SLENA-2008,

Summary of talks

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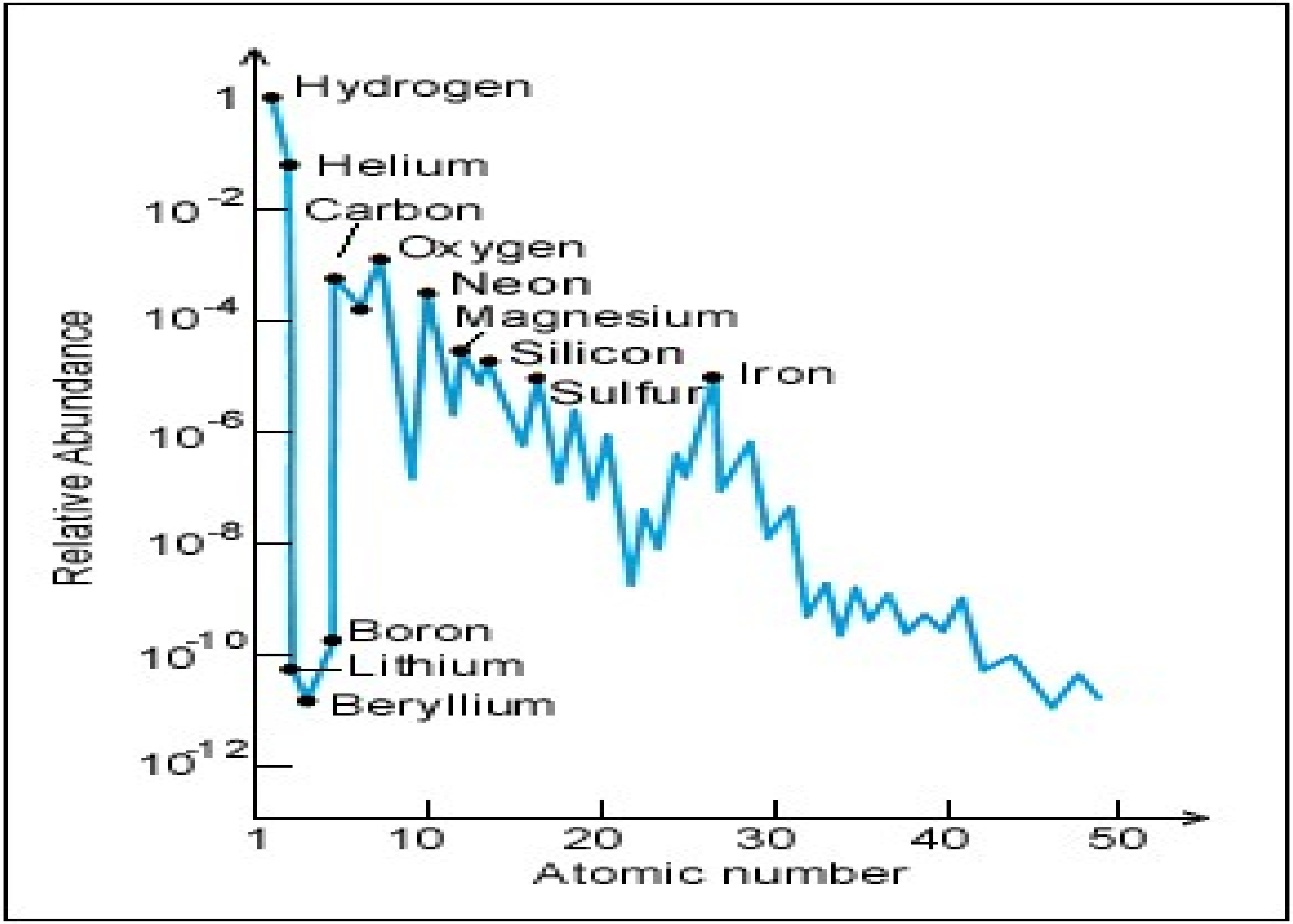
Theme : Accelerator based Nuclear Astrophysics – expt , first time in India

Why Astro physics here : History of SINP , MN Saha

Prof. Bikash Sinha, Sudeb Bhattacharya

Experience in studying nuclear spectroscopy , reactions

Detector technology



Charged particle reactions

Fusion, (p,γ) (α,γ) ,beta

(n,γ) s,r processes

Fe

Scope of Research

1) What reactions
2) What Accelerator
3) Experimental Techniques , Difficulties
4) Detectors
5) Theoretical models

Charged particle – Generally low energy E=kT ,T6 T9

Neutrons : 10 –100 keV

School on Low energy Nuclear Astrophysics- SLENA

Accelerator needed :

H.Oosterhout : 3 MV tandetron, HVEE , High current

H,He, Heavy Ions 12C,16O, etc.

