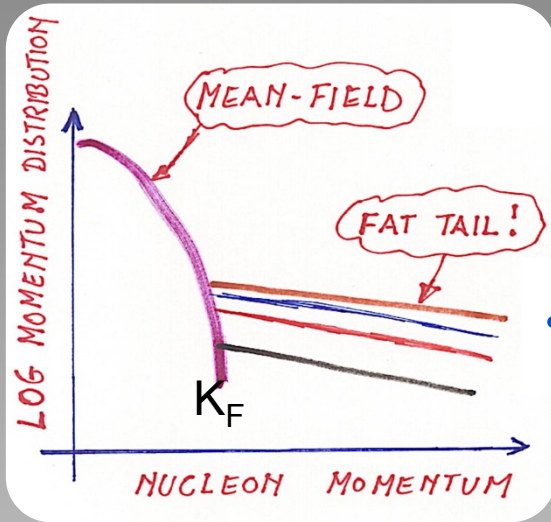
- CM corrections to  $a_2(A,Z)$  ?
- Scaling to d (what about other S,T pairs in heavy asymmetric nuclei ?







Large **high-momentum** tail similar in shape to all nuclei and dominated by 2N-SRC pairs



300 – 1000 MeV/c  
 1.5 – 5 fm<sup>-1</sup>

**Q: What happen at the edges ?:**

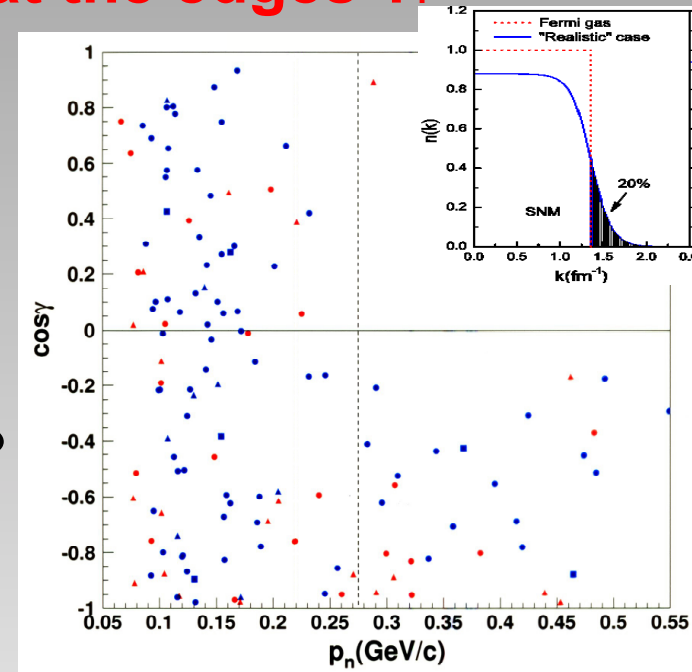
**What we know about the transition between mean-field to SRC ?**

**Nucleons with momentum > 1 GeV/c ?**

**How many ?**

**How they get that large momentum ?**

**Multi nucleons correlations ?**





transition between mean-field and SRC:

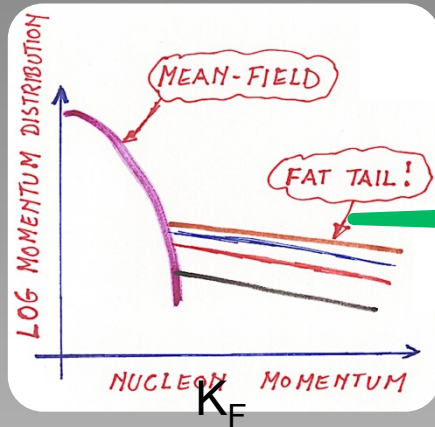
Exclusive reactions II	George Laskaris (15 min) Maria Patsyuk (15 min) Dan Watts (15 min)
------------------------	--

**Nucleons with momentum  $> 1$  GeV/c :**

Inclusive and semi-inclusive reactions I	Nadia Fomin and Misak Sargsian
$^3\text{N}$ -SRC in Exclusive Reactions	Eli Piassetzky and Mark Strikman (15 min) Erez Cohen (15 min)



Large high-momentum **tail similar in shape to all nuclei** and dominated by 2N-SRC pairs



$$\sum n_{pairs} \cdot n_{pair}(k)$$

**Can we formulate a nuclear contact theory ? Why ?**

Concept developed for dilute two-component Fermi systems with a strong short-range interaction.

