

Interdiszciplináris kutatások az informatika és a fizika területén

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ELTE IK Komputeralgebra Tanszék

Motiváció

	<u>Fizika</u>	<u>Informatika</u>
ie.2300-2700 ~ ie. 300	ókori egyiptom csillagászat	Mezopotámia abakusz
ie. 287	Arkhimédész hidrosztatika	Euklidesz algoritmus
⋮	⋮	⋮
1642		B. Pascal mechanikus digitális szg.
1687	I. Newton klasszikus mechanika	
⋮	⋮	⋮
~ 1870	J. W. Gibbs, J. C. Maxwell, L. Boltzmann 10^{23} mozg. egy.	
~ 1850	R. Clausius entrópia	
1887	H. Poencare Naprendszer stabilitása	
1894	L. Boltzmann információ fogalma	
1911	E. Rutherford atommag	
1916	A. Einstein általános relativitáselmélet	
1926	P. Dirac kvantummechanika	
1928		R. Hartley függvény
1936		A. Turing Turing teszt
1943		W. Mc Culloch, W. Pitts neuronhálózatok
1948		C.E. Shannon entrópia
1949	Wigner Jenő szimmetriák	Neumann János EDVAC
~ 1950		J. McCarthy mesterséges intelligencia
1958	E. Lorenz konvekciómodell, káosz (pillangó hatás)	Royal-McBee LGP-30
1963	M. Gell-Mann, G. Zweig kvark	
1967		G. Amdahl Amdahl törvény
1974	K. Wilson rács térelmélet	
1980		kvantumszámítógép
		P. Benioff, R. Feynman
1982	B. Mandelbrot The fractal geometry of Nature	
1990	CERN	www Tim Berners-Lee
1999	Barabási A-L. komplex hálózatok	
2003	ATLAS ~ $40 \cdot 10^6$ esemény/s (64 TB/s)(1 db 1.6MB) elsődleges trigger szűrés: 1000 esemény/sec (> 50TB/nap) 1 milliárd esemény/év, kb 3 milliárd esemény szimuláció/év 1 esemény teljes szimulálása ~ 5min 1 esemény rekonstruálása: kb 20 sec O(100)PB tárhely	
2015		szuperszámítógép Tianhe-2 33.86 Petaflop/sec
⋮	⋮	⋮

Iskolateremtés

- Modell számítások
- Módszerek
- Komplex feladatok
- Tervek

Eddigi eredmények

2006-ban csoportot hoztunk létre Dr Vesztergombi György professzor részvételével, aki a kísérleti részecskefizika kutatásban vett részt.

Külföldi ösztöndíj hallgatóknak

2015-:	Forster Richárd	Ph.D Student, CERN, Svájc;
2014-2015:	Forster Richárd	Technical Student/Scientific associate CERN, Svájc
2011-2012:	Sipos Roland	Technical Student, CERN, Svájc
2011	Bozsogi Balázs	Fellowships, Creative Electronic Systems, Svájc
2010:	Forster Richárd	Summer Student, CERN, Svájc
2010:	Sipos Roland	Summer Student, CERN, Svájc
2009-2010:	Bozsogi Balázs	Technical Students, CERN, Svájc
2009:	Bozsogi Balázs	Student program, CBM, Németország