Solid state power supply

High voltage stability, Multi-cathode source, Computer controlled,

Pulsed Beam

D.Kanjilal,

500 kV accelerator, ECR source , under ground facility (200 m2)

Stable operation for long runs. Minimum power/water consumption

IUAC machine- H,D (500 uA) Heavy Ions. Injector magnet on deck

Corona discharge in air to be prevented. Humidity low (no SF6)

Arup Bandyopadhayay : Radioactive Ion Beams

Astrophysics – Cross sections for beta unstable nuclei , r-process

Project at VECC

Driver (Cyclotron, e-LINAC) – target- Ion Source – Separator

RFQ-LINAC-charge stripper –LINAC

Major developments in

Thick target , Two Ion sources , RFQ

LINAC design completed .Some beams by 2008

Anticipate 10^6-10^8 /sec beams of
11C,13N,17F,18f,19Ne,35Ar,38K,90Kr,93Rb 460 keV/u

Research directions :

P.Banerji : Nucleo synthesis, elemental abundance

Background – Reaction rates, Gamow peaks, S factor,

Resonant & Non resonant reactions

Low c.s, intense beam, good shielding, efficient detectors

Discrepancies in existing data. 3He+4He, 14N/15N anomaly

Fusion studies, 12C+12C, 16O+16O 4He+12C,15N+p

Gamma detectors, HpGe, NaI, Pb shield, Plastic, system

Expert talks :

M.Wiescher : Univ.Notre dame

Nucleo synthesis,sites

Hydrogen ,He burning, ,HI burning,

-s,r, p processes

Basic astrophysics

Exp.difficulties from background , underground facilities

Rock mine vs salt mine

Gas jet targets,

Inverse kinematics, recoil separator

Description of various low energy facilities,

Bochum, Gran sasso,Caseta, Notre dame, North Carolina, Wash

Japan, Israel

Details of H burning- 3 pp chains : S factors for for all the steps

Coupled differential eqn's for yields

Details of all CNO cycles and their S factors : Massive stars

Uncertainties in some of the measured S factors and their implications

e.g. age of globular clusters. 14N(p,g)

Branching to 2nd CNO cycle : 15N(p,g)

Details of Helium burning, triple-alpha, resonance

Further process via 12C+α, 16O+α, 14N to 22Ne

Network reactions to look for abundances , e.g.14N

Elaborations on 12C+ α reaction, New ways of measuring

Beta delayed alpha decay on 16N, phot-dissoc of 16O

R matrix analysis

E1,E2 resonant capture, Direct capture (non-res)

Stellar neutron sources : 22Ne(α,n) starting from 14N

C.S.difficult to measure in the region 0.6-0.8 MeV, underground facility required

Expts with gas jet targets, n-detector array (multi layer, 3He counters)

Importance in weak s- processes, activity picks up near the end of He ignition.

Large uncertainties in C.S. Leads to difficulties in subsequent p=processes

Whether enough 22Ne left for the C burning stage.

Nucleosynthesis in later burning stages –Carbon,Neon,Oxygen,Si
Fusions in 12C ,16O –others photodissociation,capture
Potential models for the fusion reactions , diff S(E) predictions
Elemental abundance in late stages – details different
Electronic screening effects on S values at high density
Narrow resonances in 12C+12C
(a,p) widths vary a lot at low E –consequence on n sources
13C(a,n) 17O(a,n) 22Ne(a,n)
Measurements of (a,y) reactions with Notredame VdG
Discussed shell carbon burning
Change of elemental abundance (Network calculations)
After oxygen burning and Si burning.
Convective and hydrodynamic effects in addition to normal onion model of fixed shells.

Experimental techniques

K.E.Rehm : Argonne Nat. Lab

Detectors – E resolution, Time resolution, Efficiency, Count rate

Background, life time ,cost

Si detectors, Ion Chambers, Mag Spectrometers, Recoil Separators

Normal vs inverse Kinematics   22Ne(p,a)19F

Similar energies for both products in inverse Kin.

Particle det arrays (Si) - Legnaro, Garfield, Leda, Tuda,ANL

Large electronics

Gas Ionization chambers , Bragg detectors, range , multi anodes

Twin Ionization chamber, Signal from Frisch grid, Energy & Angle

Background counts from 210Po from soft solder –shows type of precautions required.

Ion chambers-customized, large size, long time stability, good energy resolution , but poor time resolution.