S. Tan Annals of Physics 323 (2008) 2952, ibid 2971, ibid 2987

$$r_{eff} \ll d, a_s \quad \Rightarrow \quad (|a_s|^{-1}, d^{-1} \ll k \ll r_0^{-1}) \quad \text{Scaling}$$

**In Nuclei**

$$r_{eff} = 0.5 - 1 \text{ fm} \quad d \approx 2 \text{ fm} \quad a_s \approx -20, 5 \text{ fm}^{-1} \quad k < k_F$$

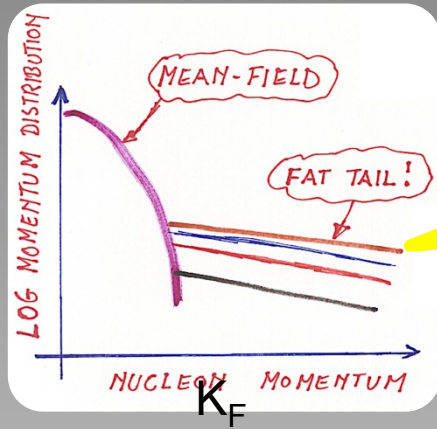




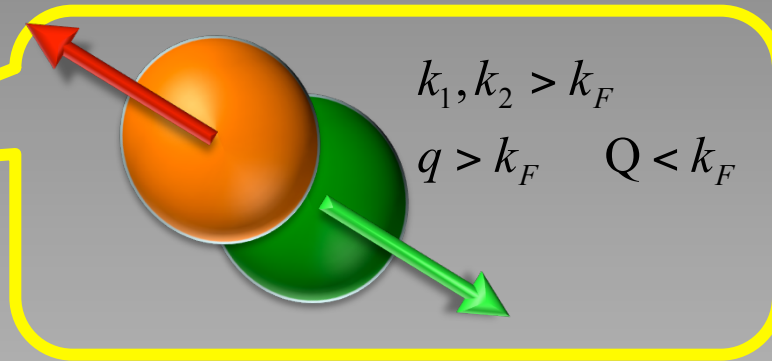
Factorization and Universality	Nir Barnea and Or Hen (30 min) Ronen Weiss (15 min) Will Detmold (15 min)
Two body densities in coordinate and momentum space	Stefano Gandolfi (20 min) Reynier Cruz Torres (10 min) Joel Lynn (15 min) Maximilian Alvioly (15 min)



Large high-momentum tail similar in shape to all nuclei and **dominated by 2N-SRC pairs**



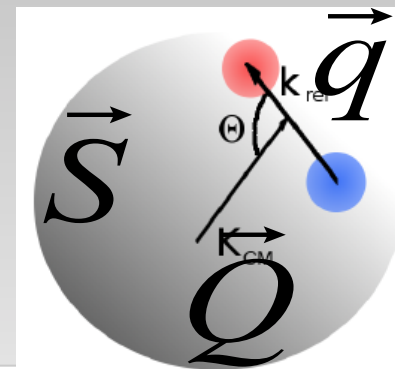
Closely proximate nucleons



How these pairs were produced ? Who are their Parents ?

What are their quantum numbers ?

How they move (CM motion, relative momentum distributions) ?



$q$   $Q$  and  $S$  have directions, we never study their relative orientation in SRC pairs

# Theoretical description of nuclei

complicated underlying N-N interaction

Dense system (all parameters are comparable)

'ab-initio' many body calculation

mean-field

EFT

Generalized contact theory



SRC in EFT	Christian Weiss (20 min) Dick Furnstahl (15 min) Sushant Mor (10 min)
Factorization and universality	Nir Barnea and Or Hen
Two body densities in coordinate and momentum space	Stefano Gandolfi



## Mean Field:

Precise calculations of a neutron skin in asymmetric nuclei neglecting SRC.



comparing the length of F and M elephants without taking the Trunk into account.