Nemzetközi konferenciák

2018:	R. Forster	GPU Days, Wigner Institut Hungary
2017:	R. Forster	GPU Technology Conference, San Jose California Szilikonvölgy, USA
2017:	R. Forster	GPU Days, Wigner Institut Hungary
2016:	R. Forster*, O. Visnyei	GPU Technology Conference, San Jose California Szilikonvölgy, USA
2016	R. Forster	Joint Conf. on Math. and Comp. Sci., ELTE IK, Eger Magyarország
2016	R. Forster	INES 2016 20. Jubilee IEEE Int. Conf., Budapest, Magyarország
2016:	R. Forster	GPU Technology Conference, Amsterdam Hollandia,
2015:	P. Fehér*, A. Fülöp, I. Csabai, G. Vesztergombi,	Int. Conf. on Mathematics and Informatics, Sapientia Univ, Marosvásárhely, Románia
2015	R. Forster*, A. Fülöp,	GPU Technology Conference, San Jose California Szilikonvölgy, USA
2013:	A. Agócs, A. Fülöp, R. Forster, Gy. Vesztergombi*,	Wigner-111 Symposium, Budapest, MTA, Magyarország
2013:	R. Forster*, A. Fülöp,	GPU Technology Conference, San Jose California Szilikonvölgy, USA
2012:	R. Sipos*, A. László, J. Marcinek, T. Paul, M. Szuba, M. Unger, D. Veberic, O. Wyszynski for the NA61 Collaboration,	Joint Conf. on Math. and Comp. Sci., ELTE IK, Siófok Magyarország
2012	R. Sipos*, A. László,	NA61/NA49 Collaboration Meeting, ELTE IK Budapest, Magyarország

- 2012 A. Agócs, A. Fülöp, R. Forster, G. Vesztergombi*,
IZEST(International Zettawatt-Exawatt Science and Technology)
University of Strathclyde Skócia
- 2012 A. J. Marcinek, T. Paul, Dr. M. Szuba, M. Unger, D. Veberic,
O. Wyszynski, R. Sipos*, A. László,
International Conference of Computing in High Energy and
Nuclear Physics, New York, USA
- 2012 O. Wyszynski, A. László, A. Jerzy Marcinek, T. Paul, R. Sipos*,
M. Szuba, M. Unger, D. Veberic,
International Conference of Computing in High Energy and
Nuclear Physics, New York, USA
- 2011: G. Benelli, B. Bozsogi*, A. Pfeier, D. Piparo and V. Zemleris,
IEEE-2011: Nuclear Science Symposium and Medical
Imaging Conference,, Valencia Spanyolország
- 2011 R. Sipos*, O. Wyszynski,
Na49/61 Collaboration Meeting
Ruder Boskovic Institute, Zürich, Svájc
- 2010: Á. Agócs*, Á. Fülöp,
Joint Conf. on Mathematics and Computer Science
Selye János Egyetem, Komárno, Szlovákia
- 2009: Á. Fülöp, Z. Gilián, Gy. Vesztergombi*
Zimányi 2009 Winter School on Heavy Ion Physics
Wigner Intézet, Budapest Magyarország
- 2009: Á. Fülöp, Z. Gilián, Gy. Vesztergombi*
European Strategy for Future Neutrino Physics Workshop,
Zürich, Svájc

Publikáció

A diákok részvételével készült publikációk az MTMT adatbázisban elérhetőek.

Doktori program

Doktori témavezetés

2015-2018 :Forster Richárd (ELTE IK, CERN Collab.)

Dokt. Isk. Abszolutórium 2018,

'Párhuzamos algoritmusok alkalmazása GPU-n a kísérleti és elméleti fizikában'

16 cikk(4 WoS), 1 könyv, 5 előadás, 8 poszter (konf.: USA, Svájc, Hollandia)

Fontosabb eredmények, cikkek

- Yang-Mills lattice on CUDA,
- Chaotic behavior of the lattice Yang-Mills on CUDA,
- Jet browser model accelerated by GPU,
- Parallel k_T jet clustering algorithm

Előadás a doktori iskolában

- Nemlineáris jelenségek modellezése rácson
- Szimulációs módszerek

További tevékenységek:

Tudományos Diákkör témavezetés

-Forster Richárd, Sipos Roland, 'Nagy adatbázisok párhuzamos feldolgozása', I. díj kari TDK (2010), külön díj OTDK (2011)

-Agócs Ádám, Bozsogi Balázs, 'Nagy hatékonyságú trigger algoritmusok', II. díj kari TDK (2008), III. díj OTDK, (2009)

Kutatási témák

- jet algoritmusok párhuzamosítása,
- pálya rekonstrukció, szimuláció
- rácstérelméleti algoritmusok párhuzamosítása
- DNS szekvenálás
- adatbázis feldolgozás
- dinamikai rendszerek kaotikus viselkedés
- komplexitás
- számelméleti fraktálok