Magnetic spectrometers : good kinematic focussing,

Large solid angles (100 msr)

Magnox(Catania), Prisma(Legnaro), Vamos (Ganil)

Good E res, Good Ct.rate, Particle separation, but high weight, S.A limitation

Helios – Particles separated along axis, 3Tesla , m/q separation

P (21ns), d,a(43ns),t(65ns), h(32ns)

E,angle can be known from kinematics. Backgnd clean

Mass, charge determination

Mass – TOF, Mag.rigidity, Recoil separator

Si det, start-stop, E and tof ,gives m : dm/M related to dE/E,dt/t

C-foil+micro-channel, PPAC, Pulsed beam

For low E, ch.plate+ch.plate+IC , SiN foils, 130nm

Mag,rigidity, E= $(q^2/2m).(Bp)^2$ E vs Bp gives m/q separation

Recoil Separator, E/q and p/q , ED,MD , FMA,FRS,Dragon

Excellent mass separation, m/q ambiguity, TOF, limitation from E/q

Charge – energy loss, range, x-rays, gas-filled magnet

dE vs E, Bohr formula – dE prop to MZ^2/E

Good particle separation, above Bragg Energy

Charge determination thru range determination, R=E2/MZ2

PPAC followed byIC,Anode shielded by Frisch grid.

Different range particles drift to anode at different times,

T,E plot gives different ranges,hence Z

Characteristic x-rays give Z. Production C.s difficlut to know , also x-ray multiplicity required.

Gas filled magnet. $B\rho = m/Z^{\gamma}$

Nitrogen gas at a few torrs. Mean charge q ~ $v.Z^{\gamma}.f(z,v)$

Good Z separation even at low energies 58Ni-58Fe below 1 Mev/u

Gas pressure can be adjusted, Foil plays some role, SiN can be used. Other gases can be used – Co, Kr,Ar, He etc

Difficulties in expts.

Beam and target contaminants : m/q ambiguity from ECR source – tandems a little better , because of –ve ions

18O(p,y) 19F ,use FMA to reject beam and detect 19F

Low c.s. ,any F in target giving eelastic scatt complicates matter

Beam suppression was 10^^12

44Ti in Supernova (half life 40 yrs)

Gamma spectroscopy Results form SN1987A and Cas –A

Observed abundance of 44Ti is 160+/- 60 uM.

Theoretical results much smaller.

40ca(a,y) 44Ti , also 44Ti(a,p)47V

Tried inverse reaction 44Ti+4He ,with 44Ti beam using FMA

Also did 40Ca(a,y) and studied 44Ti with AMS technique.

Results obtained from TRIUMF also, who did energy excitation function

New measurements show 50% higher value than theory .

F.Kaeppler : Karlsruhe

Kirchoff and stellar spectra, elemental abundance peaks,

Neutrons make 75% elements (though only 0.005% abundance)

Tc in red giant stars –Merill 1952

Stony meteorites – isotopic compositions , Chondrites,

Noble gas isotopic composition different from solar, Red giants env.

S-process, r-process, flow equilibrium, $N\sigma$=constant

Peaks in abundance curves near N magic Numbers, 50,82,126

S-only , r-only nuclei, p-process

Neutrino induced reactions

Accelerators as neutron sources

For study of (n,y) reactions

Sources - Pulsed van de Grafs, Spallations from meson factories

Quality- N-flux, energy, resolution

Sample- available mass, purity, activity

Detectors – resolution, efficiency, granularity

Data acq. Fast digitizer, off-line analysis

Facilities at Karlsruhe, Los Alamos, CERN, Gelina, Orella

Compared fluxes, rates, pulse widths, path lengths and energies

Some newer facilities

Detectors, Large efficiency, multi-detector arrays, background suppression

Use proton beams

7Li(p,n) reaction to generate neutrons. Take them out thru large TOF. Put samples, Detector arrays

Measured 142 Nd (n, γ) 143Nd(n,γ)

Revised C.s. values

Stellar Enhancement factors.

Beta decay lifetimes change in stellar environment because of high temperature

Population at higher excited states , less lifetime.

HF calculations . Transm Coeff from optical model (for n-channel) from GDR for (gamma channel)

CERN spallation sources , 20GeV protons, 300 n from each p

Sample size 0.5 gm – 5 gms

Activation Techniques

(n,y) c.s measured

Selective process Natural samples can be used

147Pm+n=148Pm radioactive count gamma rays

Proton beam, 7Li(p,n) –as neutron source

Sample removed to low b.g and then counted

$A = \Phi.N.\sigma.f$, $c = A.K.e.I.\ (1-\exp(-t/tm).\exp(-t/tw)$

Flux normalization with 197Au

Adv : Flux much larger than in TOF, very small samples – ng to pg

Other sources of n : 18O(p,n)18F ,kT=5.1 keV

3H(p,n)3He ,kt = 52 keV : Half lives , B.E. storage rings used