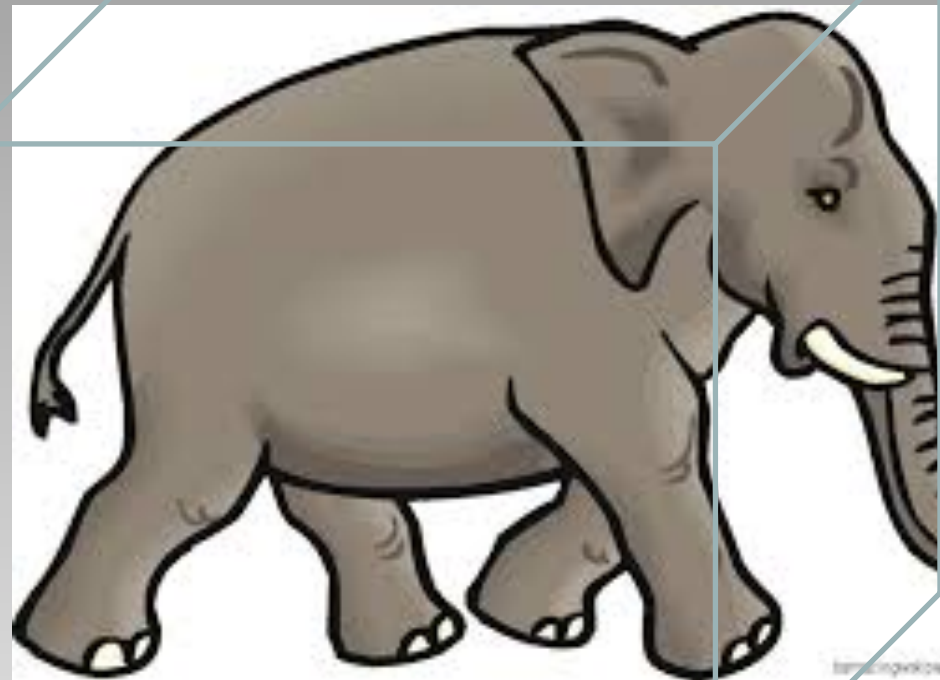


EFT is a great way to do Gastroenterology  
is it also an effective way to do  
Otolaryngology ?



TEL AVIV UNIVERSITY

**gastroenterologists**



**Otolaryngologists**



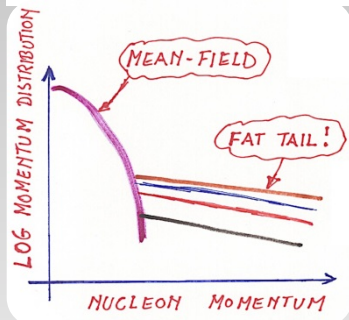
Q: Do all the experts think that the EMC has to do with modification of nucleons in nuclei ?

Sunday, Dec. 4<sup>th</sup> (EMC),

Kolker room, 26-414,

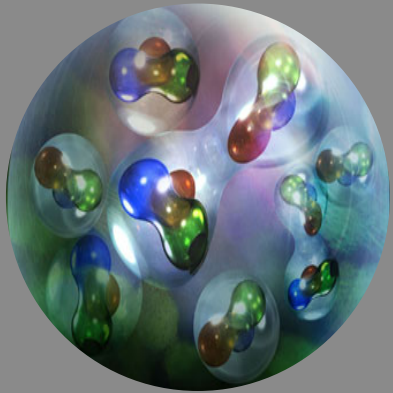
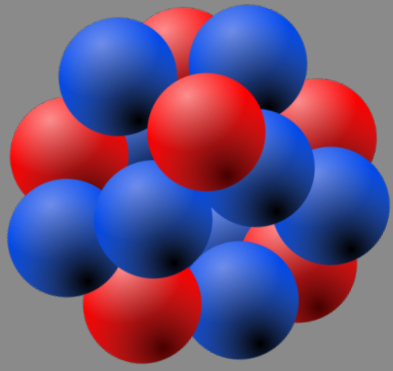
Jerry Miller / Larry Weinstein

9:00 – 10:00	EMC Overview	Mark Strikman and Jerry Miller
10:00 – 11:00	EMC Theory	
11:00 – 11:30	<i>Coffee Break</i>	
11:30 – 12:30	Tagged Structure Functions	Shalev Gilad
12:30 – 14:15	<i>Lunch Break</i>	
14:15 – 15:30	Isospin dependence and PVDIS	Seamus Riordan and Ian Cloet
15:30 – 16:15	In-Medium Form-Factors and the coulomb sum rule	Steffen Strauch



Q: modification of ‘mean field’ vs. ‘tail’ nucleons?

# SRC are the frontier of cold dense nuclear matter study



- Nuclear:  $0.16 \text{ nucleons/fm}^3$
- Nucleon:  $0.36 \text{ nucleons/fm}^3$
- SRC pair:  $\sim 0.55 \text{ nucleons/fm}^3$

SRC pairs  $\sim$  **x3.5** saturation nuclear density!