Felhasznált eszközök: C, GPU, VHDL

Tervek

- kvantum számítógépek
- meteorológiai rendszerek és a káosz kapcsolata
- skálázható hálózatok
- q-learning rendszerek

⋮

Wigner-111

Scalable CaloTracker (SCT) proposal for Ultra High Energy (UHE) accelerators

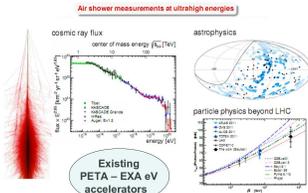
Adam Agocs¹, Agnes Fulop¹, Richard Forster¹, G. Vesztegombi^{1,2}*

¹ Roland Eotvos University, Budapest.

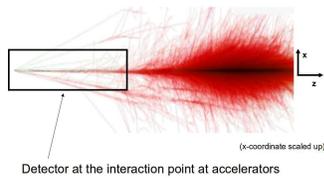
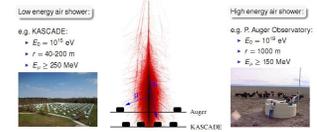
² Wigner RCP, Budapest, Hungary and Roland Eotvos University, Budapest, Hungary
vesztegombi.gyorgy@wigner.mta.hu

After discovery of Higgs-boson the particle physicist community should turn its attention for new challenges directing the focus toward Ultra High Energies. The hope in new accelerator technologies is greatly enhanced by invention of the laser driven plasma wake field methods which in principle, can produce beams with PeV (10^{16} eV) energy, which could open the way to perform experiments in controlled conditions in circumstances accessible earlier only for cosmic ray experiments. From the history of LHC it is a well-known proverb, there is no doubt that one can build the accelerator but how can we construct the detectors which can use it effectively. Thus one cannot start early enough to think about the necessary instrumentation, the particle detectors. Here we should like to present a new concept which is radically different from the present onion shell design (vertex pixel, tracker, em-calorimeter, hadron calorimeter and muon detector). This new system would have a completely homogeneous structure built from standard elements in a scalable way serving at the same time as a very fine resolution TRACKER and an absorption CALORIMETER with full 4 π coverage for both charged and neutral particles with the usual exception of penetrating neutrinos. Though one is not expecting accelerators with PeV beams before 2050, one can test the SCT (Scalable CaloTracker) detector principle at lower energies due to its modular scalable structure. The key element is a massively parallel information system which can process the complete shower development on track-by-track base on adaptive granulation levels [1].

[1] A. Agocs and G. Vesztegombi, Scalable CaloTracker (SCT) proposal for universal particle detector from zero till practically infinite energies, Open Symposium on European Strategy for Particle Physics, 10-12 September 2012 Krakow, Poland, <https://indico.cern.ch/contributionsDisplay.py?contribId=114&confId=175067>

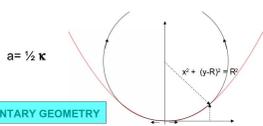


COSMIC RAY PHYSICS: un-known position of beam particles



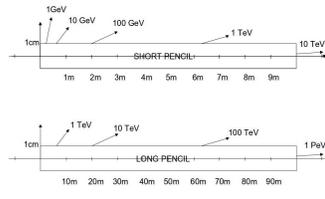
CIRCLE = PARABOLA

The circle equation is $x^2 + (y-R)^2 = R^2 \rightarrow y^2 - 2yR + x^2 = 0$
 $R [m] = p_0 / (0.3 B) = 2 p_0 [\text{GeV}/c]$, if $B=5/3$ Tesla, curvature: $\kappa [m^{-1}] = 1/R$
 All high energies the first solution for y if $x/R \ll 1$:
 $y = R (1 - \sqrt{1 - (x/R)^2}) = R (1 - (1 - (x/R)^2/2) + \dots) = (1/2) \kappa x^2$
 Parabola with curvature κ : $y = a x^2 = \kappa x^2 / 2$