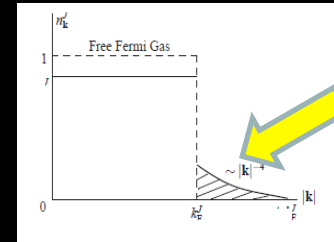
**SRC pairs probe densities relevant to neutron stars!**

# Tensor correlations (np - dominance):

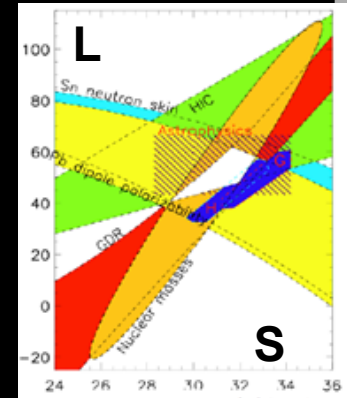
Reduce the kinetic symmetry Energy (at  $\rho_0$ )

$$E_{sym}(\rho) \approx E(\rho)_{PNM} - E(\rho)_{SNM}$$

(nn- pairs)
(np- pairs)



Enhance the potential symmetry Energy (at  $\rho_0$ )

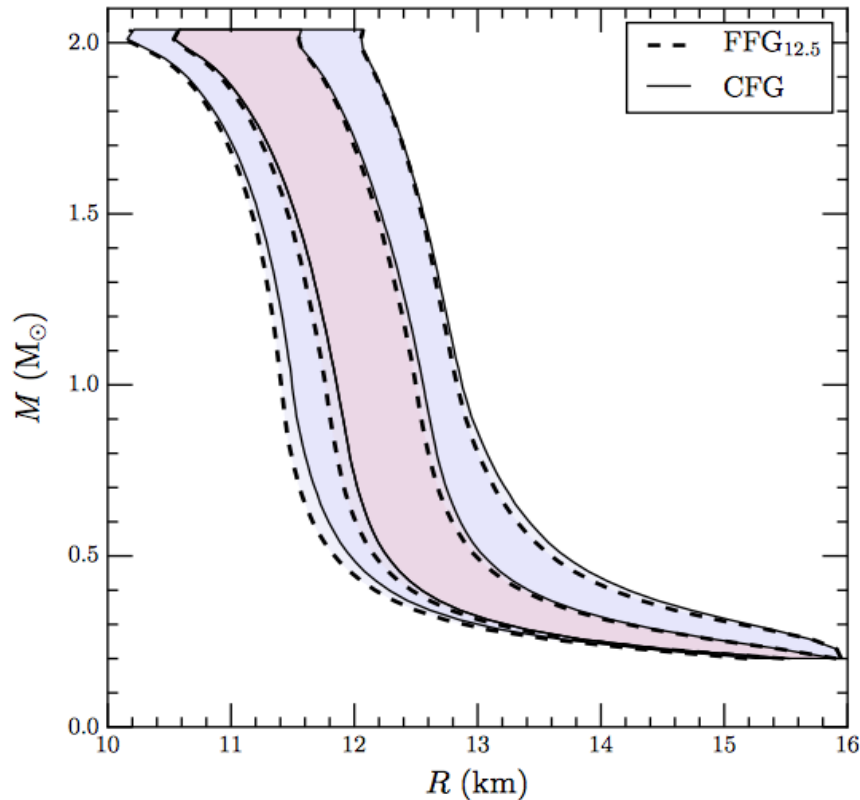


Soften the potential symmetry density dependence

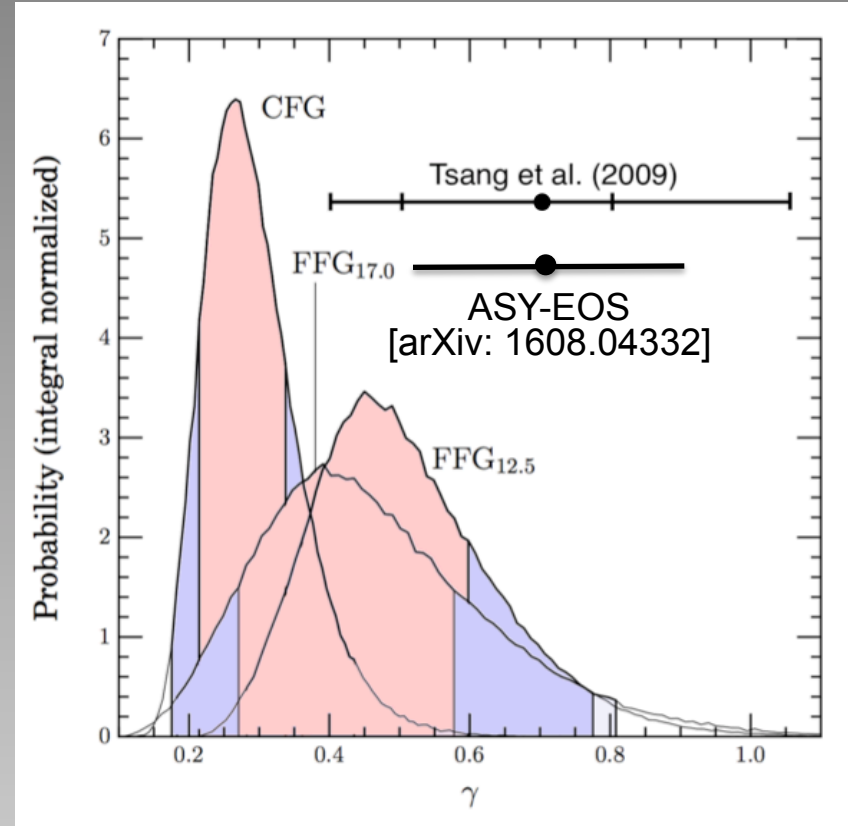
Impact on Compact Astronomical Systems  
and HI Reactions ?

# Incorporating SRC Into N. Star Global Analysis

reduces the density dependence of the symmetry potential!



O. Hen and A. W. Steiner et al.,  
arXiv: 1608.00487 (2016).



$$E_{sym}^{pot}(\rho/\rho_0) = S_{pot} \cdot (\rho/\rho_0)^\gamma$$

How does it affect neutron  
stats properties?

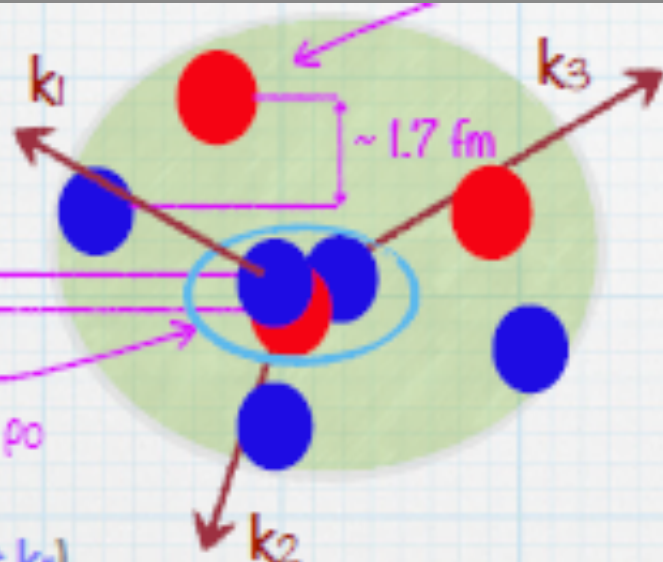
# Study of 3N correlation

## What is 3N-SRC?

$$|\vec{k}_1 + \vec{k}_2 + \vec{k}_3| < k_F$$

$$|\vec{k}_1|, |\vec{k}_2|, |\vec{k}_3| > k_F$$

$\sim 1 \text{ fm}$   
 $\rho \gg \rho_0$



Large relative & small c.m. momentum (w.r.t  $k_F$ )

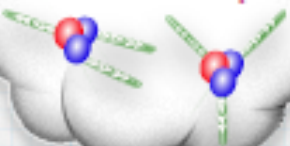
Isospin structure:

fraction of

nnn / ppp / nnp / npp?

Geometry:

Co-linear/Isotropic?



3N-SRC in Exclusive Reactions

Eli Piasetzky and  
Mark Strikman (15 min)  
Erez Cohen (15 min)



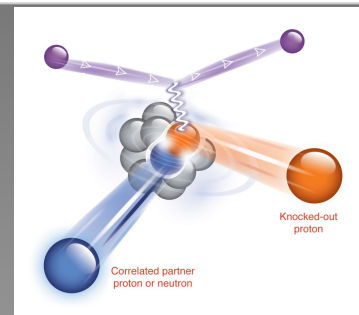


quo

vadis

src

# Next generation experiments, even the exclusive, can yield 1-2 order of magnitude more SRC events



experiment	pp pairs	np pairs	nn pairs
EVA/BNL	-	18	-
E01-015/JLab	263	179	-
E07-006/JLab	50	223	-
CLAS/JLab	1533	-	-
Total	<2000	<450	0

$^{12}\text{C}(p, 2pn)$   
 $^{12}\text{C}(e, e' pn)$   $^{12}\text{C}(e, e' p)$   
 $^4\text{He}(e, e' pn)$   $^4\text{He}(e, e' p)$   
 C, Al, Fe, Pb  $(e, e' pp)$