ELEMENTARY GEOMETRY

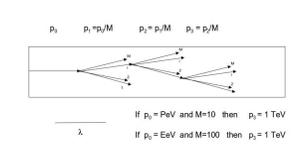
ELEMENTARY GEOMETRY for PENCIL DETECTOR



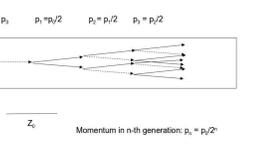
eV	TeV	Short pencil [L]=10m	Long pencil [L]=100m	R	$\kappa [m^{-1}]$	N	$\Delta x [m]$
10^8	0.1 GeV	0.63 m	-	2 m	5	6	-
10^9	1 GeV	2 m	-	2 m	$5 \cdot 10^2$	20	-
10^{10}	10 GeV	6.3 m	-	20 m	$5 \cdot 10^3$	63	-
10^{11}	100 GeV	20 m	-	200 m	$5 \cdot 10^4$	200	-
10^{12}	1 TeV	6.3 m	2.5 mm	2 km	$5 \cdot 10^5$	630	-
10^{13}	10 TeV	20 m	25 μ m	20 km	$5 \cdot 10^6$	10^3	10^3
10^{14}	100 TeV	6.3 m	2.5 μ m	200 km	$5 \cdot 10^7$	10^4	10^4
10^{15}	1 PeV	20 m	25 μ m	2 10^3 km	$5 \cdot 10^8$	10^5	$3 \cdot 10^5$
10^{16}	10 EeV	6.3 km	2.5 μ m	2 10^4 km	$5 \cdot 10^9$	10^6	10^6
10^{17}	100 EeV	20 km	2.5 μ m	2 10^5 km	$5 \cdot 10^{10}$	10^7	10^7
10^{18}	1 ZeV	63 km	2.5 μ m	2 10^6 km	$5 \cdot 10^{11}$	10^8	10^8
10^{19}	10 ZeV	200 km	2.5 μ m	2 10^7 km	$5 \cdot 10^{12}$	10^9	10^9

If Magnetic field = 5/3 Tesla: $p [\text{GeV}/c] = 0.3 B [\text{Tesla}] R [m] = 0.5 R$, $\kappa = 1/R [m^{-1}]$
 According to the PDG formula the curvature resolution $\delta\kappa = \delta x / L^2 \sqrt{20(N+4)}$ [1] $m = \delta x / L^2 \sqrt{20(100 \cdot 10^4)}$, where $N = 100 m^2 / L^2 [m]$

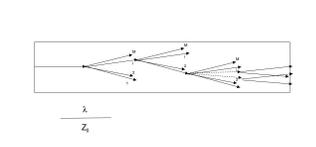
Inclusive single arm hadron: primitive model fixed multiplicity M = 10-100



Inclusive single arm EM



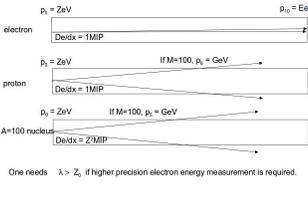
Inclusive single arm mix



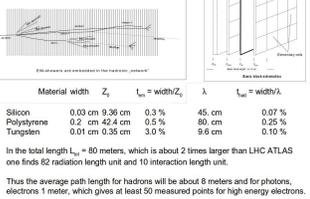
After 3-4 interaction lengths the momenta become precisely measurable

In EM-showers one needs 10 generations to go down 1000 in momenta.

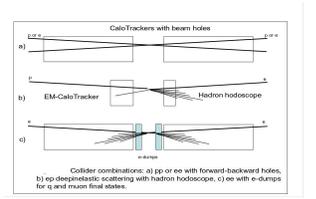
ZeV case story assuming $\lambda = Z_0$ (LONG-PENCIL) with 101 (1=10Z0) jet-core



CALOTRACKER [REF 1]



Colliders





Chaotic behaviour of the lattice Yang-Mills on CUDA

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Eotvos Lorand University

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Eotvos Lorand University



We present an algorithm, which enables to study the chaotic behaviour of complex dynamical systems of the Yang-Mills fields and the energy energy relation utilizing the Kahanban-Semi-entropy. We demonstrate the numerical algorithm to apply CUDA to calculate the eigenvalues of the corresponding matrix, which is an 8d sparse matrix (8-256). We use a hybrid block Hessenberg reduction system to compute the required eigenvalues, that makes us capable to achieve 2-3 times higher performance than the CPU only version.