**12 GeV JLab:**

$$\frac{\sigma_{MOTT}(12\text{GeV})}{\sigma_{MOTT}(4\text{GeV})} \approx 8$$

**Detector acceptance: 5**  
 (e, e' p)

**How to use this high statistic capability ?**

# Proton and $^{12}\text{C}$ beams

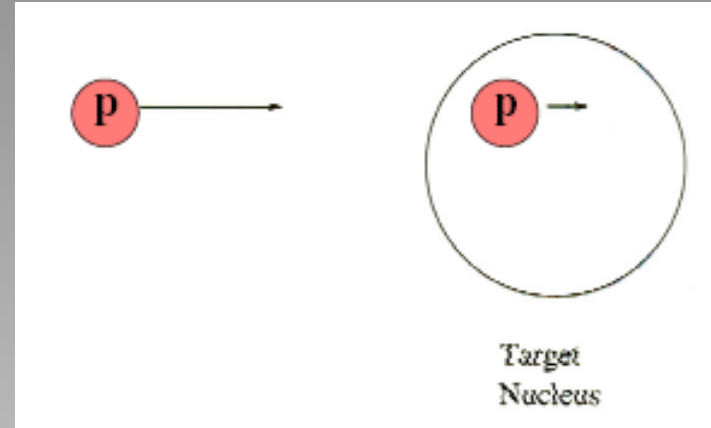
Dubna / GSI :

5-10 GeV/c

$10^9$  protons/sec

pp  $\rightarrow$  pp elastic scattering  
near  $90^\circ$  c.m.:

$$\frac{d\sigma}{dt} \propto s^{-10}$$



pay selective attention to SRC

Lower energy increase the cross-section and the sensitivity to SRC via  $S$  weighting. But... need to keep a hard process.

4 – 6 GeV beams are ideal!

Exclusive reactions II

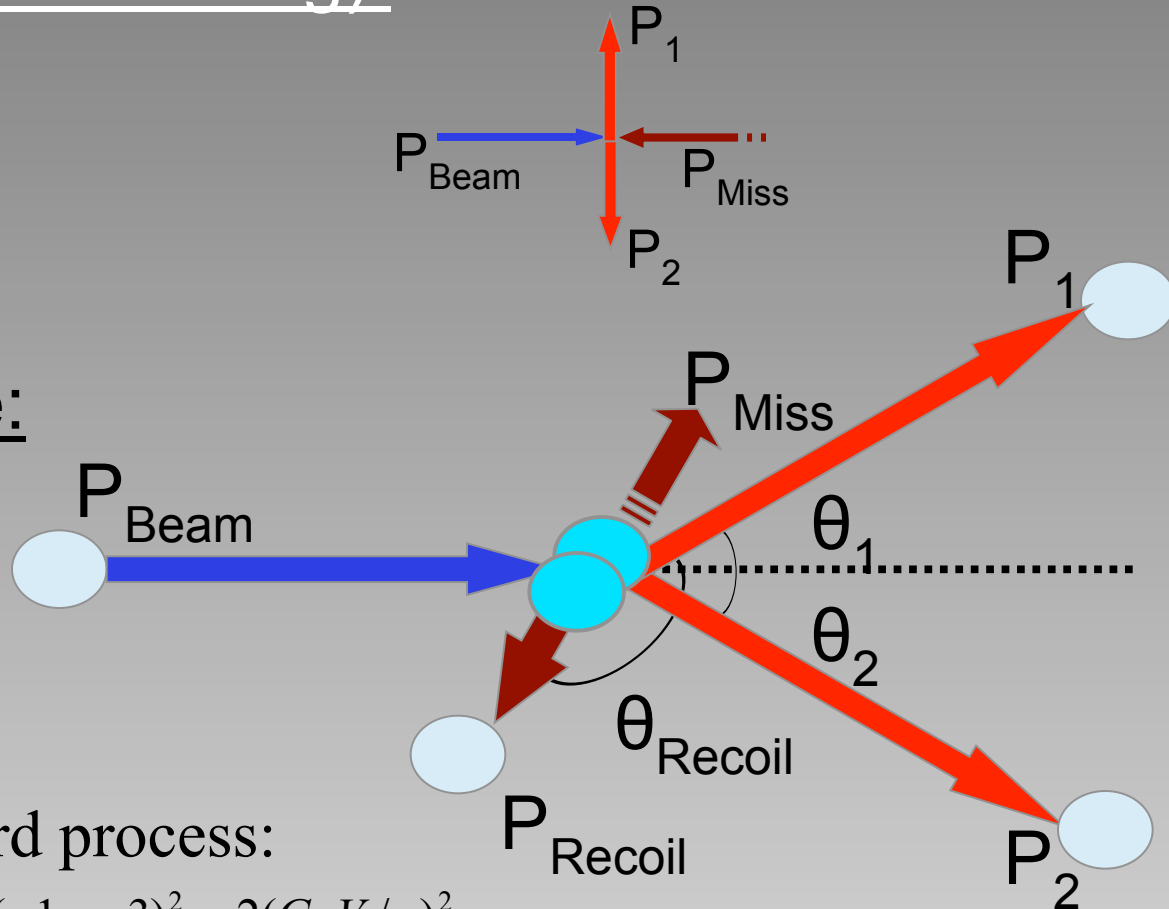
George Laskaris (15 min)

Maria Patsyuk (15 min)

Don Watts (15 min)

# C.M. Frame ( $80^\circ \sim 90^\circ$ scattering):

## Lab Frame:



- SRC dominance:

$$|p_{recoil}| \geq 250 \text{ MeV} / c$$

$$\theta_{recoil} \geq 90^\circ$$

- Hard process:

$$-t = -(p_1 - p_3)^2 > 2(\text{GeV} / c)^2$$

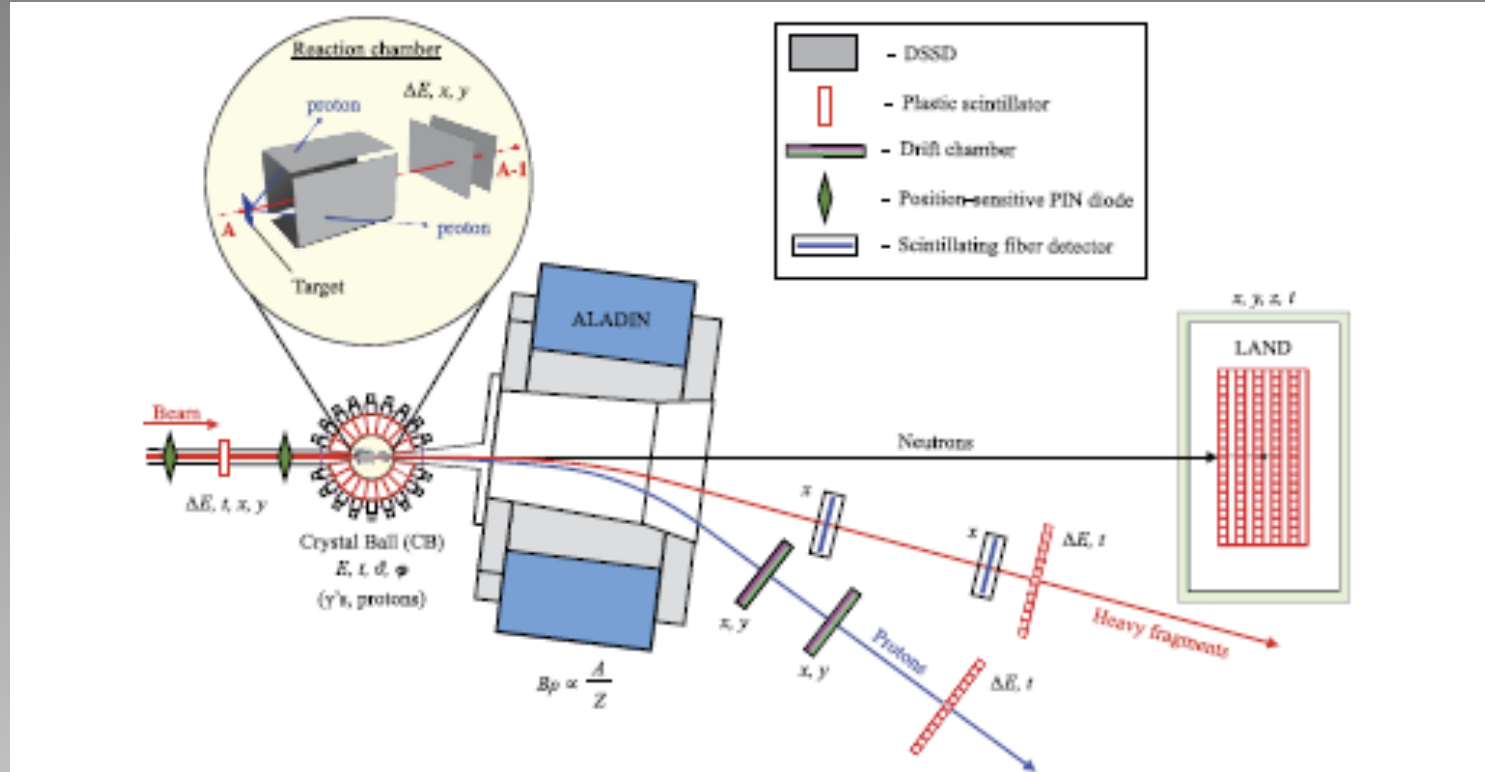
$$-u = -(p_1 - p_2)^2 > 2(\text{GeV} / c)^2$$

$$s > 7(\text{GeV} / c)^2$$

$$\theta_1 = 27.5^\circ \pm 7.5^\circ, \theta_2 = -27.5^\circ \pm 7.5^\circ \quad (\vartheta_{cm} \approx 90^\circ)$$