Homogeneous Yang-Mills Fields

The Yang-Mills gauge field theory was introduced to understand the strong interaction of elementary particles. The homogeneous Yang-Mills equations describe the non-abelian gauge field theory.

$$F_{\mu\nu}^a = \partial_\mu A_\nu^a - \partial_\nu A_\mu^a + g f^{abc} A_\mu^b A_\nu^c$$

where A_μ^a is the gauge field, f^{abc} are the structure constants of the Lie algebra of the gauge group, and g is the coupling constant.

Lattice Yang-Mills Fields Theory

The lattice Yang-Mills fields theory is a discretized version of the Yang-Mills theory. The lattice spacing a is the distance between adjacent lattice sites. The lattice action is given by

$$S = \sum_{\square} \text{Tr} [U_\mu U_\nu U_\mu^\dagger U_\nu^\dagger] - \sum_{\square} \text{Tr} [U_\mu U_\nu U_\mu^\dagger U_\nu^\dagger] + \sum_{\square} \text{Tr} [U_\mu U_\nu U_\mu^\dagger U_\nu^\dagger]$$

where U_μ is the link variable, and \square is the plaquette.

Hessenberg reduction

The Hessenberg reduction is a numerical algorithm for reducing a matrix to Hessenberg form. The Hessenberg form is a matrix with zeros below the first sub-diagonal. The algorithm is based on the Householder transformations.

$$H = U_1 A U_1^T + U_2 A U_2^T + \dots + U_{n-1} A U_{n-1}^T$$

where U_i are the Householder matrices.

Hybrid Hessenberg reduction

The hybrid Hessenberg reduction is a numerical algorithm for reducing a matrix to Hessenberg form. It combines the CPU and GPU to achieve higher performance. The algorithm is based on the Householder transformations.

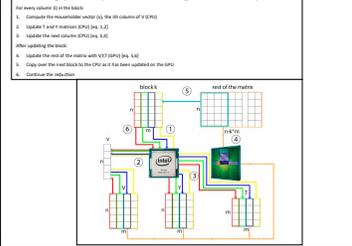
$$H = U_1 A U_1^T + U_2 A U_2^T + \dots + U_{n-1} A U_{n-1}^T$$

Chaotic behaviour of the lattice Yang-Mills

The chaotic behaviour of the lattice Yang-Mills fields is studied by calculating the Lyapunov exponents. The Lyapunov exponents are the logarithmic growth rates of the perturbations. The algorithm is based on the Hessenberg reduction.

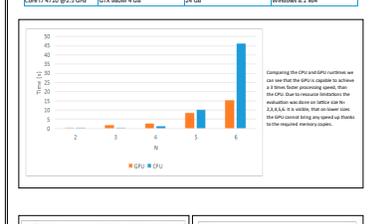
Conclusion

The chaotic behaviour of the lattice Yang-Mills fields is studied by calculating the Lyapunov exponents. The algorithm is based on the Hessenberg reduction. The results show that the system is chaotic.



Results, conclusions

The results show that the hybrid Hessenberg reduction algorithm achieves a 2-3 times higher performance than the CPU only version. The algorithm is based on the Householder transformations.



References

1. S. Weinberg, *Gravitation*, Wiley, 1973.
2. R. Feynman, *Quantum Electrodynamics*, Wiley, 1962.
3. J. D. Bjorken and S. D. Drell, *Relativistic Quantum Fields*, Wiley, 1964.
4. L. D. Landau and E. M. Lifshitz, *Classical Theory of Fields*, Butterworths, 1962.
5. R. Forster, *Chaotic behaviour of the lattice Yang-Mills fields*, arXiv:1508.01234.