# Inverse complete kinematics



A-2

Physics Letters B 753 (2016) 204-210

GSI setup used with  
0.4 GeV/c beam

5 GeV/c  $^{12}\text{C}$  beam at Dubna

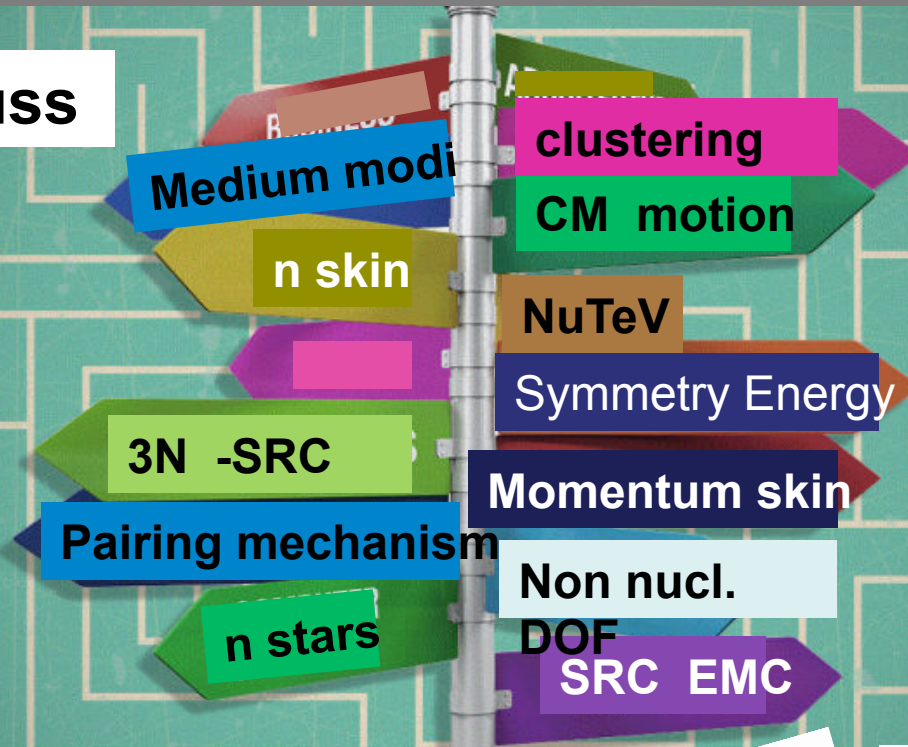
Exclusive reactions II

Maria Patsyuk (15 min)

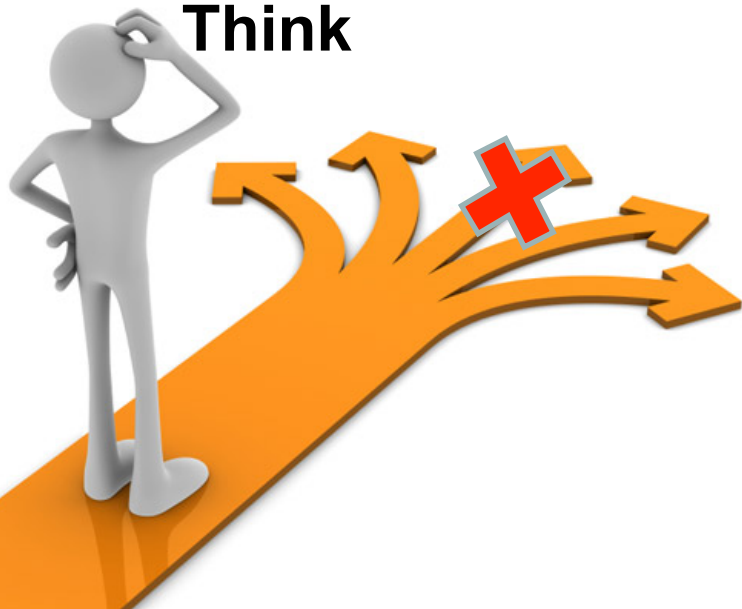
Don Watts (15 min)



**discuss**



**Think**



**write**

